Permanent Final Quadrupole Magnet Option and Prototype at ATF2

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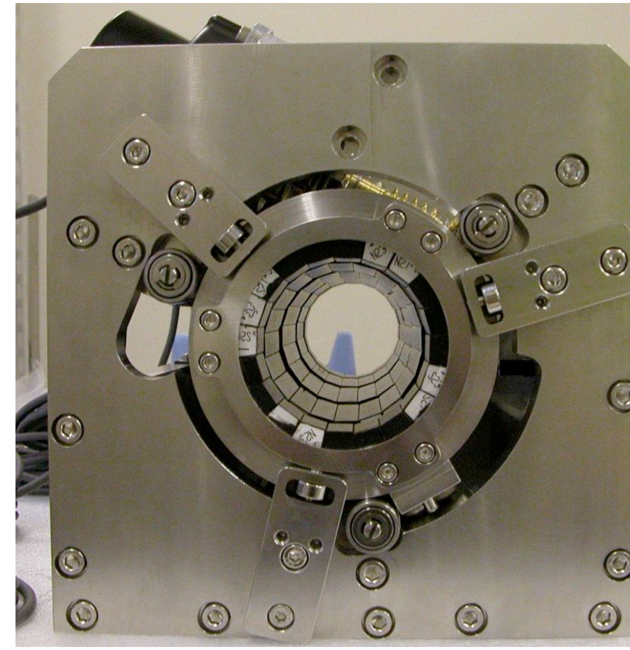
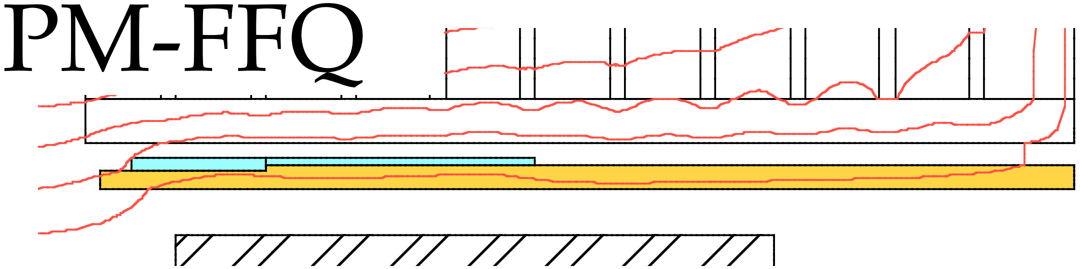
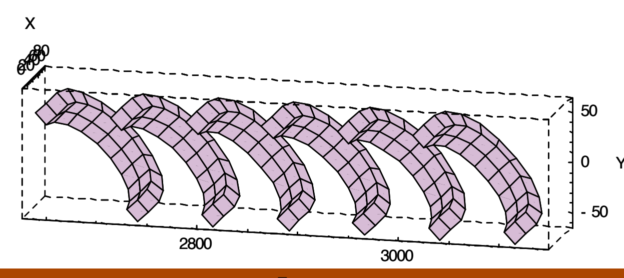
Contents



- Prototype of Gluckstern's 5-ring singlet
  - ➡ review, status
- Anti-Solenoid for PM-FFQ

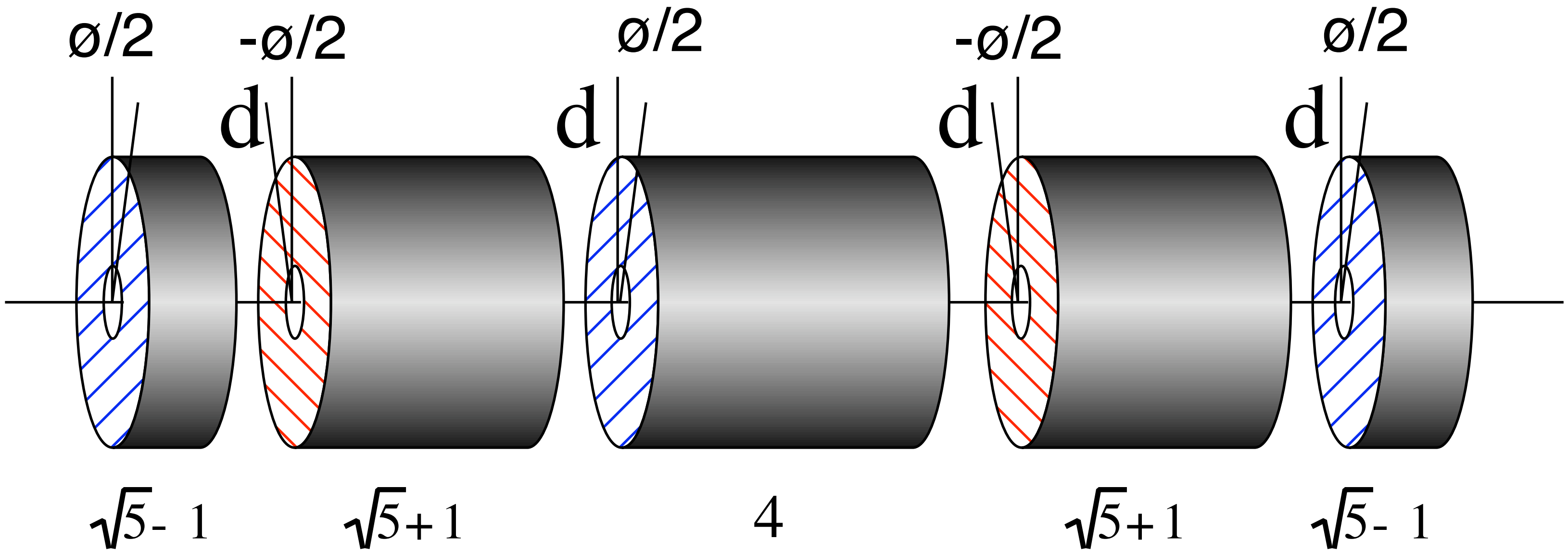


- Local Anti-DiD
  - ➡ passive
  - ➡ active



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

$$M0=\begin{pmatrix} \mathtt{Cos[el\ k]} & \frac{\mathtt{Sin[el\ k]}}{\mathtt{k}} & 0 & 0 \\ \mathtt{-k\ Sin[el\ k]} & \mathtt{Cos[el\ k]} & 0 & 0 \\ 0 & 0 & \mathtt{Cosh[el\ k]} & \frac{\mathtt{Sinh[el\ k]}}{\mathtt{k}} \\ 0 & 0 & \mathtt{k\ Sinh[el\ k]} & \mathtt{Cosh[el\ k]} \end{pmatrix}$$

$$kL \to \Gamma$$

$$k = \frac{G}{B\rho}$$

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

$$M = \begin{pmatrix} Mxx & Mxy \\ Myx & Myy \end{pmatrix} \quad Mxy = \begin{pmatrix} Mxy_{1,1} & f(k,L,d,\alpha) \\ Mxy_{2,1} & Mxy2,2 \end{pmatrix} \cdots L0 = \alpha L$$

$$\text{Solve}: \ f(k,L,d,\alpha) \approx \sum_{n=0,4} \frac{d^n}{d\alpha^n} f(k,L,d) \ \frac{\alpha^n}{n!} = 0$$

α = -458.949, -1.01896, 0.318954, 460.003

Tolerances

To keep beam size $\Delta X < X/10$

★Rotation Error

➡ see table

★Length Error

➡ <100μm

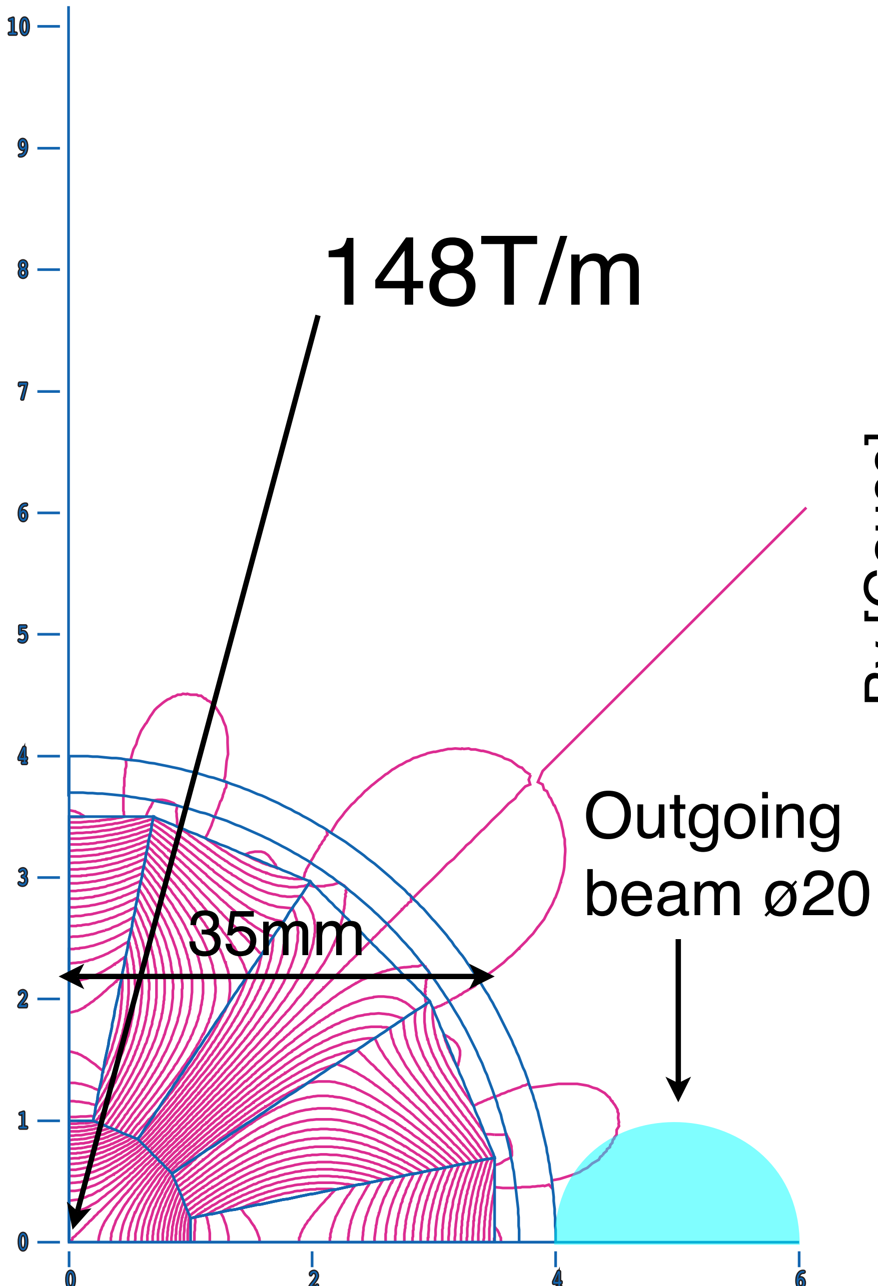
★Position Error

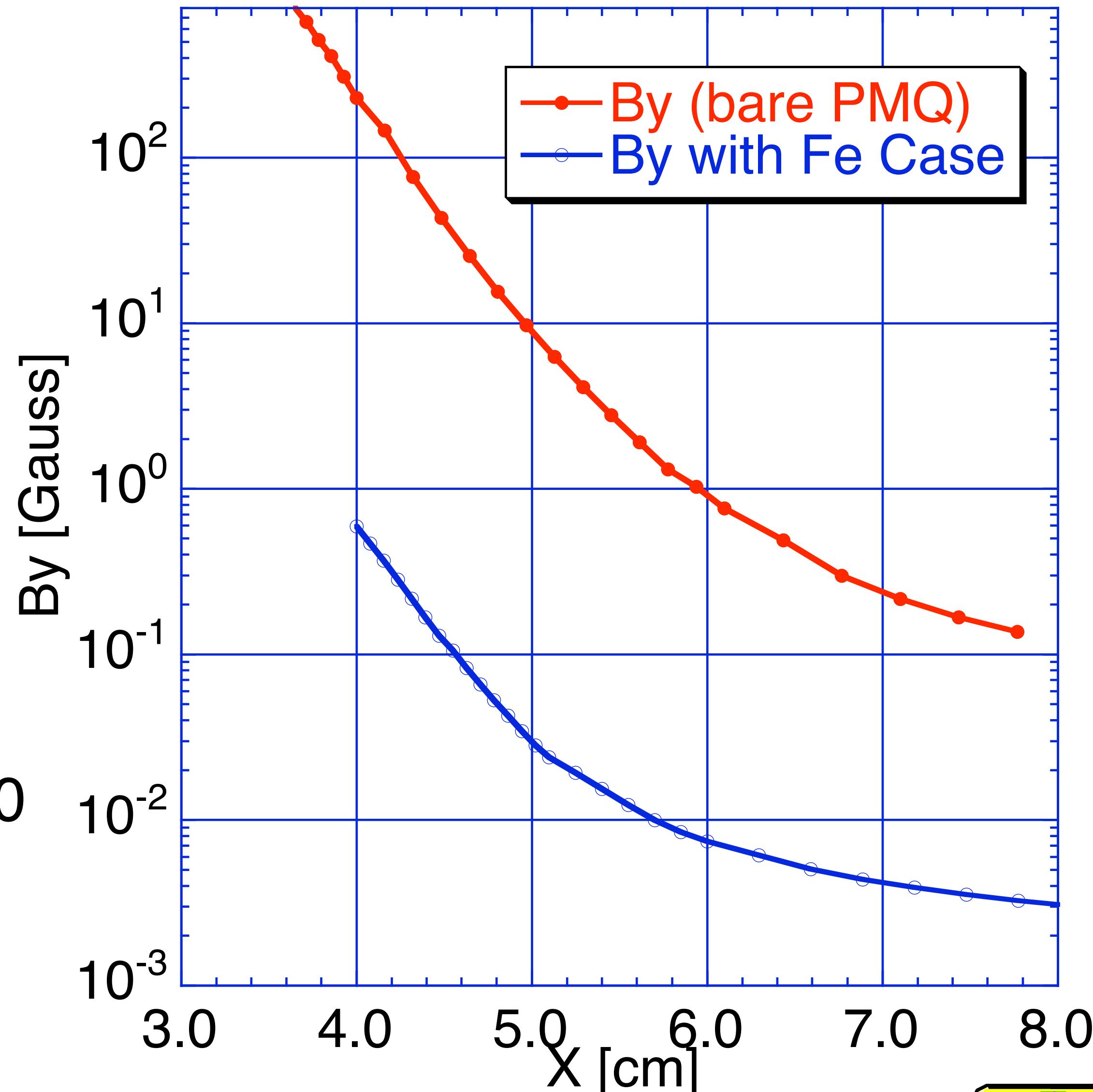
➡ No effect on beam size.

➡1μm tolerance of FFQ for 1nm shift at IP

Disc	Length[mm]	Tolerance [rad]
1st	17.33	$< 2.2\times10^{-4}$
2nd	55.00	$< 7.0\times10^{-5}$
3rd	75.34	$< 5.3\times10^{-5}$
4th	55.00	$< 7.6\times10^{-5}$
5th	17.33	$< 2.5\times10^{-4}$

External Stray Field





ATF2 and ILC

Para. at IP	ATF2	ILC
Beam Energy [GeV]	1.3	250
Length to the FFQ [m]	1	3.5-4.2
$\gamma\varepsilon_x$ [m-rad]	3×10^{-6}	1×10^{-5}
$\gamma\varepsilon_y$ [m-rad]	3×10^{-8}	4×10^{-8}
β_x [mm]	4.0	21
β_y [mm]	0.1	0.4

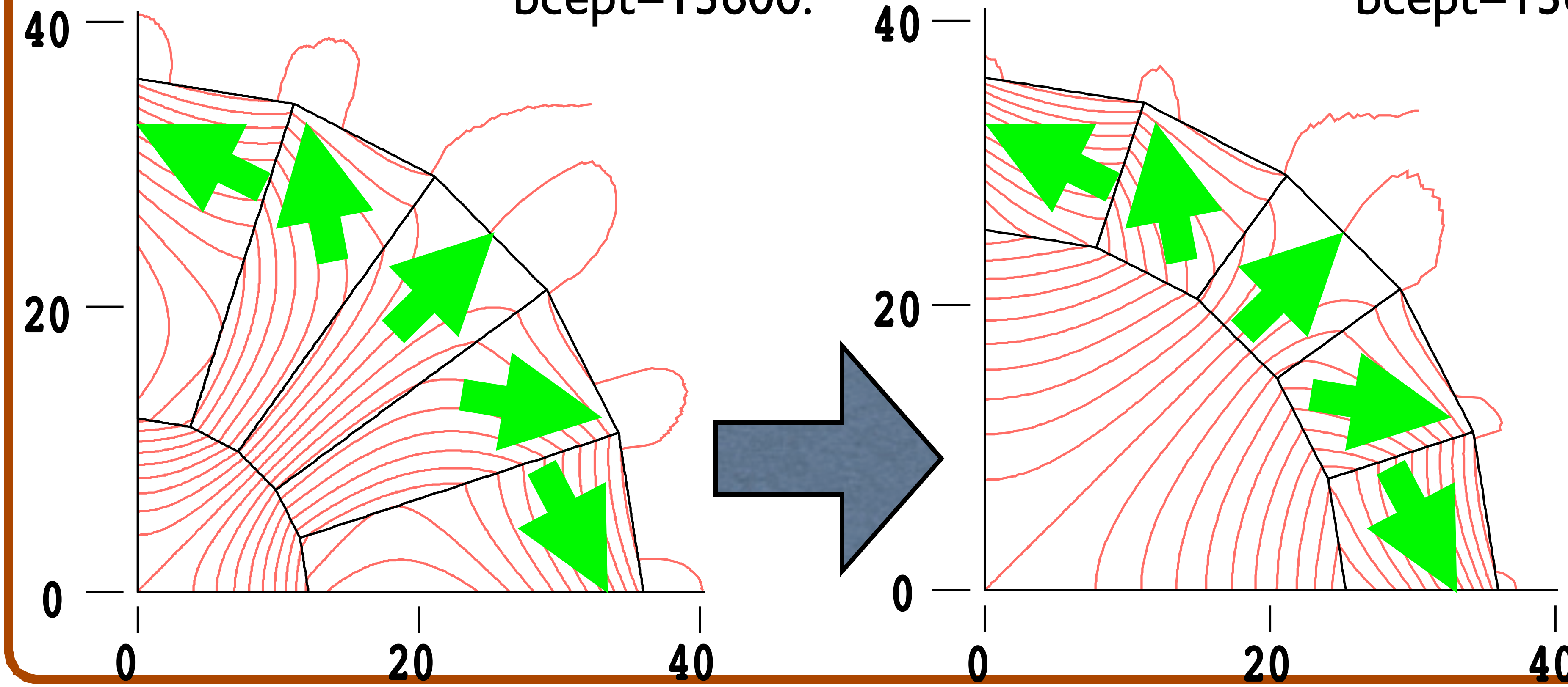
*ATF2 proposal, ATF2 Group, Aug. 11, 2005

Test at ATF2 – replace QD0

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

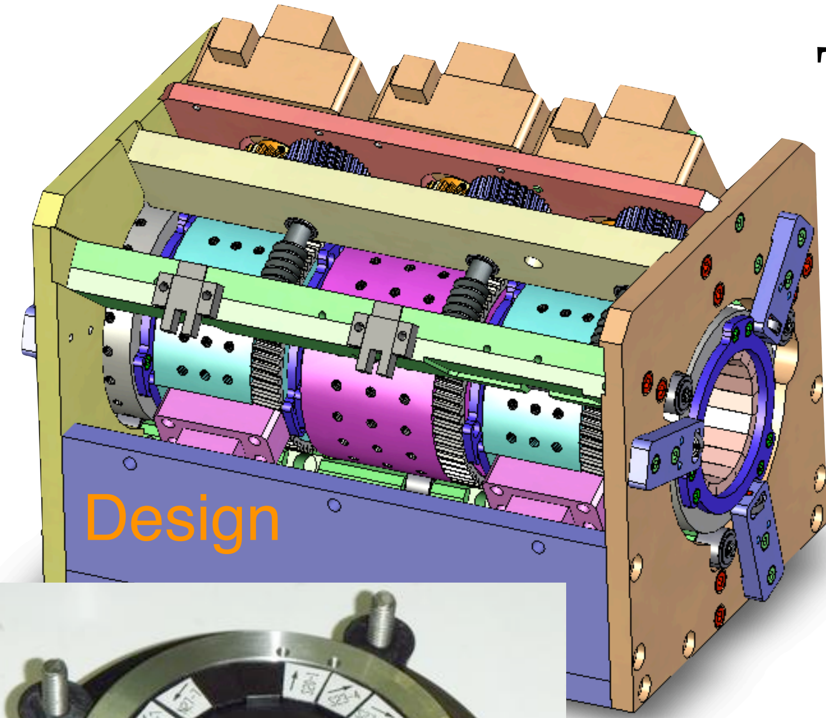
OD: ø72 (=2x(56-20)) 14mr x 4m=56mm

140T/m @ ø24	48H hcept=-12890, bcept=13600.	30T/m @ ø50	48H hcept=-12890, bcept=13600.



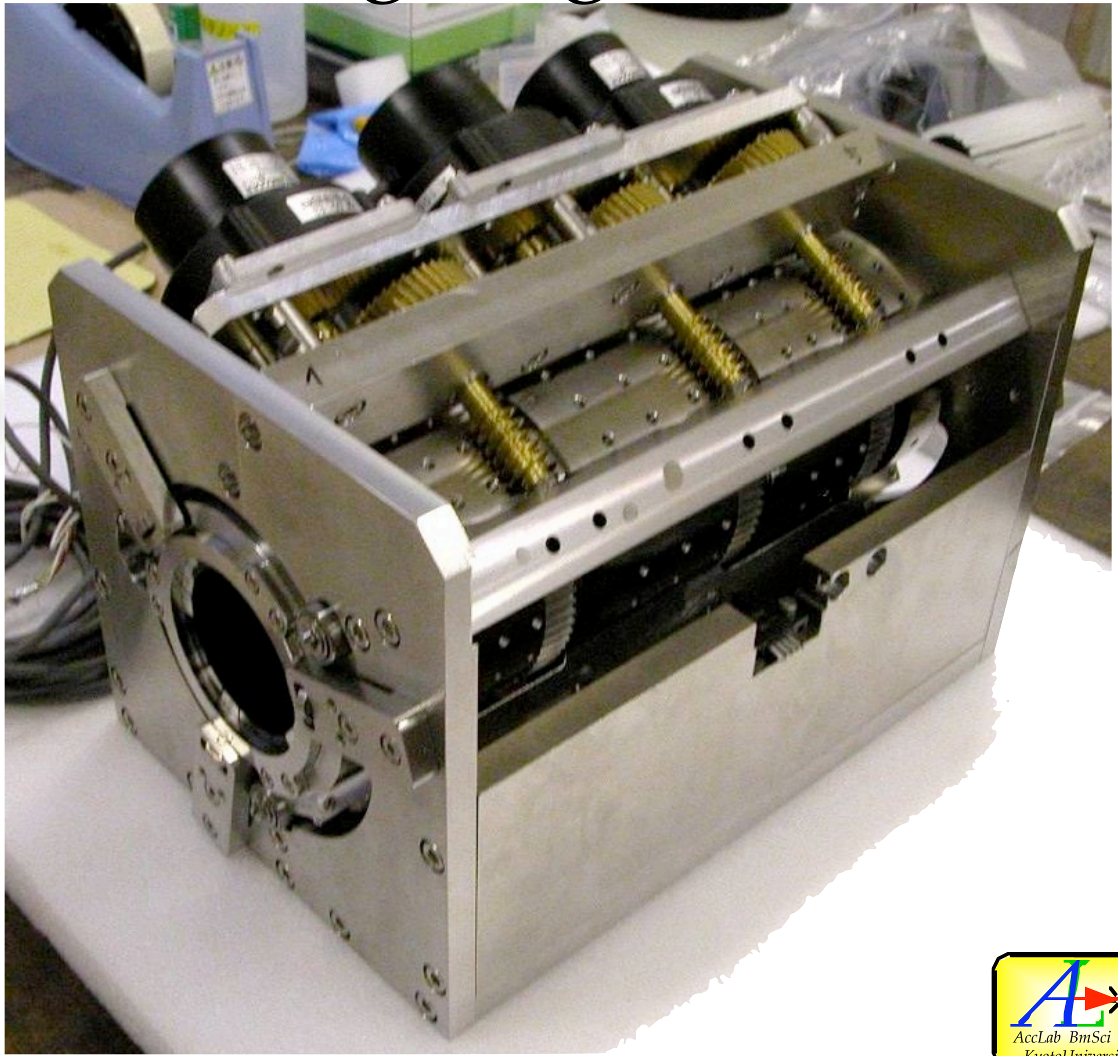
Gluckstern's 5-ring PMQ Singlet(2):

"Continuously Adjustable" PMQ fabricated



Disc(20mm)

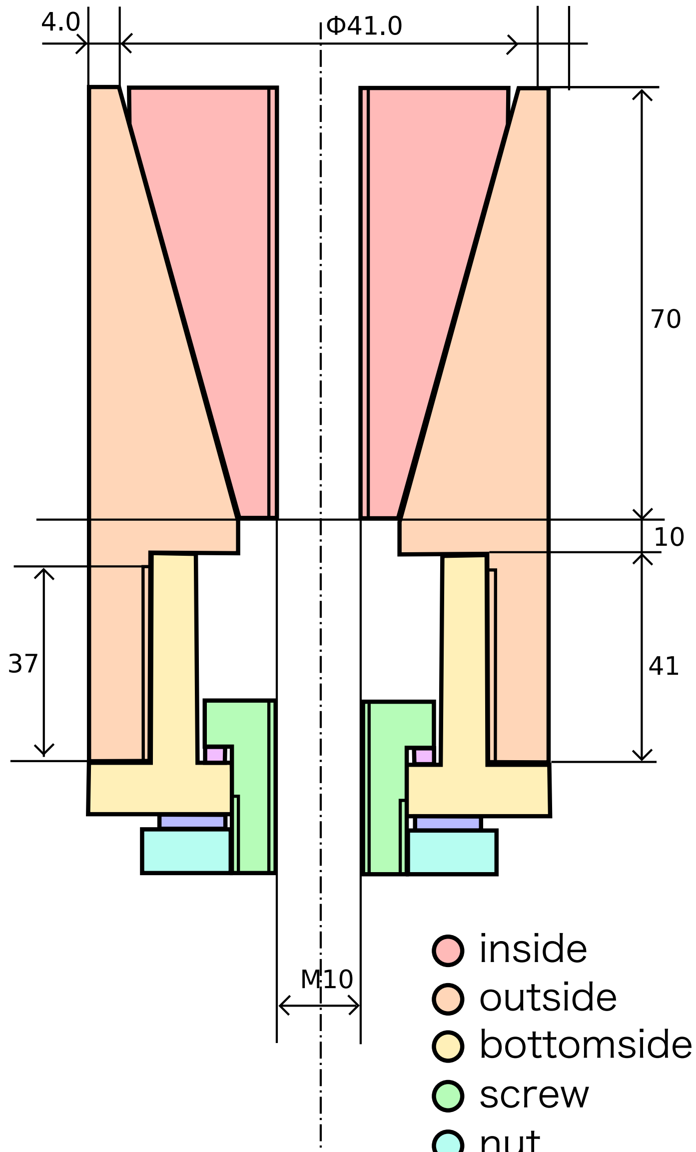
The 5-ring singlet PM-FFQ



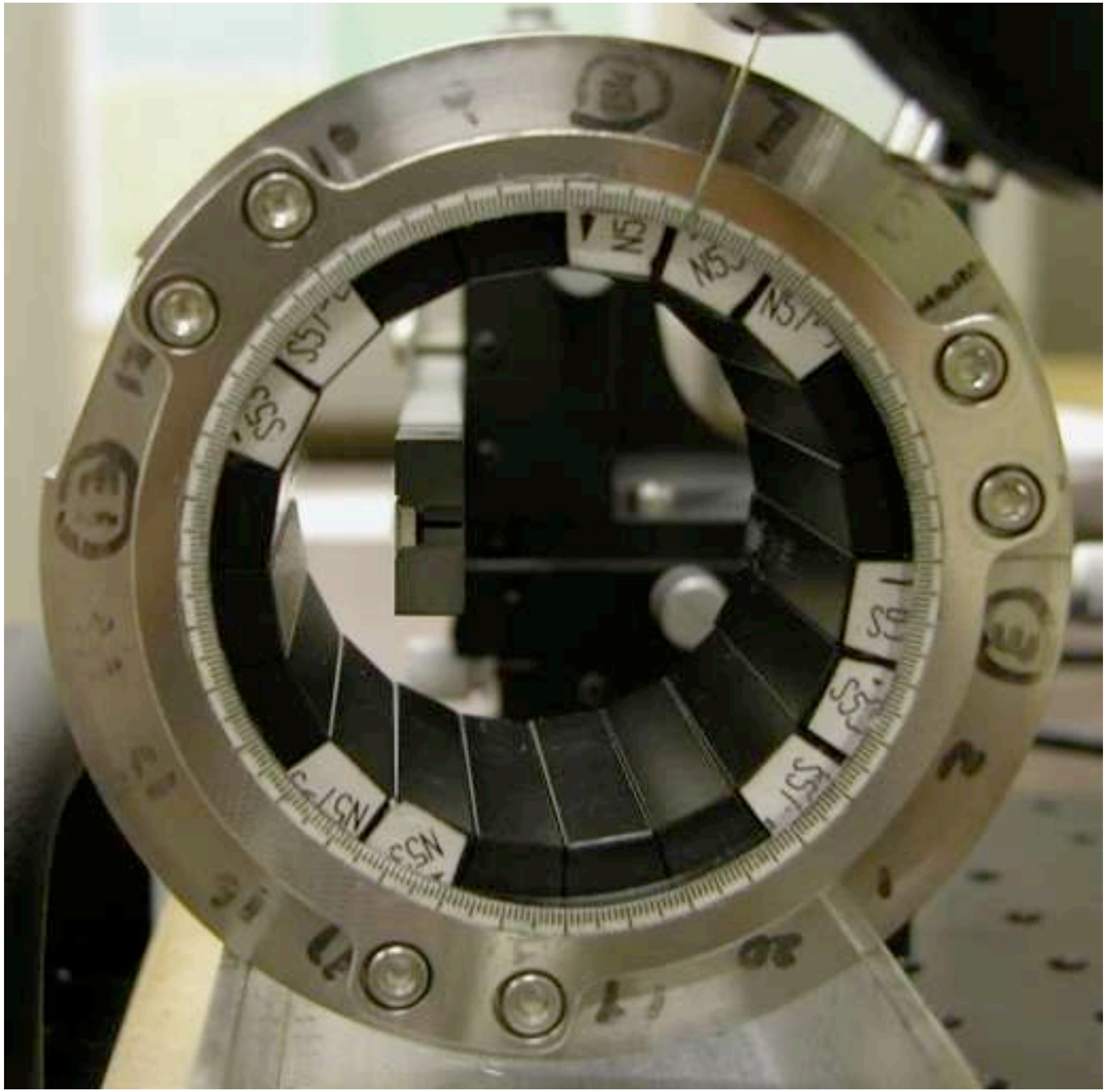
Adjustment

Adjustment:

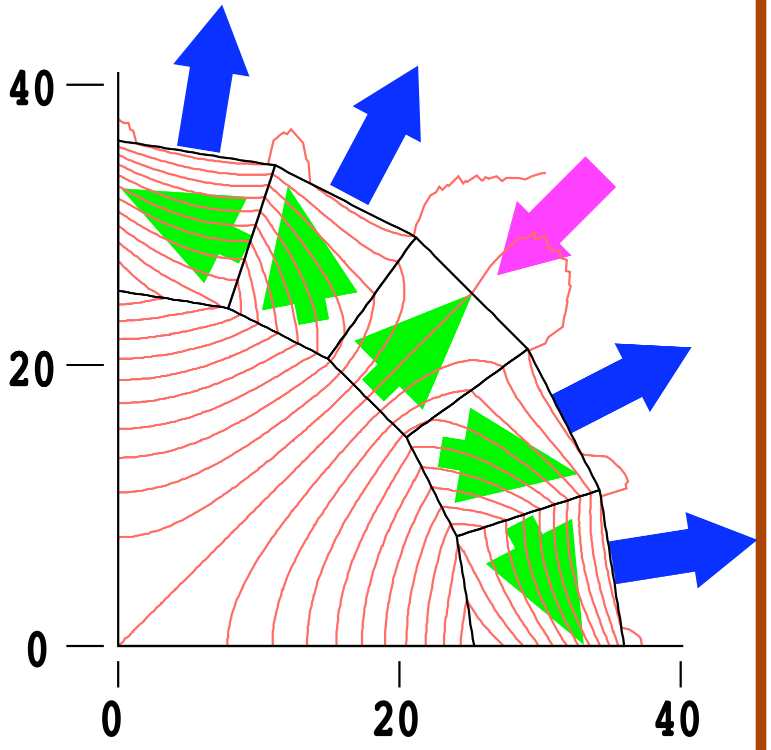
Jig for placing magnet parts



Magnet Bore



Pole magnets are attracted.

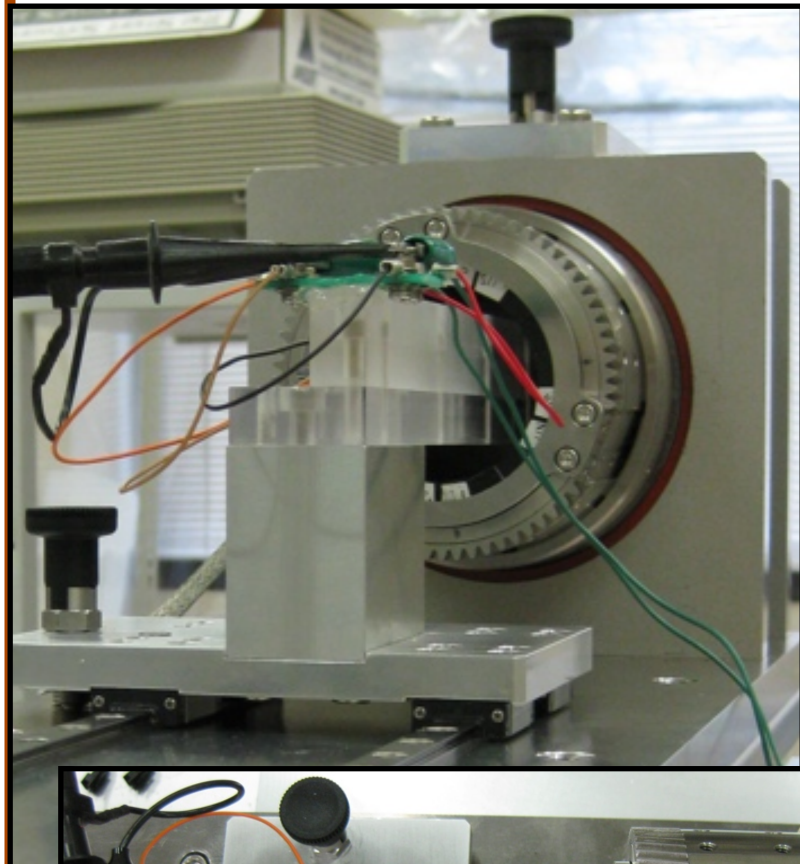


Others are repulsive.

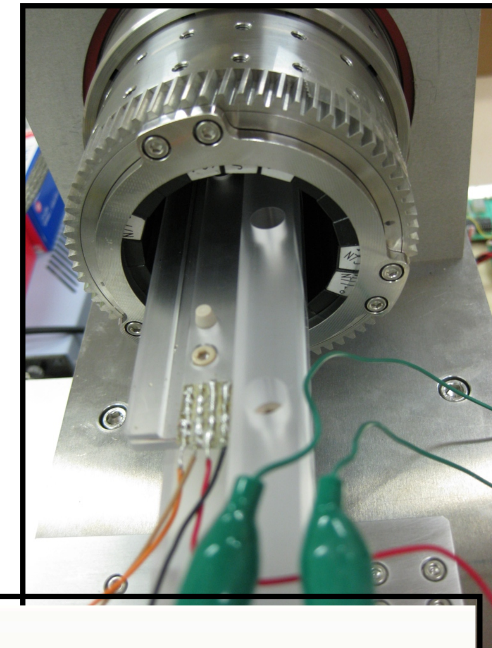
Alignment Jig

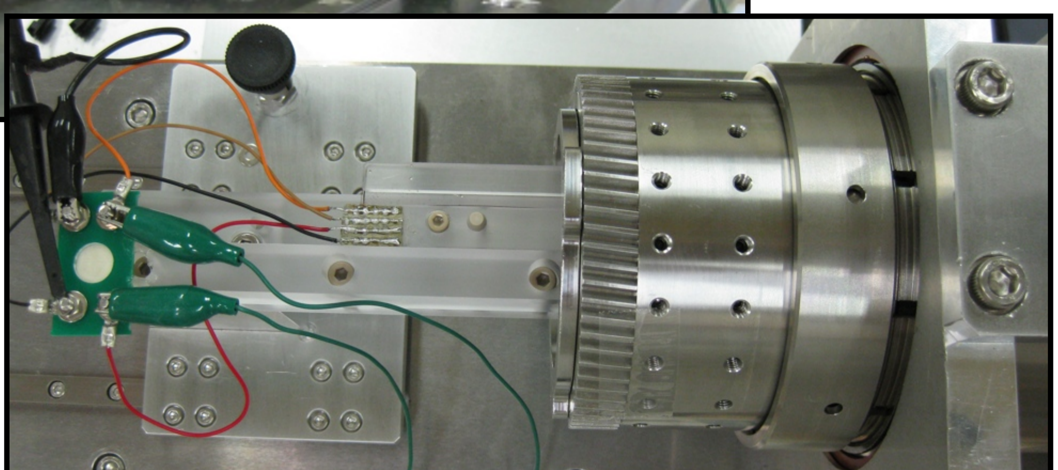
Field Measurement (just status report)

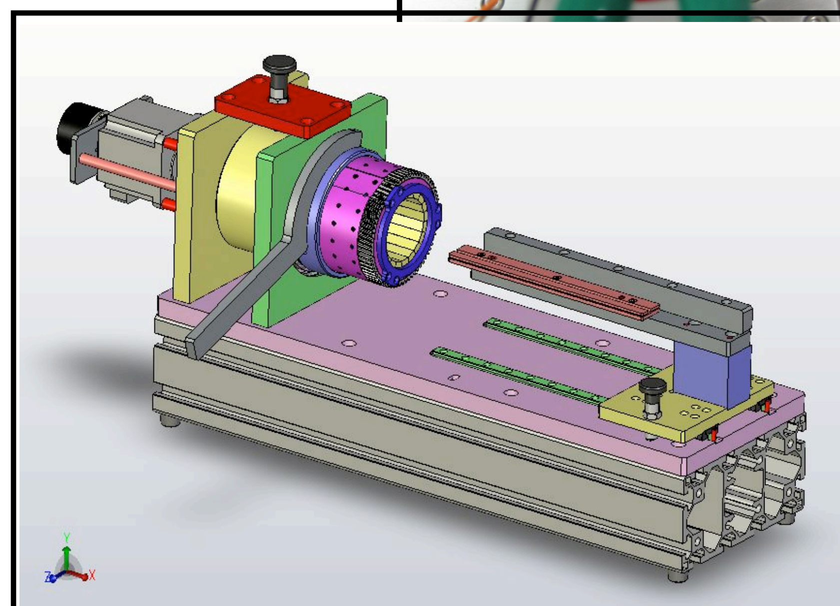
Field Measurement (1):
Rotating magnet instrument



Magnets are rotated to find their magnetic center against the outer shell.

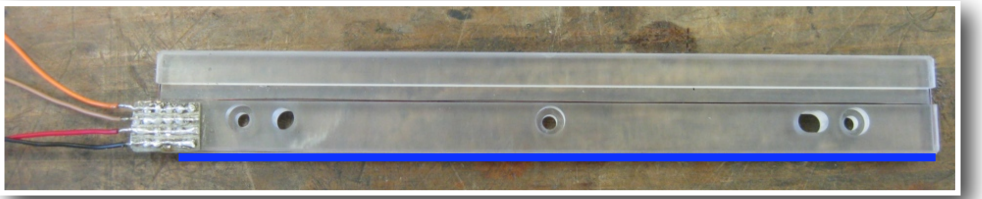






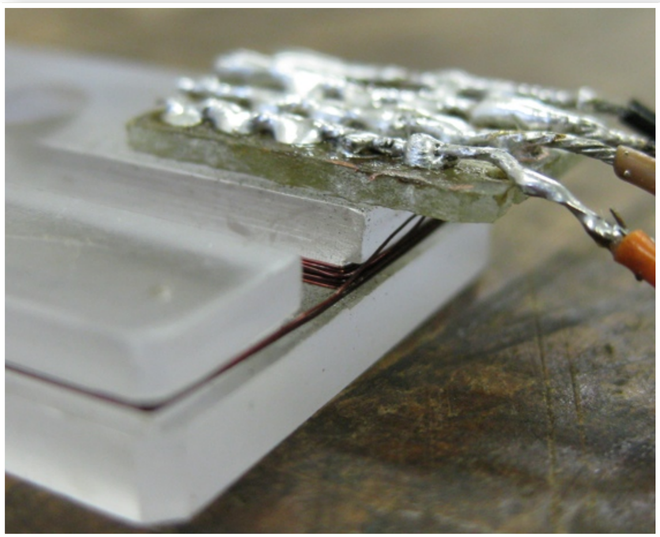
Field Measurement (2):

Rotating magnet instrument



Two coils with different radii

Bucking coil at the center



Cancel out the main quad components to measure other components: dipole for magnetic center offset, multipoles ...

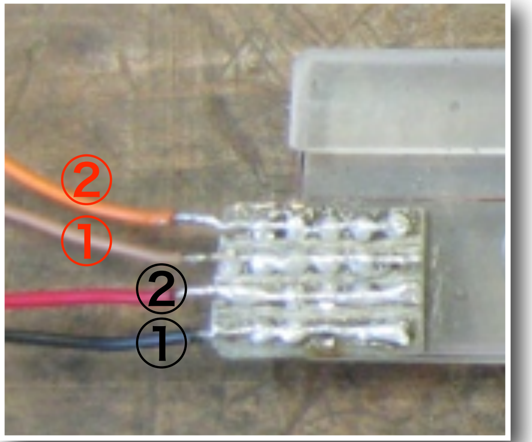
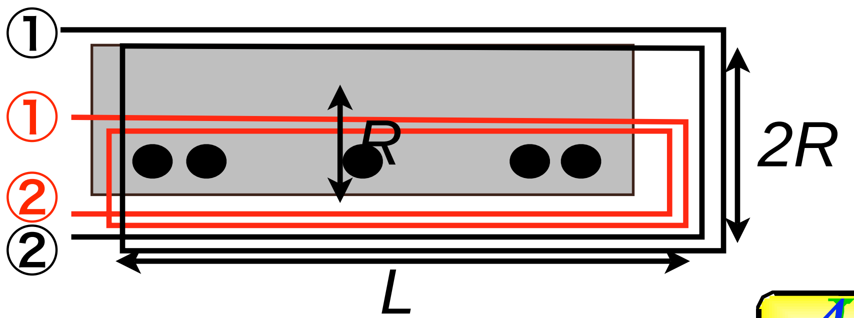
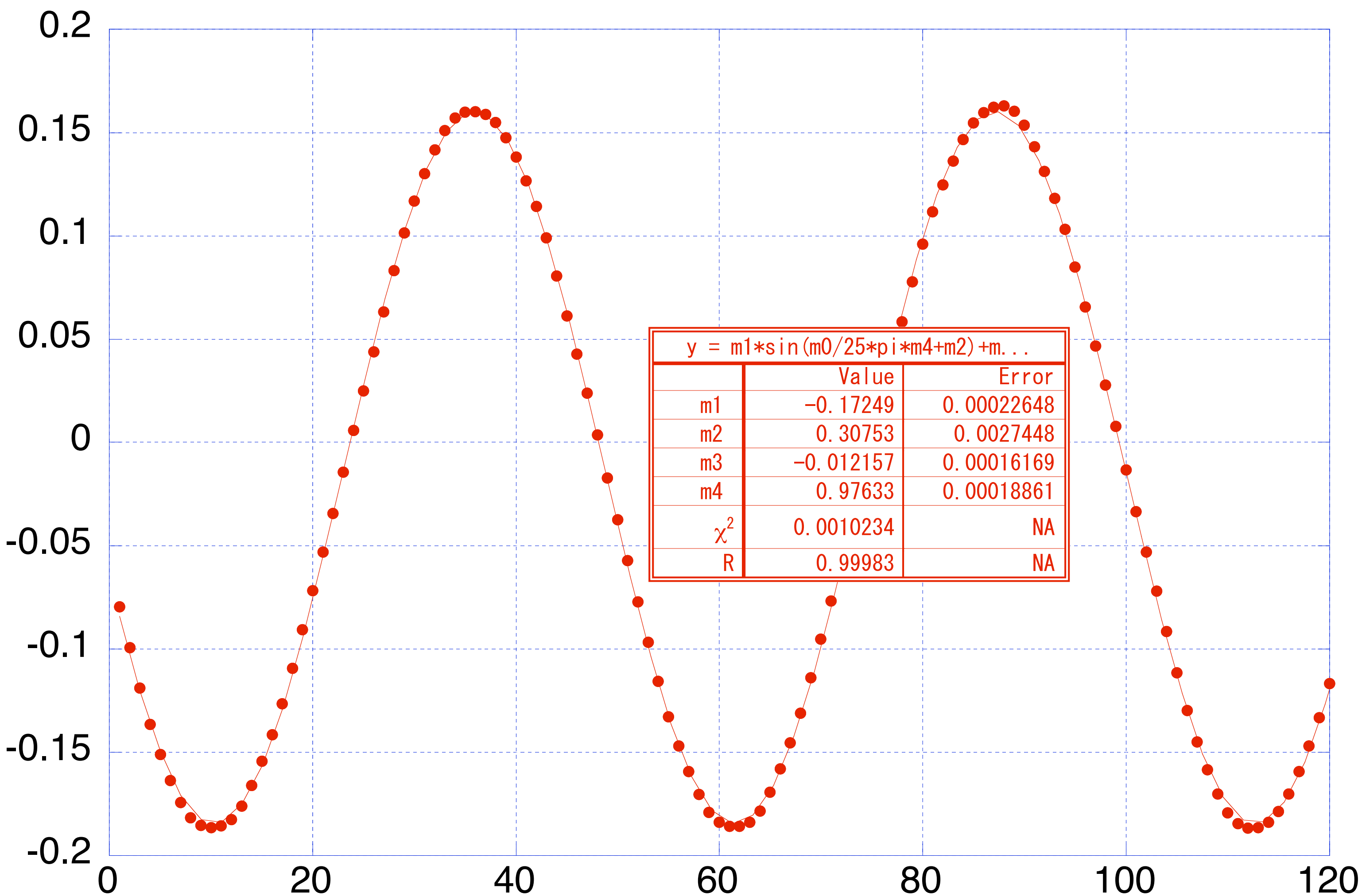


Table 3: Two coils properties

Coil	Area	Turns
①—② (coil1)	LR	12
①—② (coil2)	$2LR$	3



It just started.
No result yet, Sorry!!



Anti-solenoid for PM-FFQ

Cross Section

— ATF2 version in a support tube —

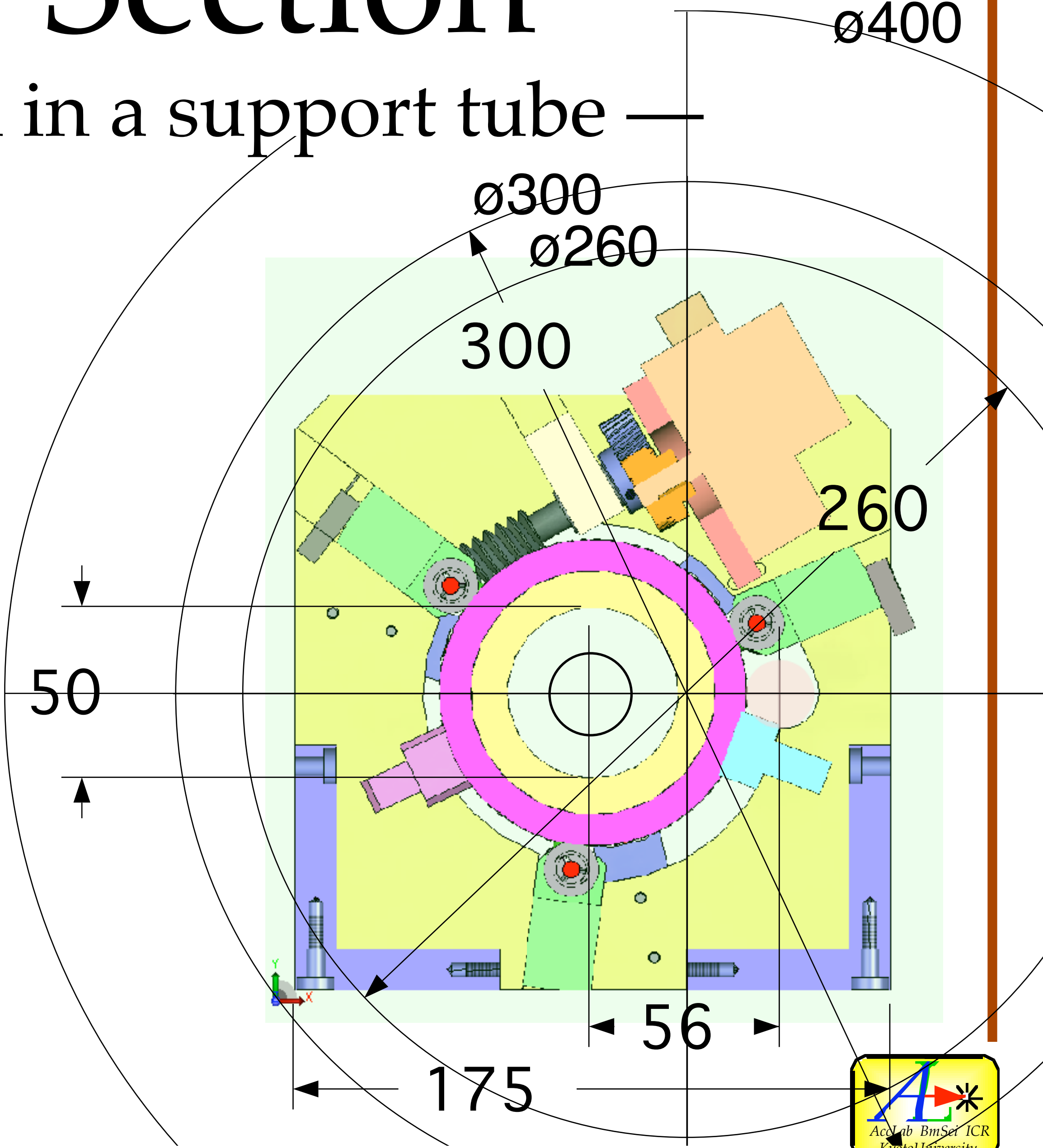
- Separation:

14mr x 4.0 = 56mm

14mr x 4.5 = 64mm

14mr x 5.0 = 70mm

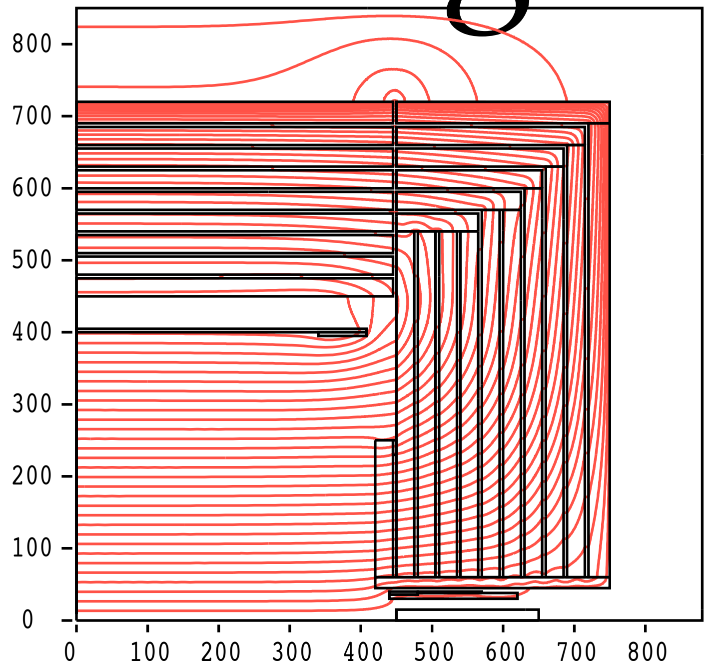
- Corners may be cut.
- No magnetic mat'l.
- SS Motor.
- Mover to be installed
- How to support?

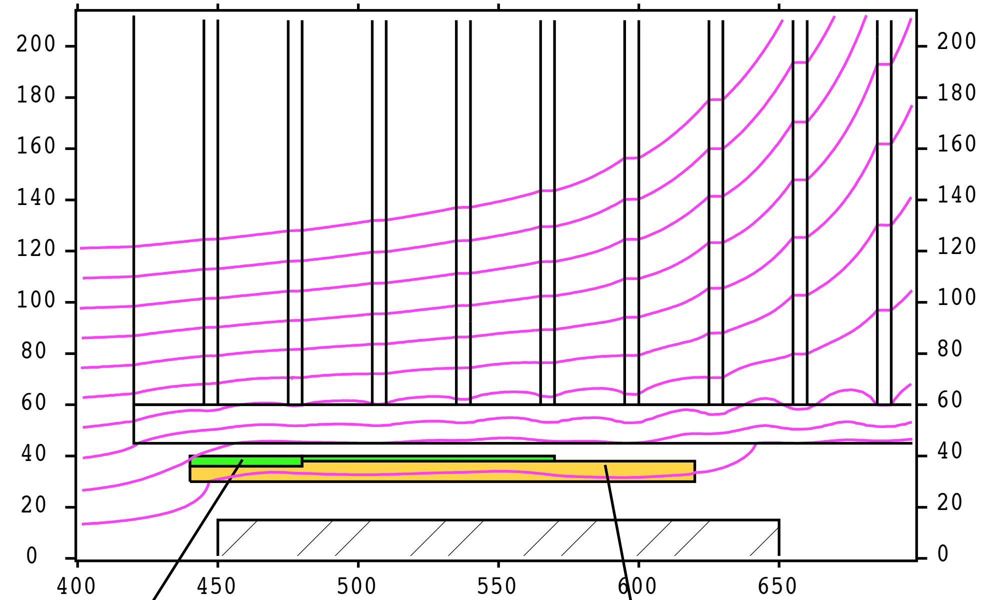


To be considered

- The 5-ring-singlet:
  - ☑ No soft magnet.
  - ➡ Antisolenoid is still needed but partial. Vibration from Superconducting Mag. may be small effect on beam. (HTc coil?)
  - ➡ Magnetic force should be small.
    - Demagnetization resistance has to be checked.
    - Effect on beam of $\mu_{\perp}$>1.0 has to be checked.
    - What about SD0?

Rough Calculation

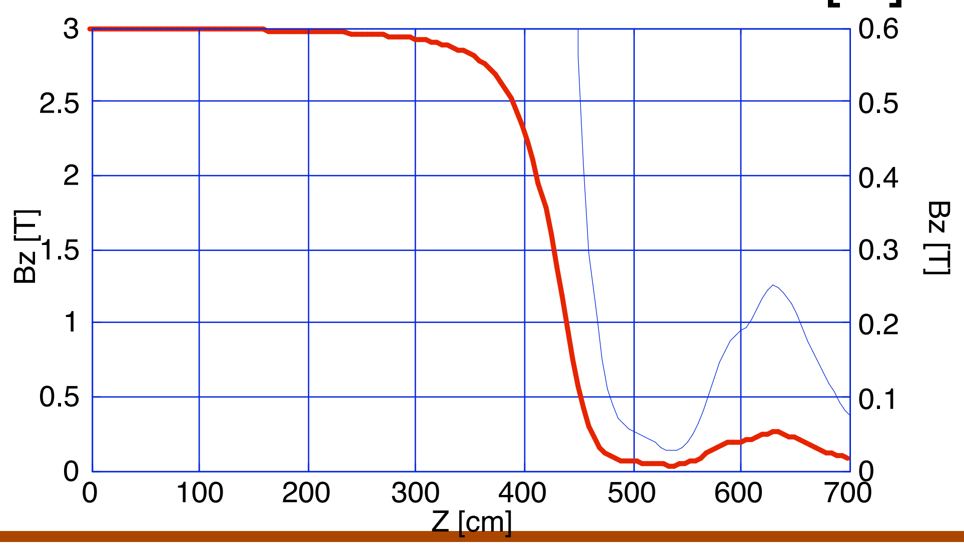




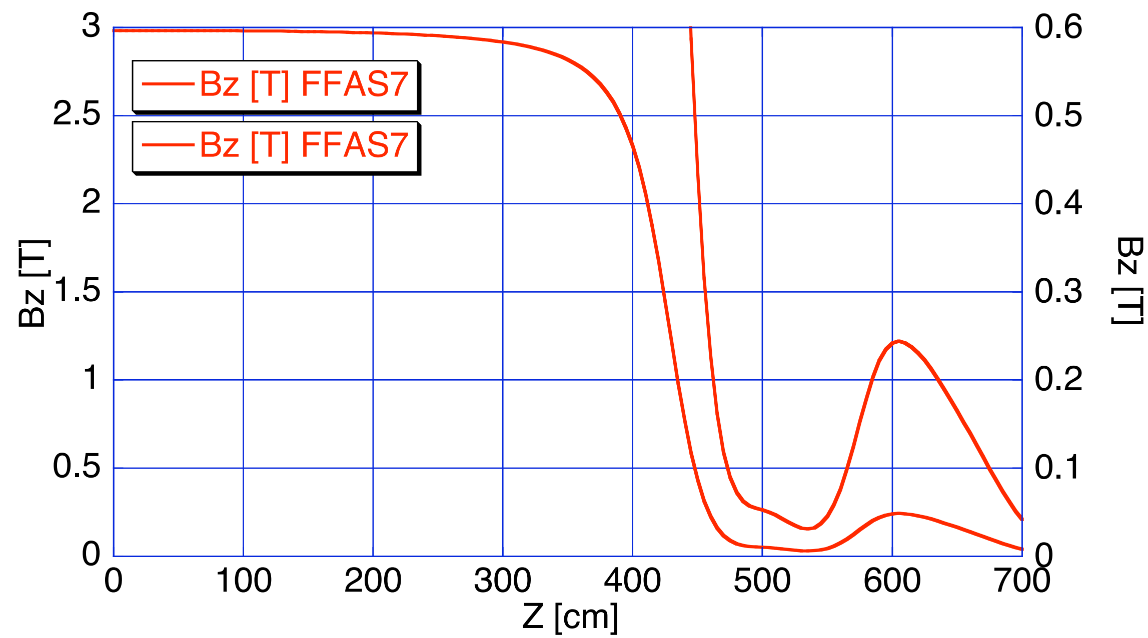
3kA/cm² 2.82E5 -5.31E4 [N]

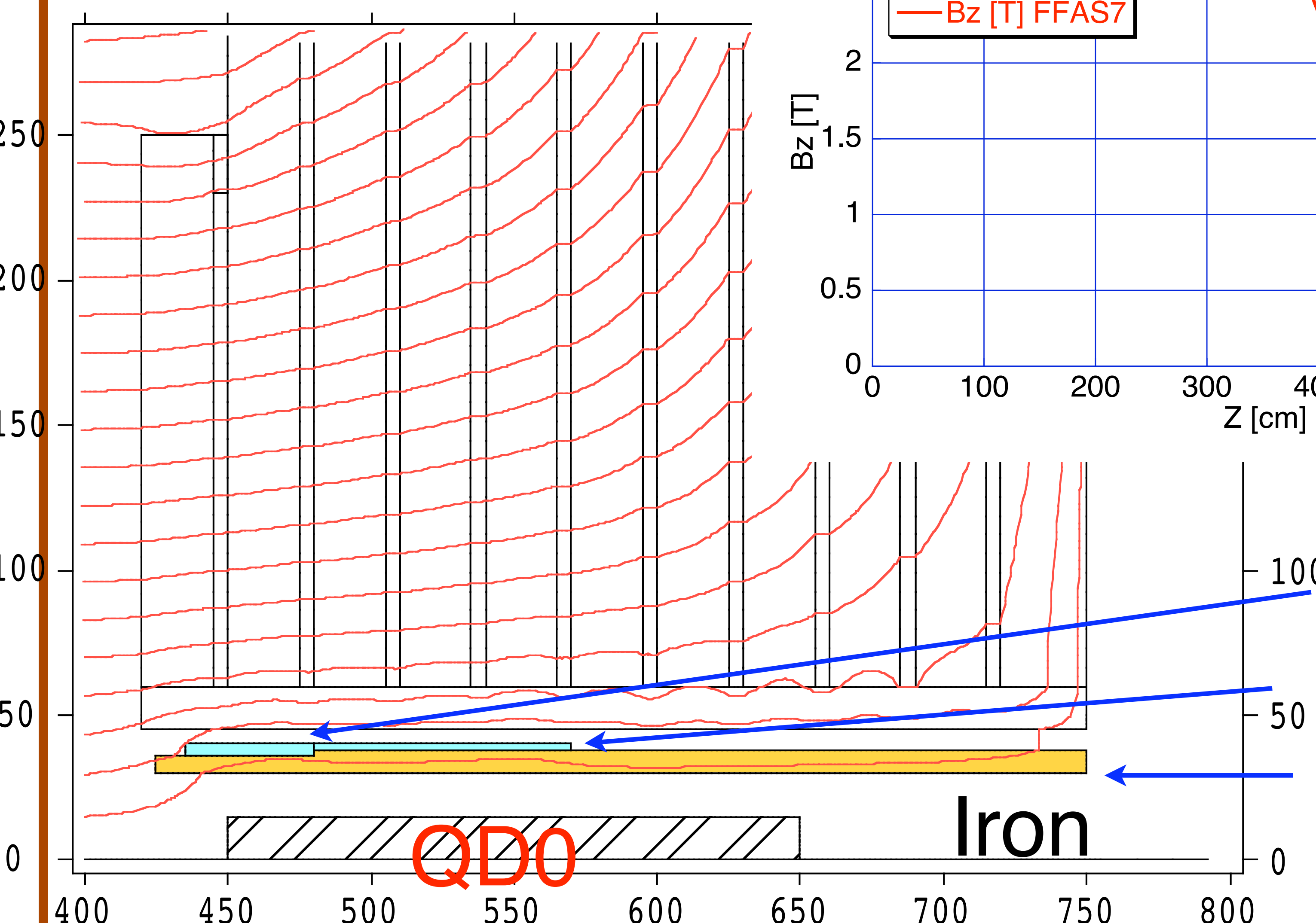
iron shield
-1.08E5 [N]
= 12t

GLDFFAS



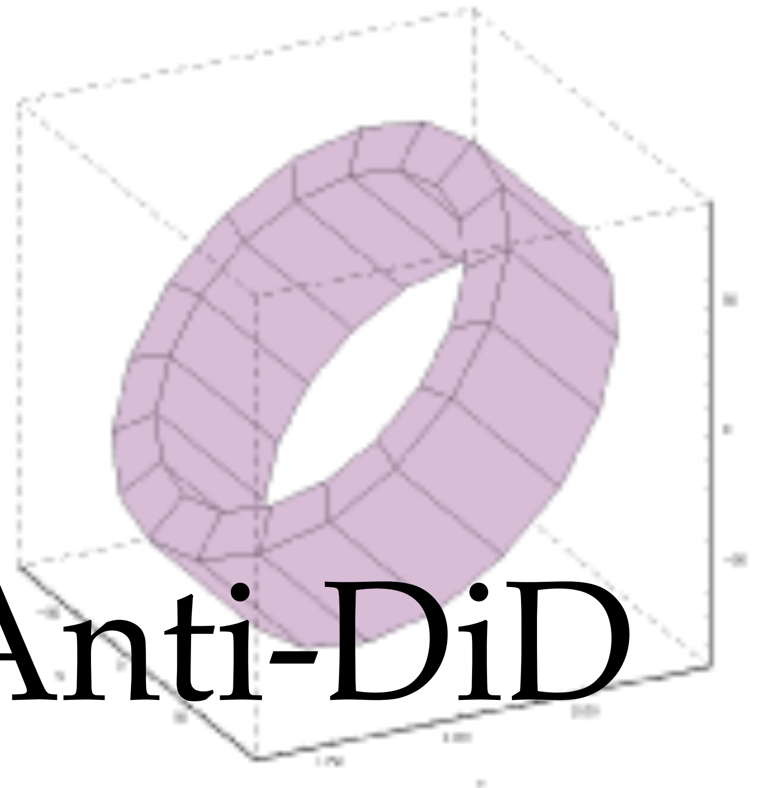
Reduced Force Anti-Solenoid



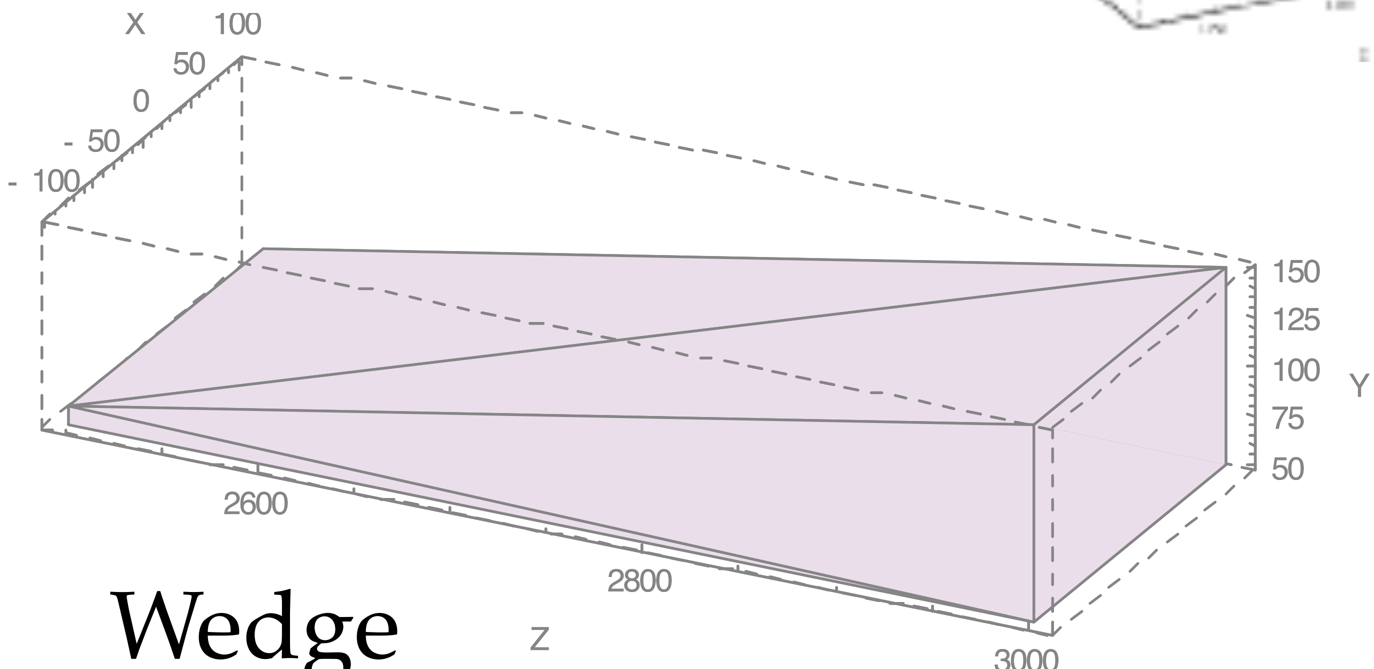


Local Anti-DiD

Ring train

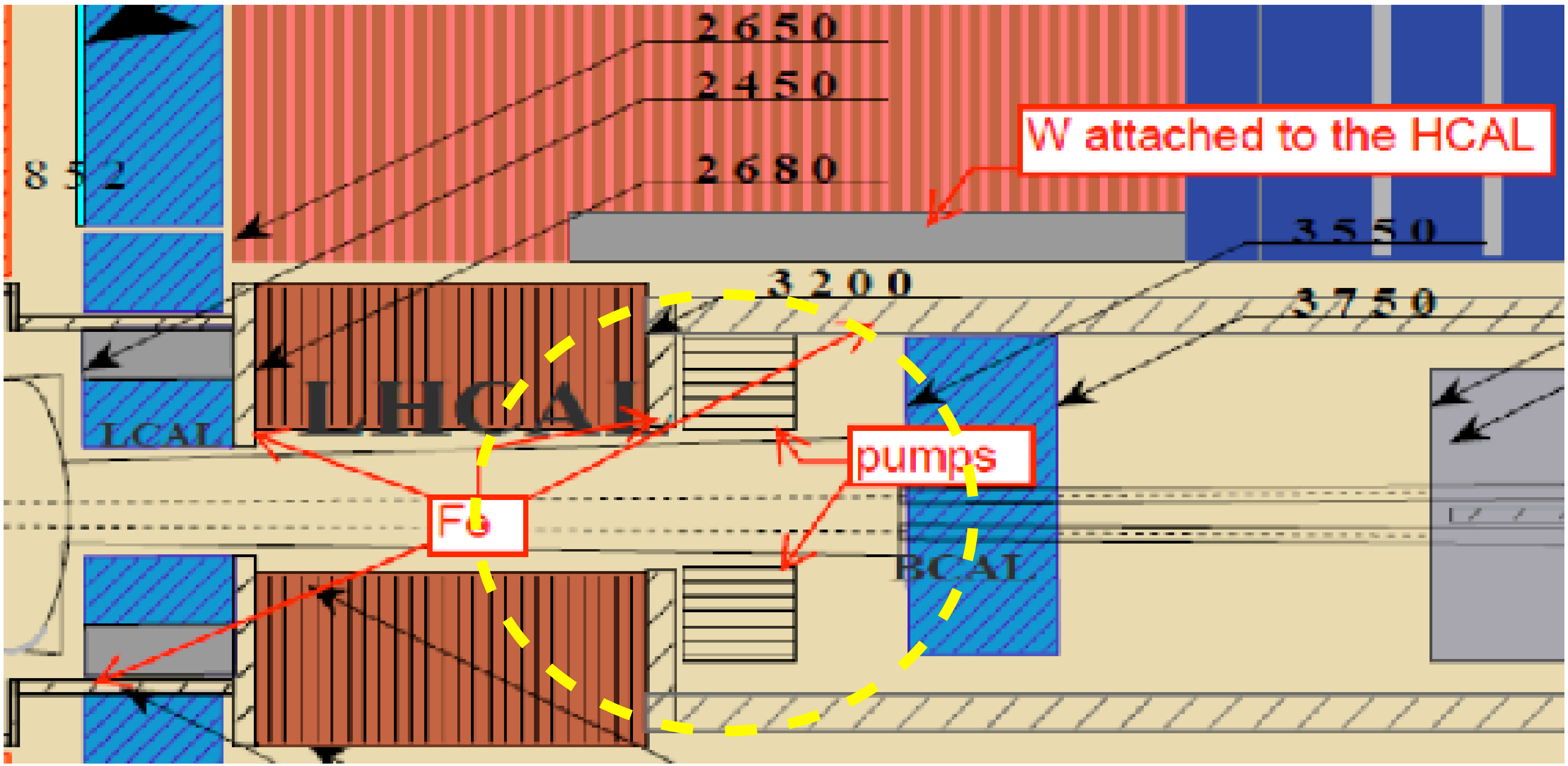


Passive Anti-DiD

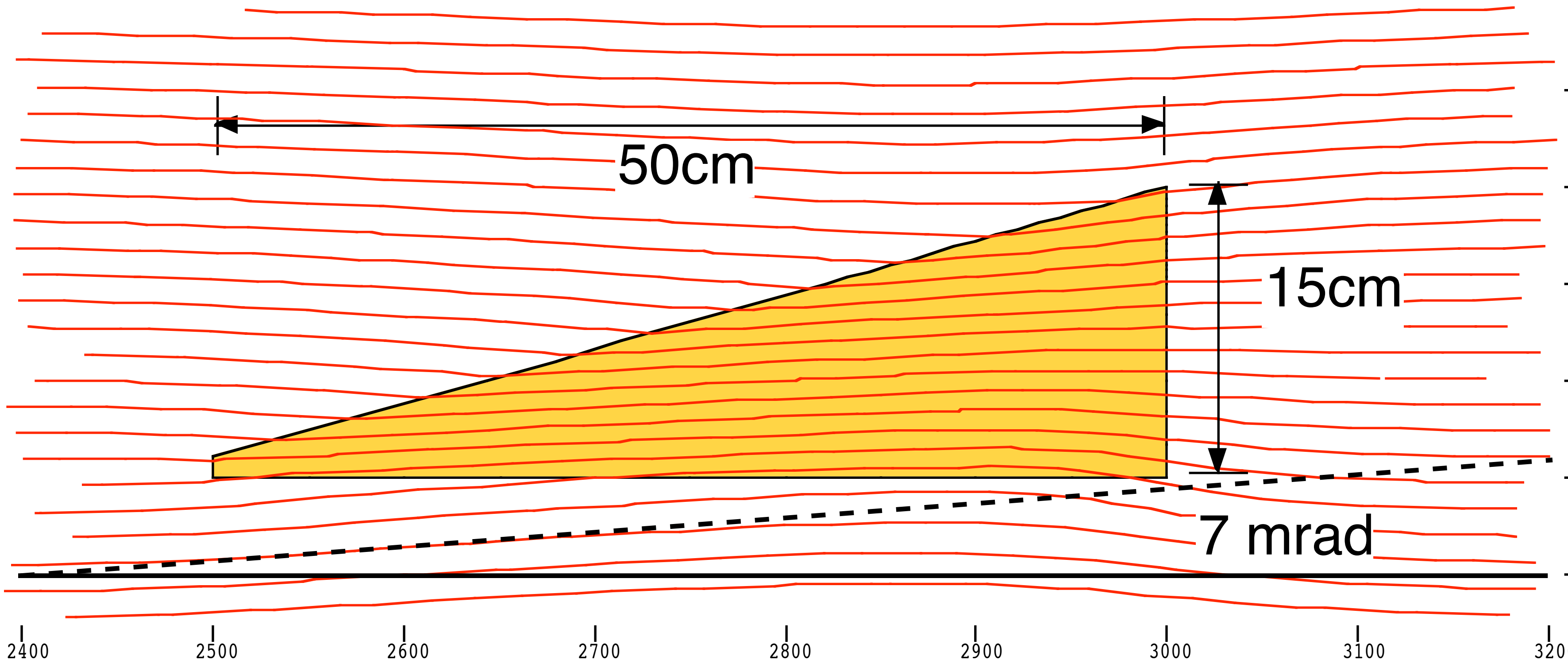


Wedge

Available space

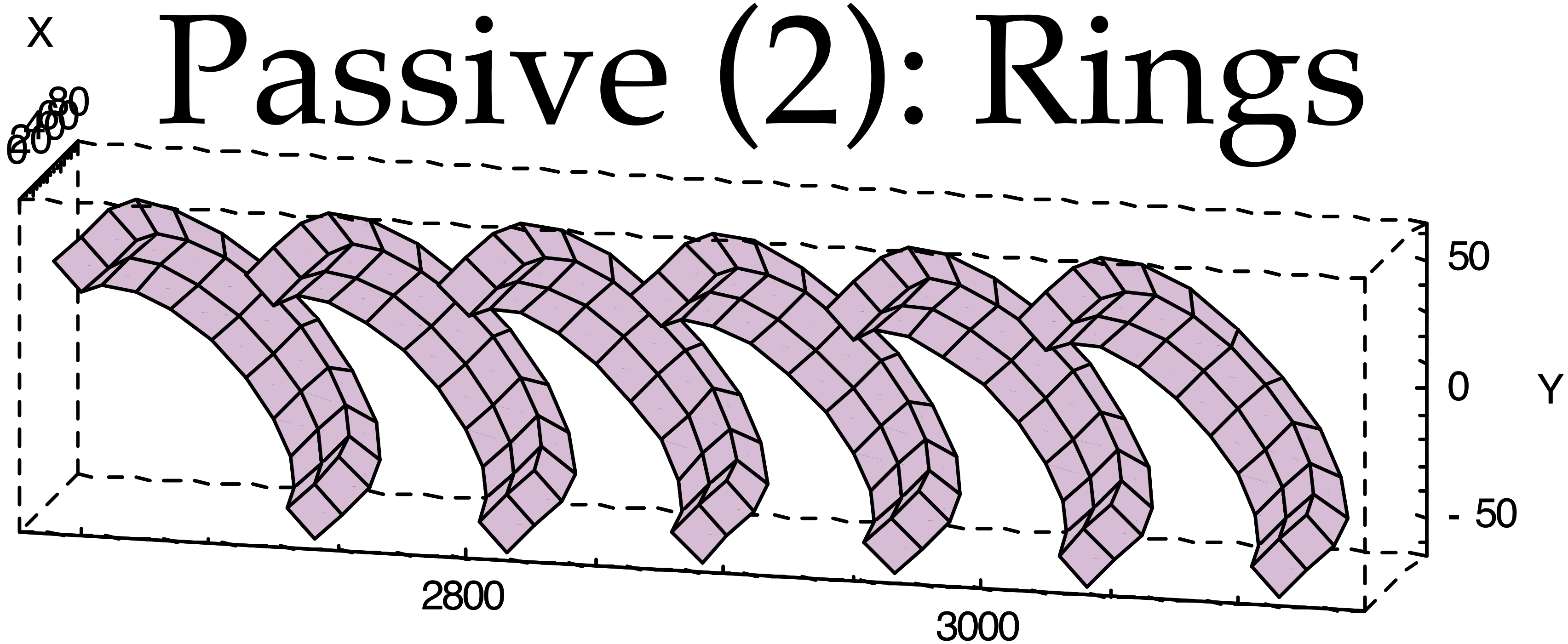


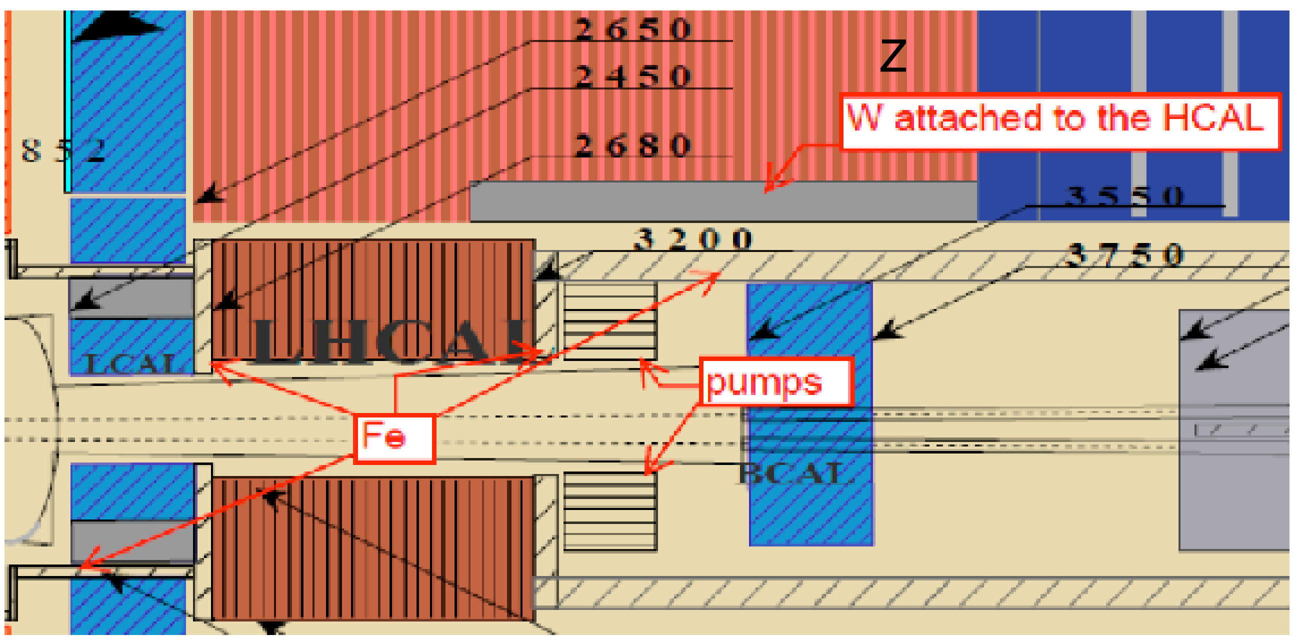
Passive (1): Wedge



Too big to fit in the area?

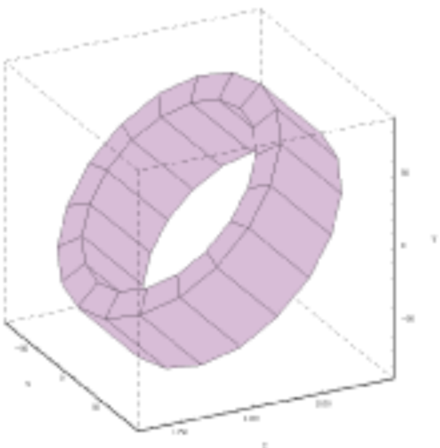
Passive (2): Rings



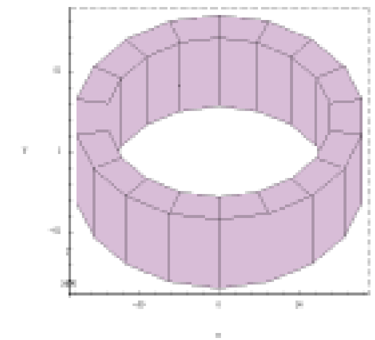


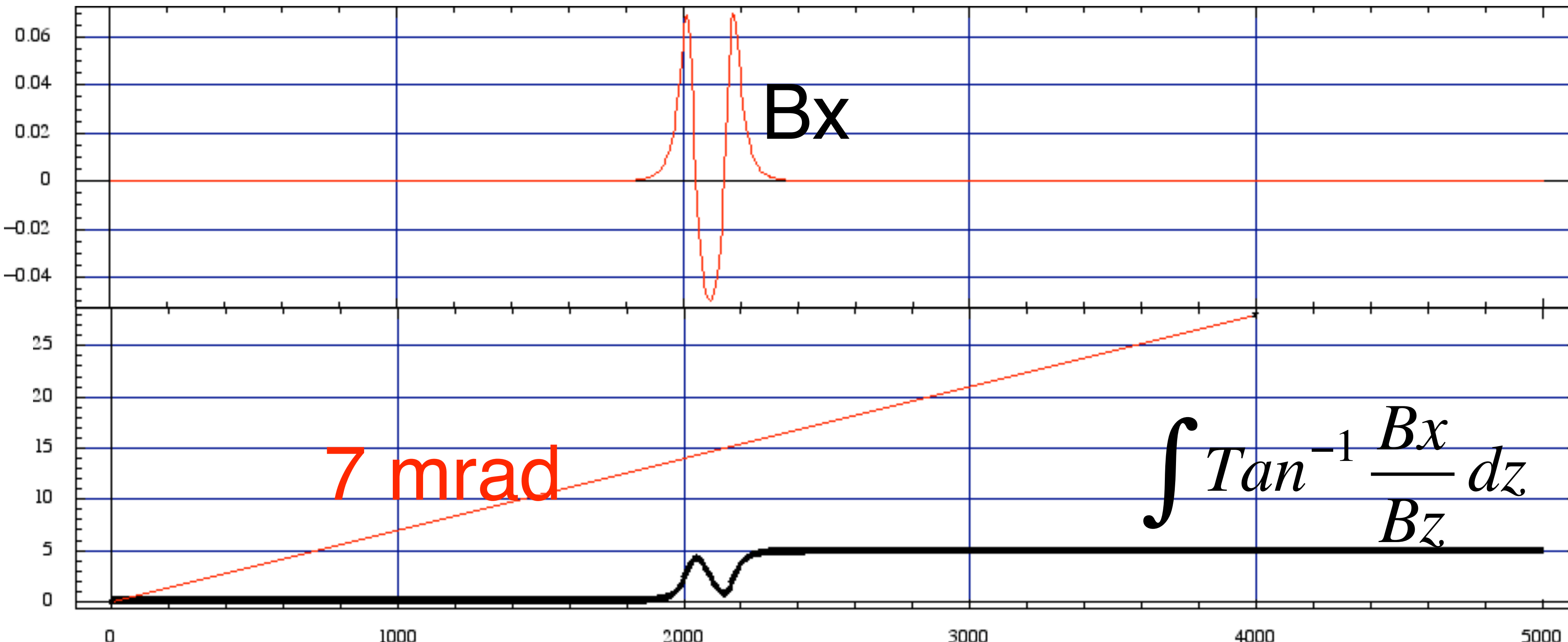
Space seems not available...

Single Tilted Ring

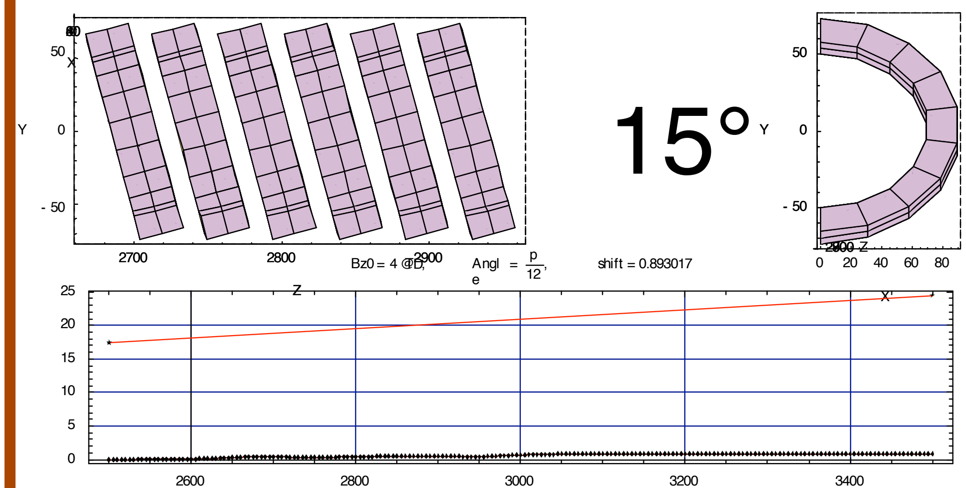


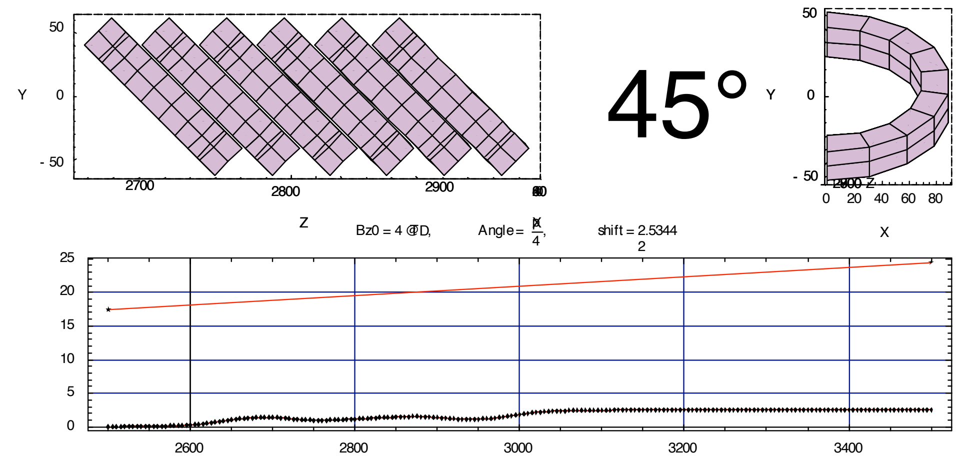
- 45 °
- r1=70; r2=90; thk=60

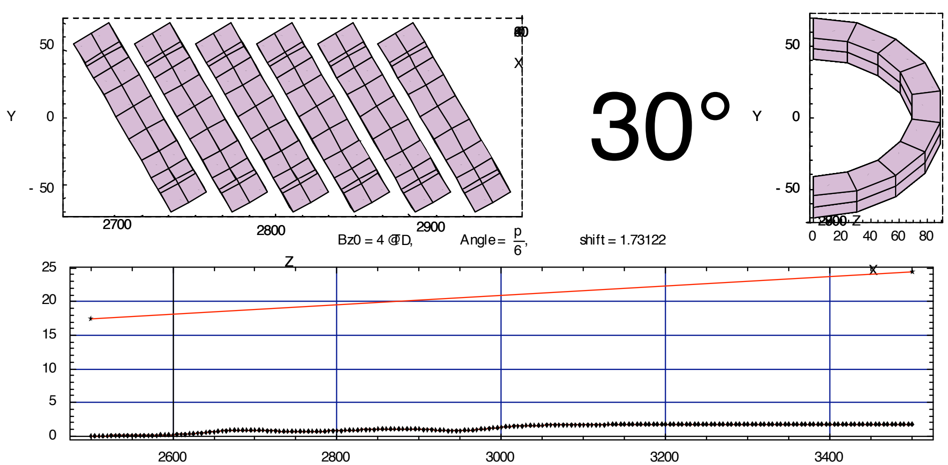




Train of Tilted Ring







2500 3500

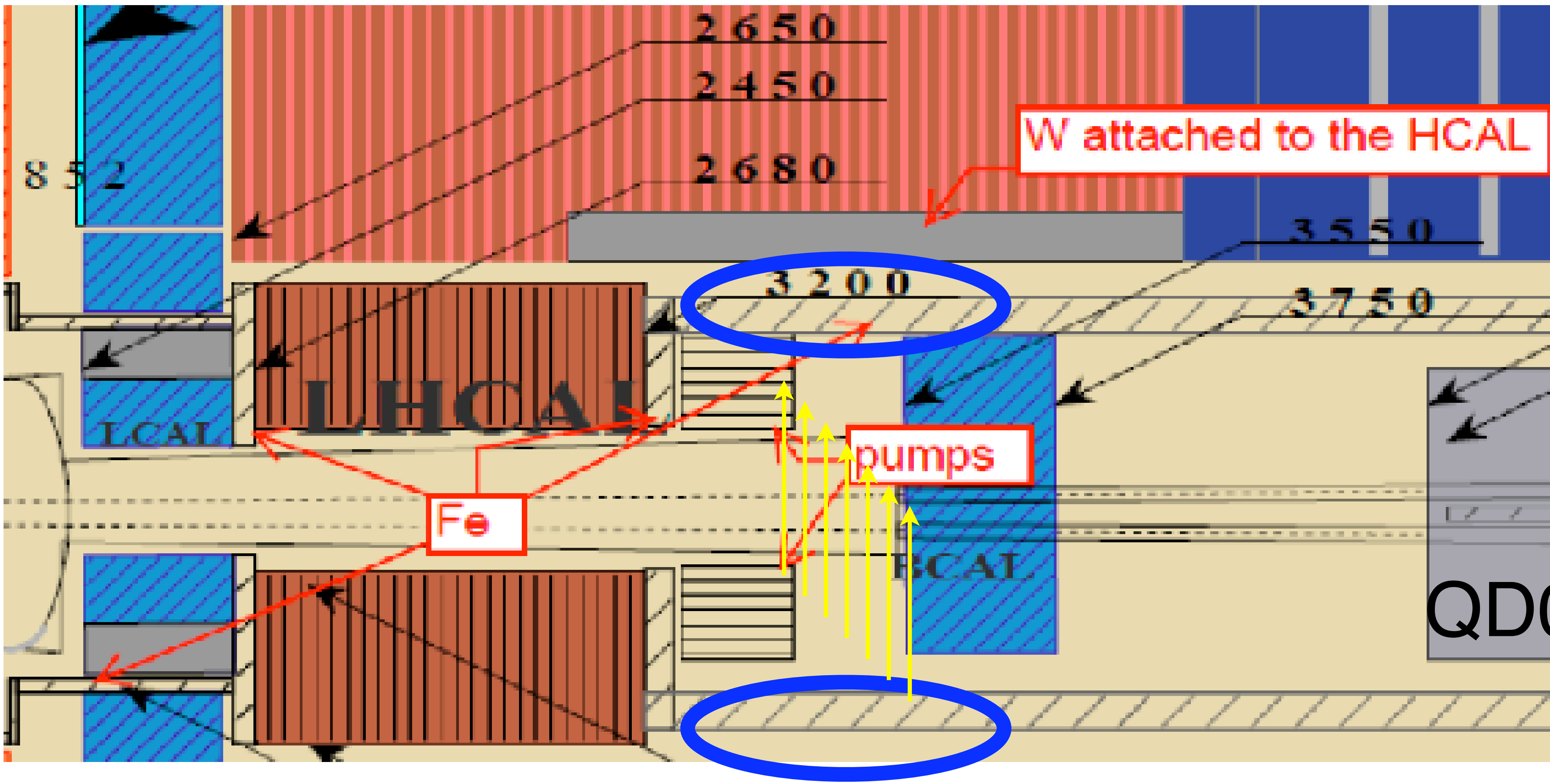
- r1=70; r2=90; thk=60
- Adjustable
- Need to optimize the shape to increase the effect.

AccLab BmSci ICR KyotoUniversity

2008.10.25

Local Anti-DiD with Coil

(not investigated well)



Coil current (NC or HTc)

Heat Removal necessary (heat pipe?)

Summary

- Five-Ring-Single PM-FFQ:
  - ➡ Adjusting and Measuring aiming at a test in ATF2 beam line.
  - ➡ Movers have to be installed.
- Anti-Solenoid is required for PM-FFQ.
- Local anti-DiD is investigated.
  - ➡ Passive: wedge, rings
  - ➡ Active: coils (NC or HTC)?

Appendix

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.