IR-14mr PM FF magnets

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Permanent Magnet Study Short History

2002~2005 First R&D program for FFQ

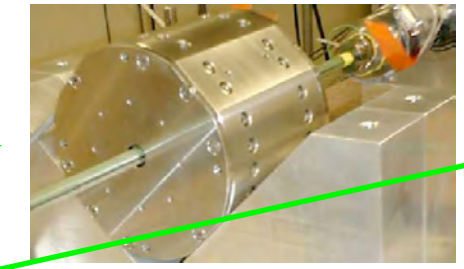
Permanent Magnet Quadrupole for Final Focus Lens in a Linear Collider

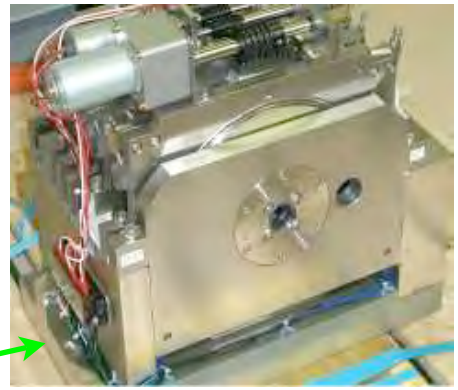
2002 Fixed strength PMQ

2003 Adjustable PMQ (double ring)

2004 Measurement and fine tuning

2005 Higher gradient at small bore





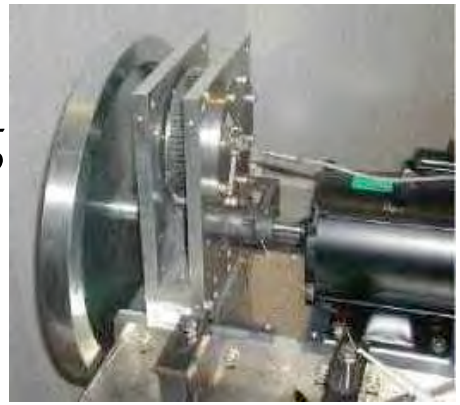
2006~2009 Second R&D program

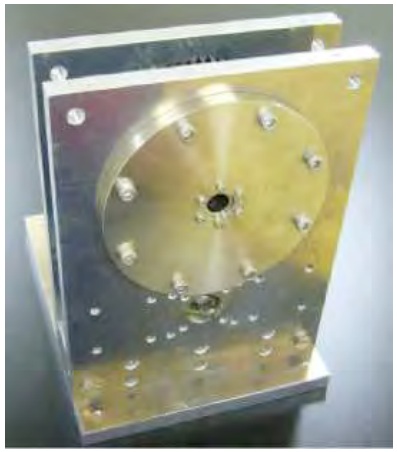
Development and Application of PMQ for Linear Collider and Neutron optics

2006 Half scale Model of Rapid Cycling Sextupole

2007~Adjustable PMQ（2nd model）

2008 ...





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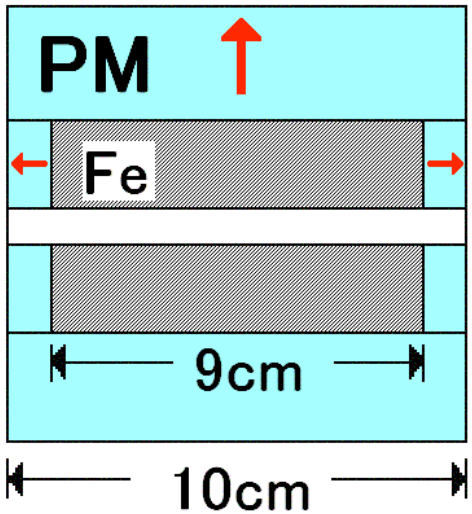
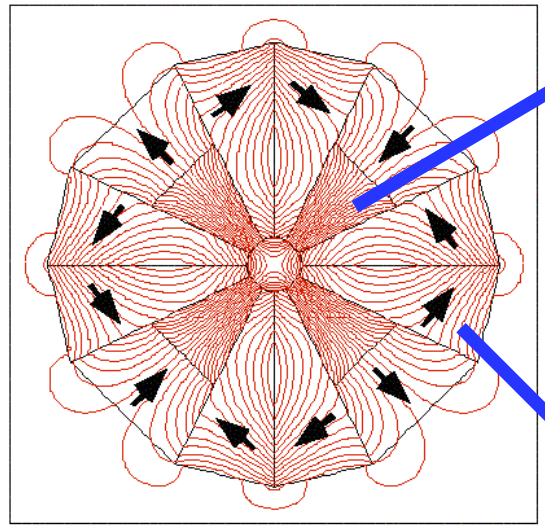
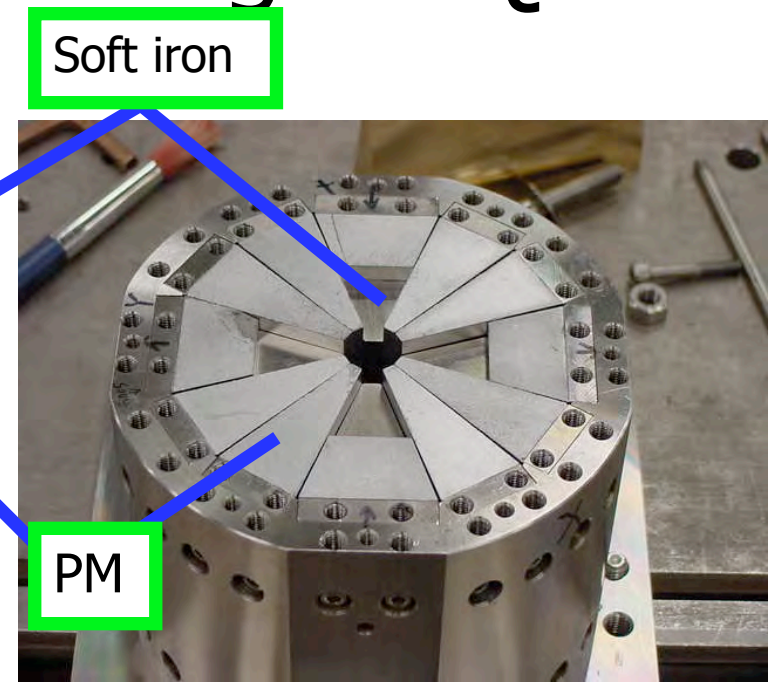
The first prototype of "superstrong" Permanent Magnet Quad.



Cut plane view



Axial view



PHOTO

Integrated gradient GL=28.5T (29.7T by calc.)

magnet size.	ø10cm
bore	ø1.4cm
Field gradient	**~300T/m**

$$GL = \int \frac{dB}{dr} dz$$

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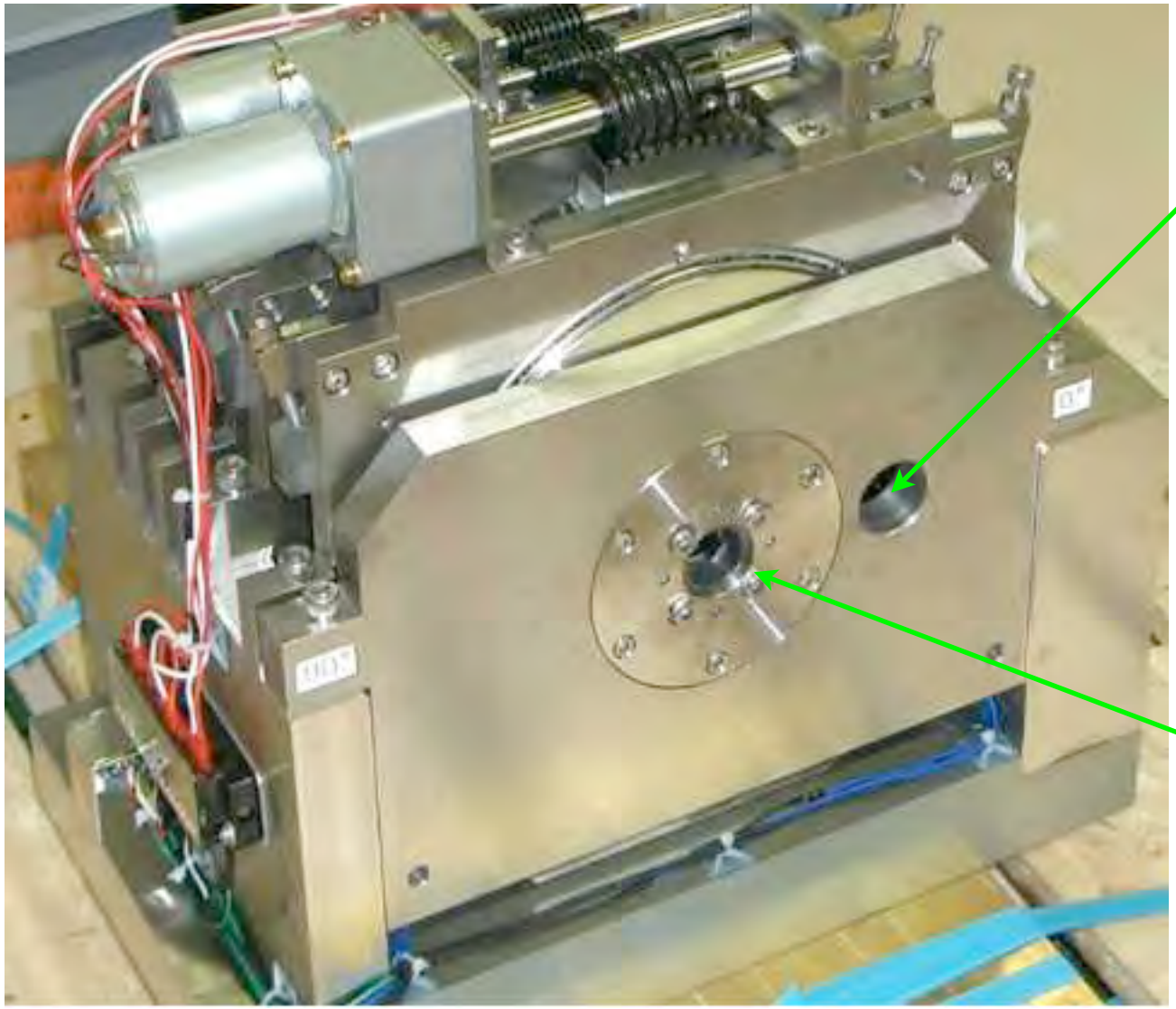
The 20mr Variable FFQ Magnet



hole for outgoing beam

hole for incoming beam

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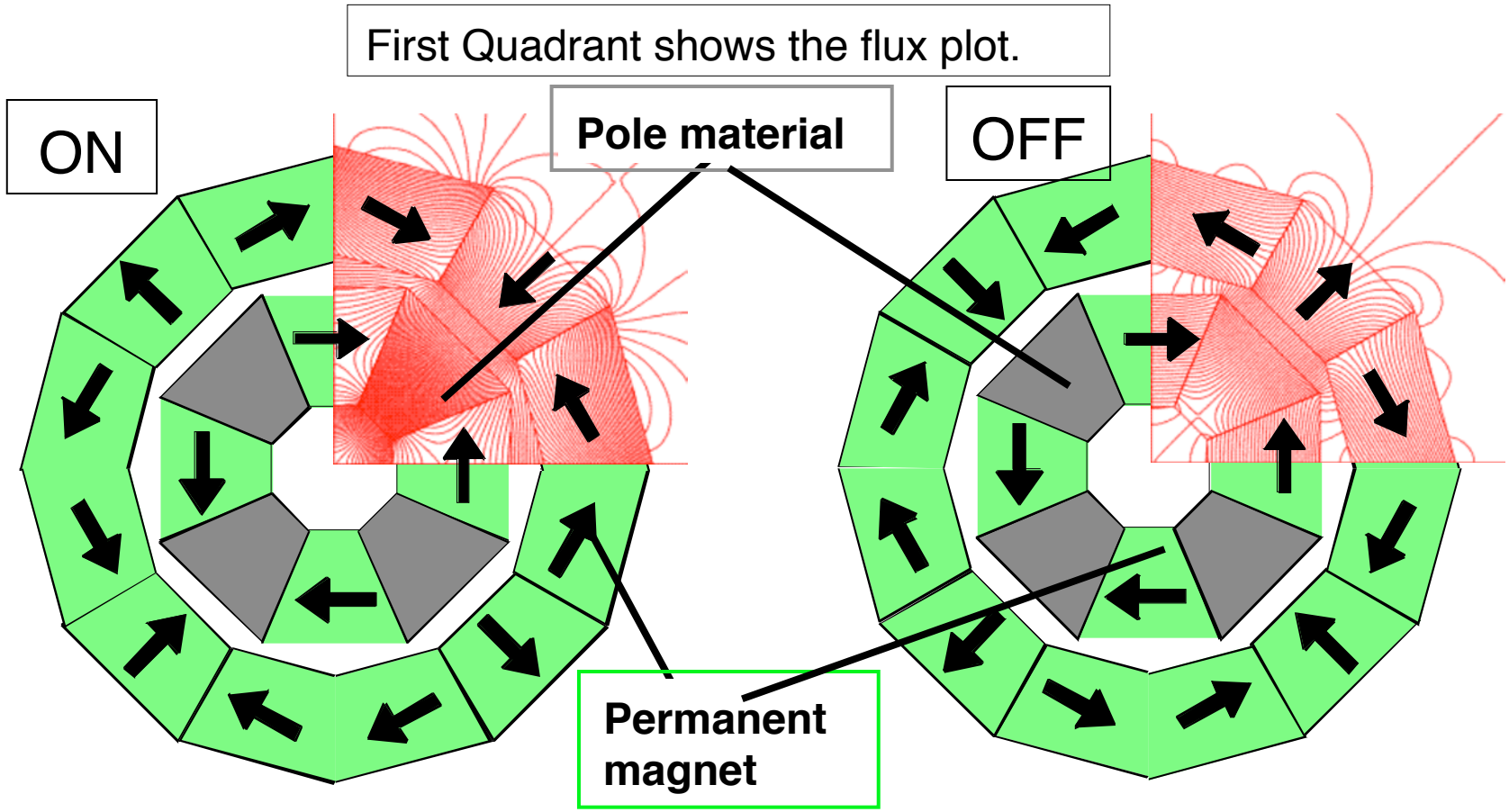
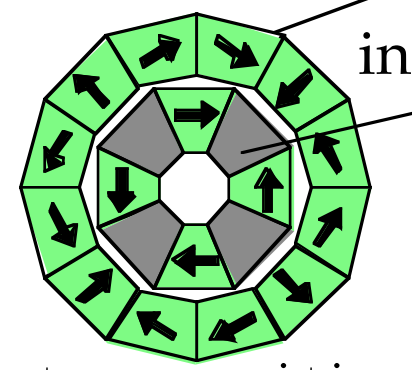
Double Ring Structure



The double ring structure

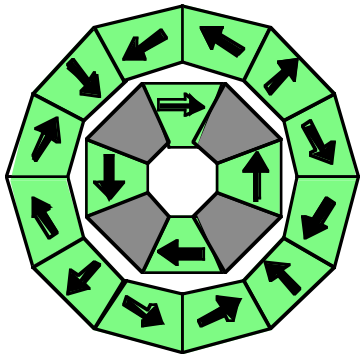
PMQ is split into inner ring and outer ring. Only the outer ring is rotated 90° around the beam axis to vary the focal strength.

Adjustable Permanent Magnet Quadrupole

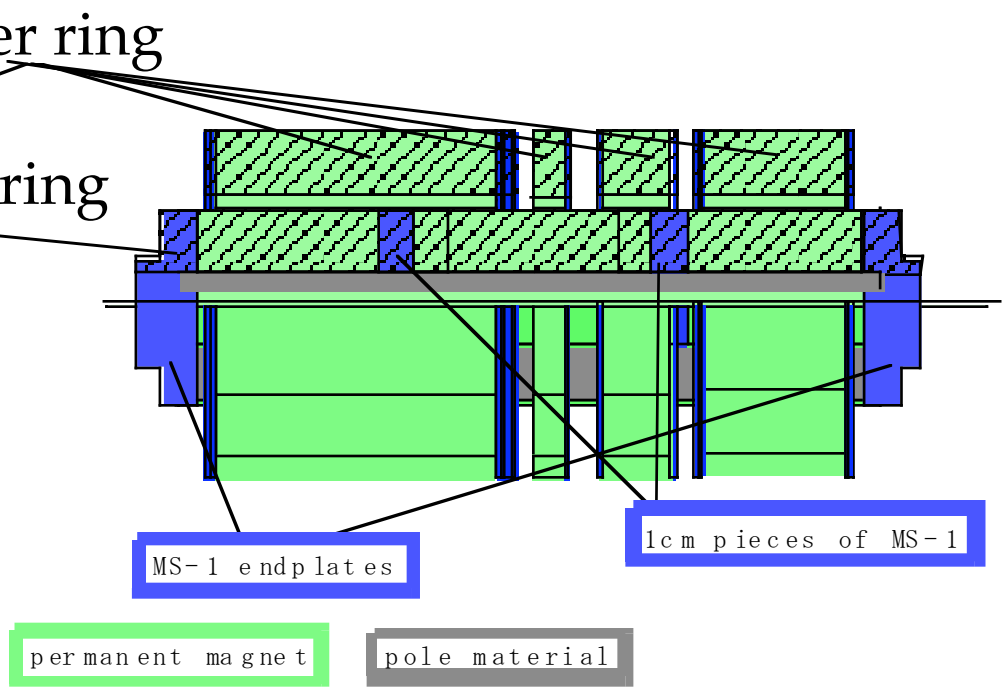


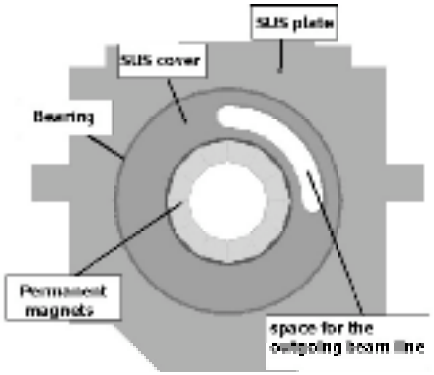
strong position

rotation



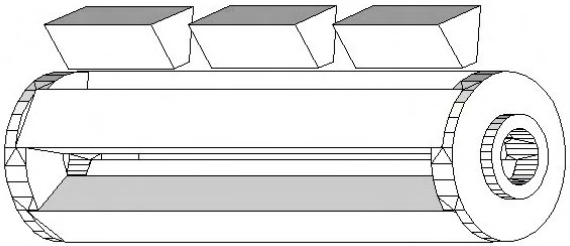
weak position





The PMQ is composed of an inner ring and four outer rings (Double Ring Structure). Only the outer rings are rotated in order to change the integrated gradient. The fixed inner ring suppresses any errors caused by rotation of outer rings.

Permanent Magnet (NEOMAX38AH)



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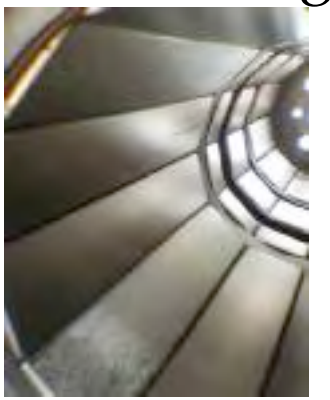
The 20mr Variable FFQ Magnet

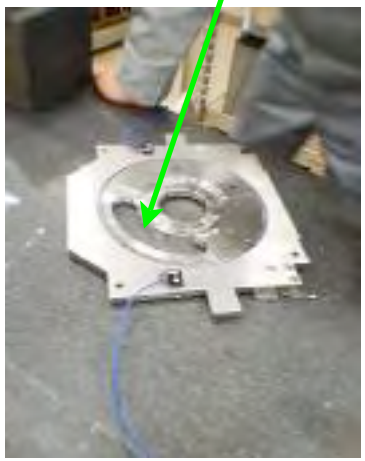
Bore radius	1cm
Inner ring radii	In 1cm out 3cm
Outer ring radii	In 3.3cm out 5cm
Outer ring section length Physical length	1cm, 2cm, 4cm, 8cm 23cm
Pole material	Permendur
Magnet material (inner ring)	NEOMAX38AH
Magnet material (outer ring)	NEOMAX44H
Integrated gradient (strongest)	24.2T
Integrated gradient (weakest)	3.47T
Int. gradient step size	1.4T

Extra beam hole

Inner Ring

Inside View of Outer Ring



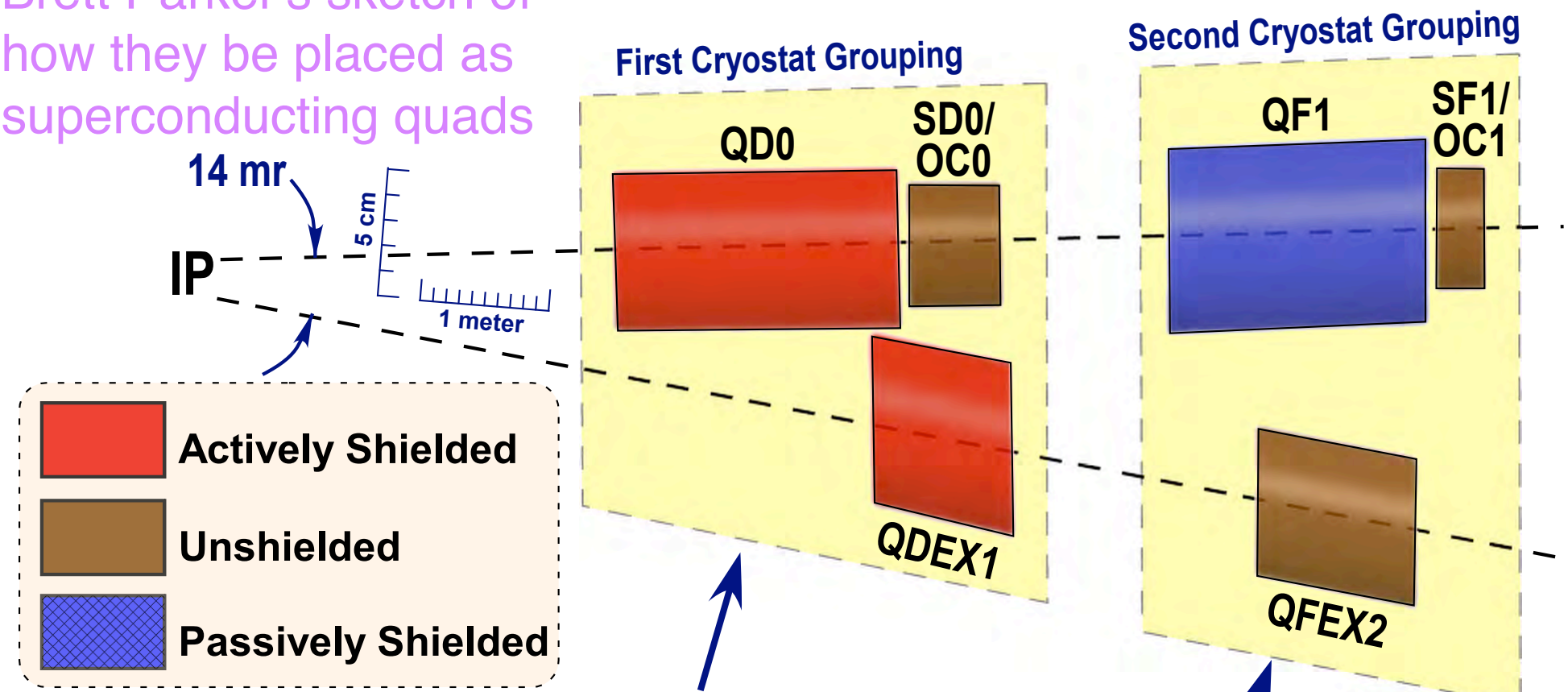


Base plate

Before assembly

Post Valencia 14 mr Magnet Layout Compatible with Push-Pull

Brett Parker's sketch of how they be placed as superconducting quads

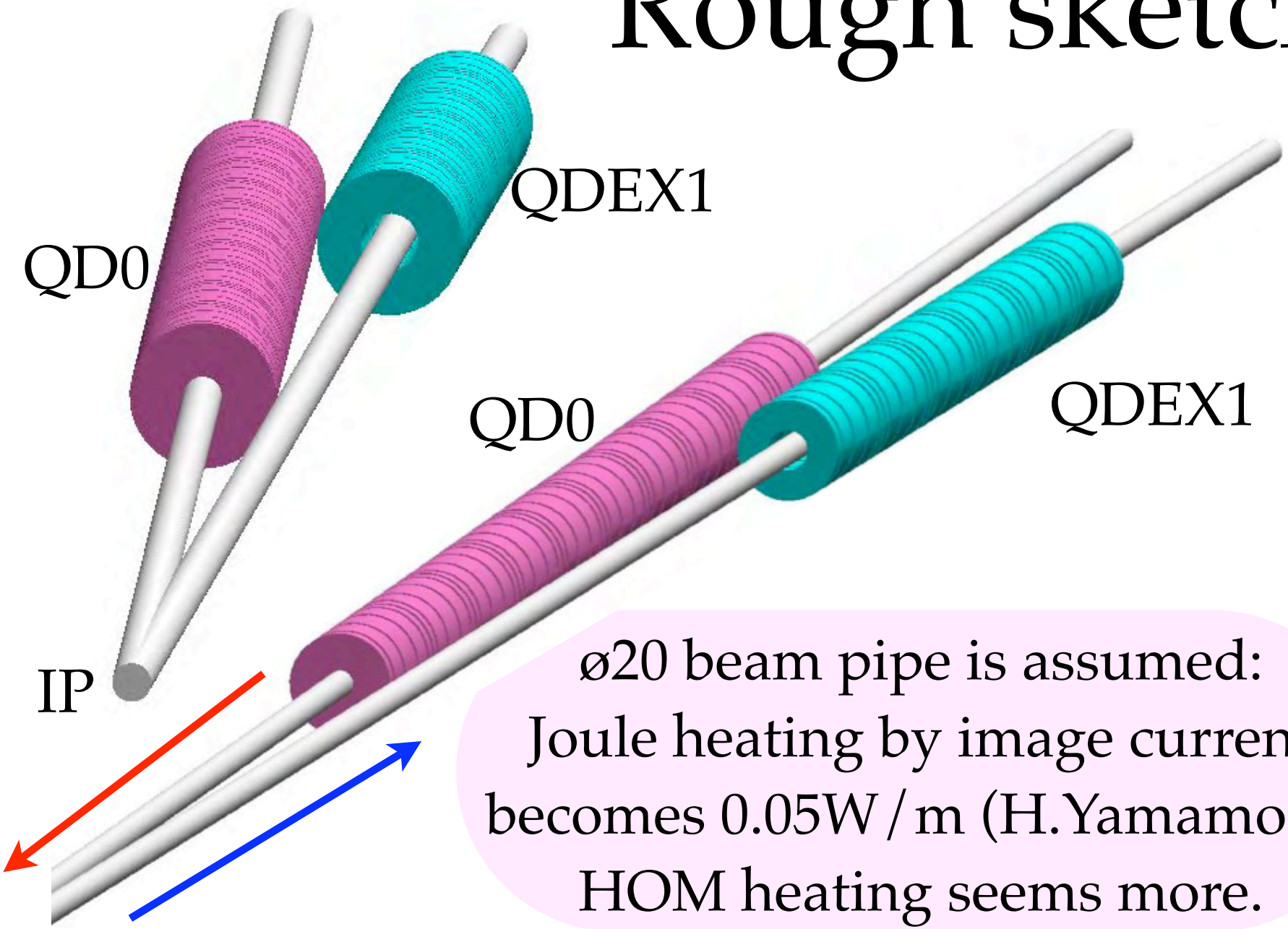


One of these magnet groups is needed in both ends of each detector (move with experiment, not shared).

One of these magnet groups is needed on each side of the common push-pull IR hall (fixed position, experiments share).

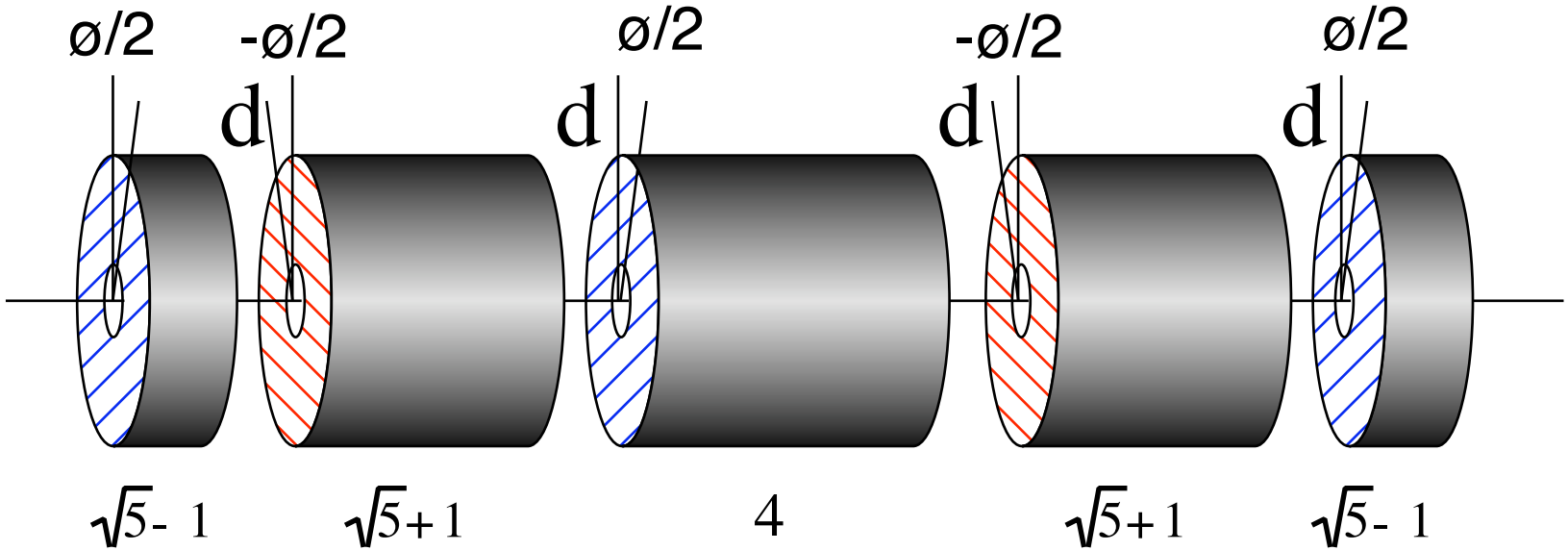
For actively shielded coils the shield is run in series with the main quadrupole current but with a trim circuit shunt power supply for fine adjustment.

Rough sketch



ø20 beam pipe is assumed:
Joule heating by image current
becomes 0.05W/m (H.Yamamoto)
HOM heating seems more.

Gluckstern's skewless variable PMQ



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

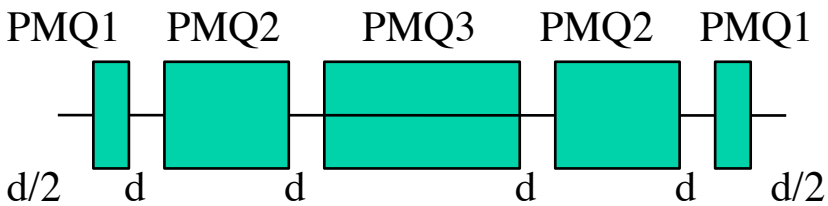
4x4 matrix: $M=\begin{pmatrix} Mxx & O^5 \\ O^5 & Myy \end{pmatrix}$ when d=0.

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

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

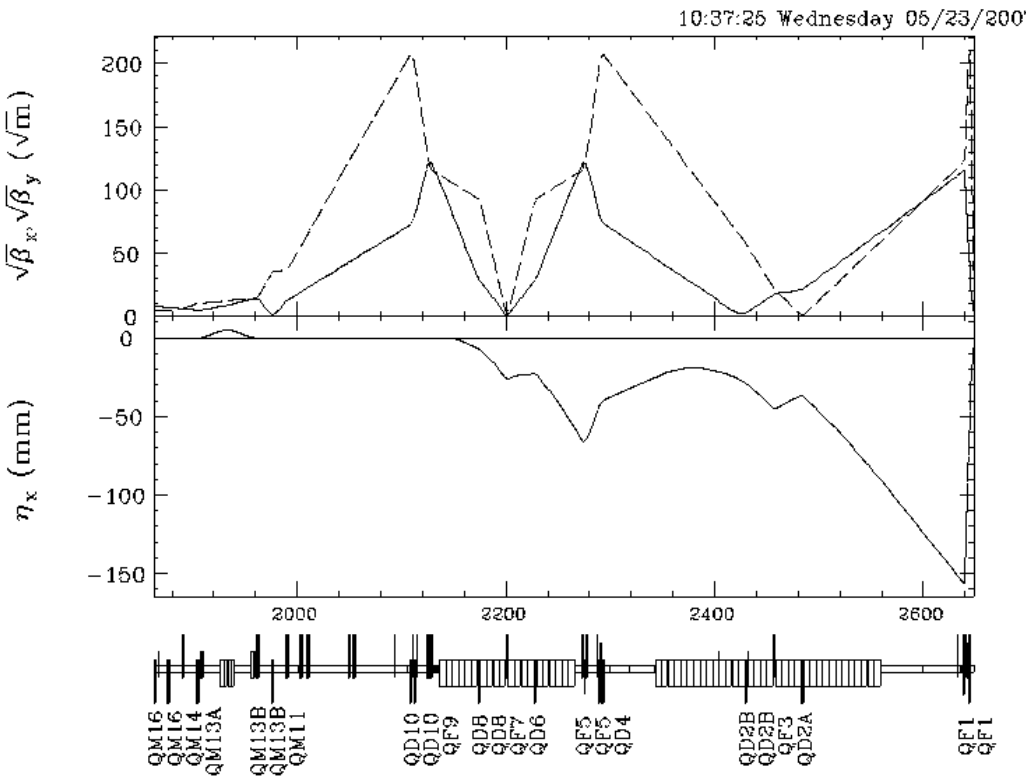
Starting with 'ilc2006b.ilcbds1'(14mrad version)
Since the original QD0 is of 2.2m length, adjustment of drift space is required to keep the total length unchanged.

D1B(QF1-SD0) L : 1.35 → 0.945m
D0 (L*) L : 3.51 → 3.105m

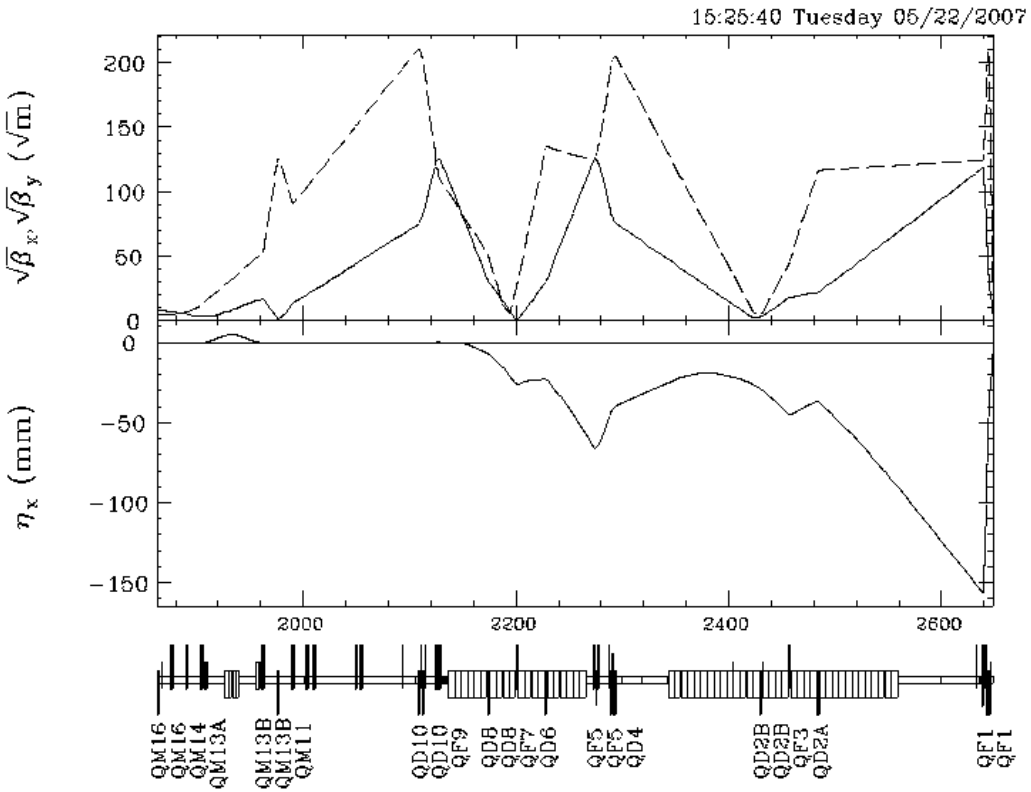
by S. Kuroda

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'

636/5.25nm (original)

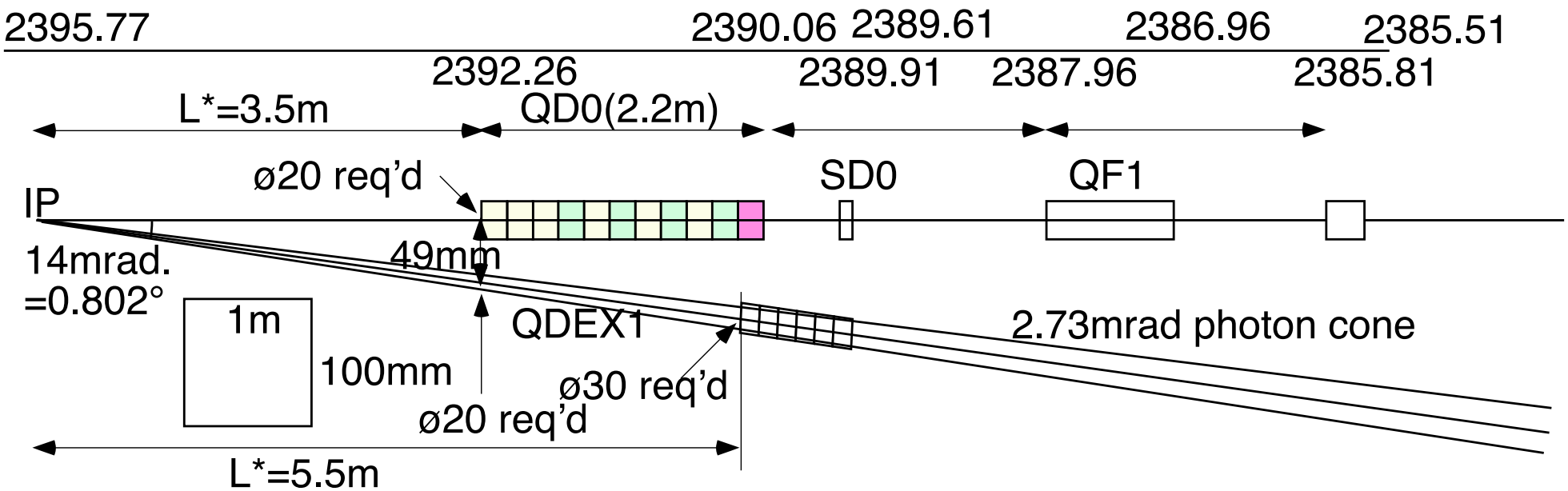
-- >

655/5.44nm

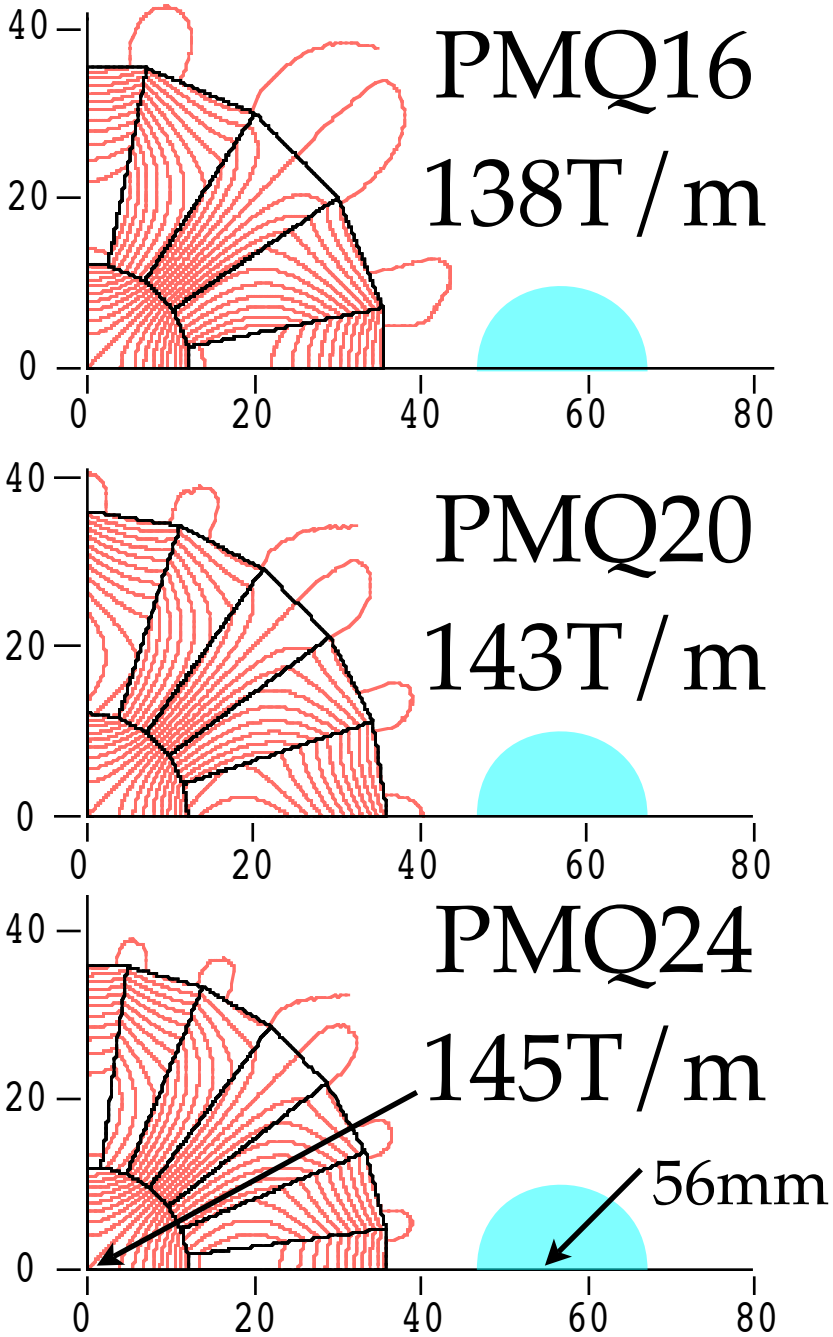
by S. Kuroda

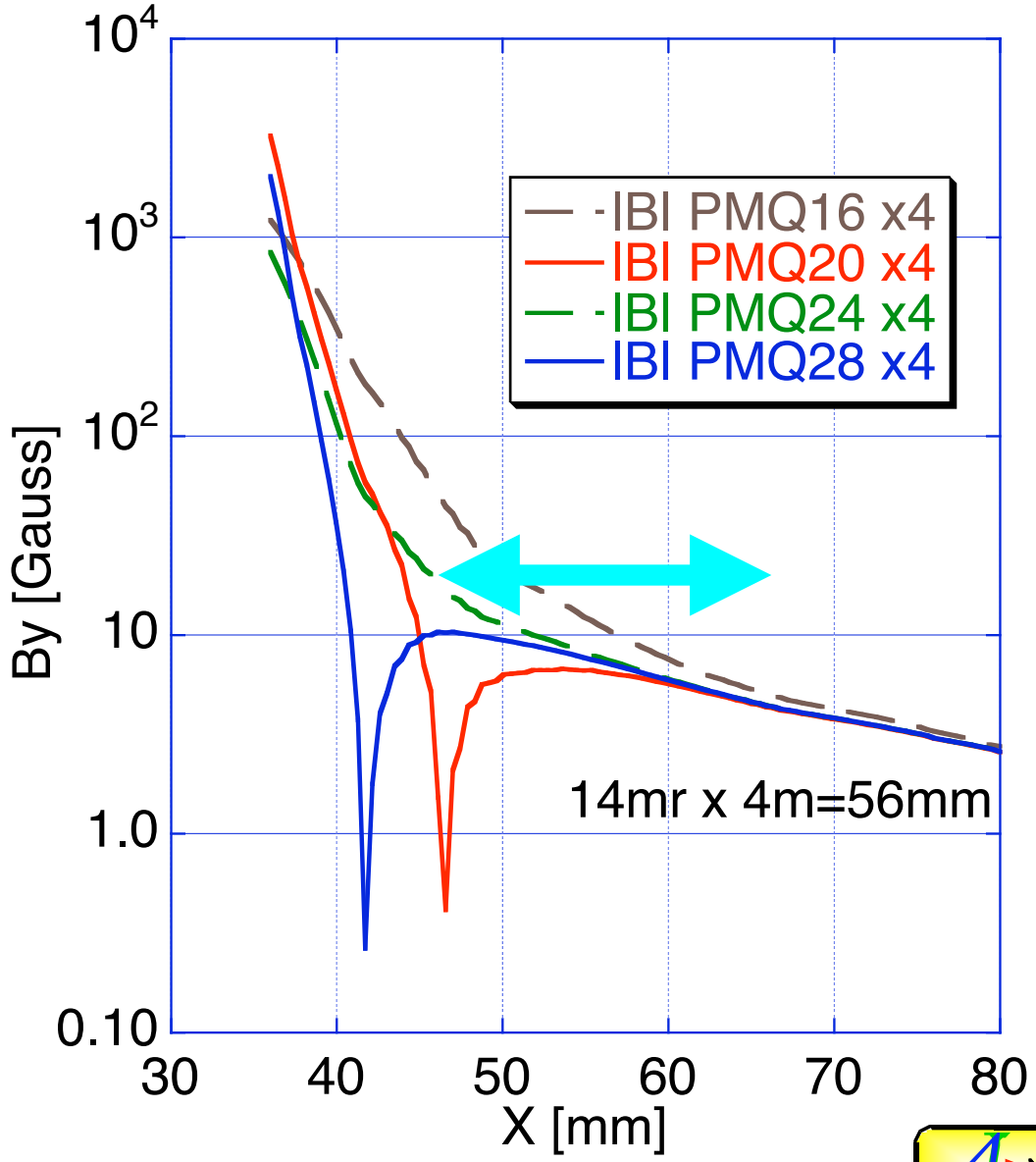
Single Ring Train Configuration

	Eff.L [m]	R [cm]	kG	kG/m	GL [kG]
QF1	2.0	1	8	803	1605
QD0	2.2	1	-14.2	-1416	-3116
QEX1	1.1	1.5	-15.0	-1000	-1060



External Field





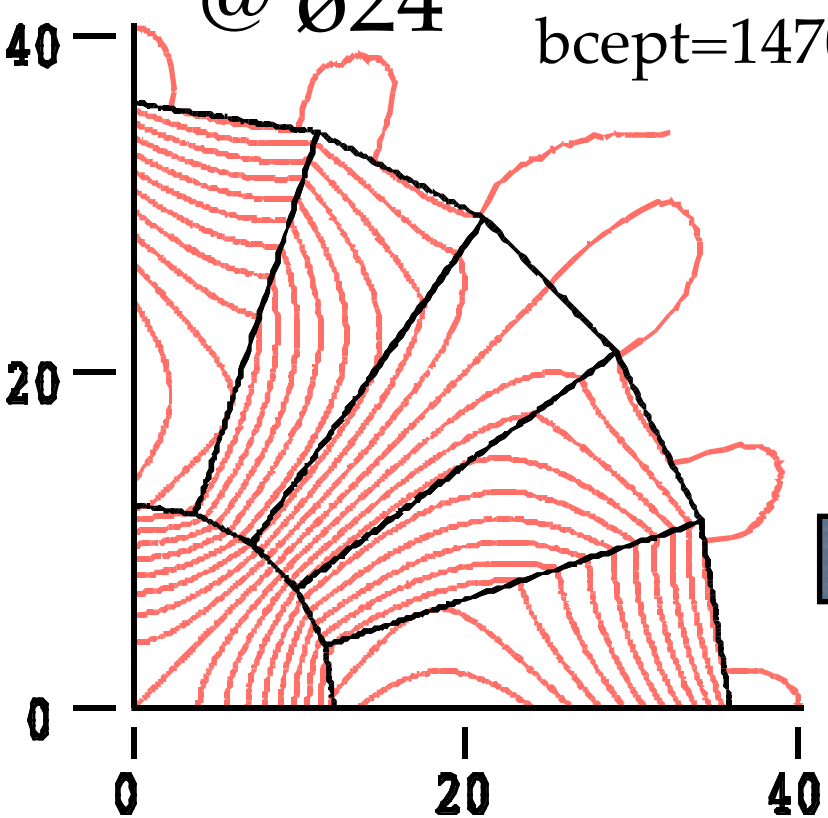
Test at ATF2?

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

OD: ø72 (=2x(56-20)) 14mr x 4m=56mm

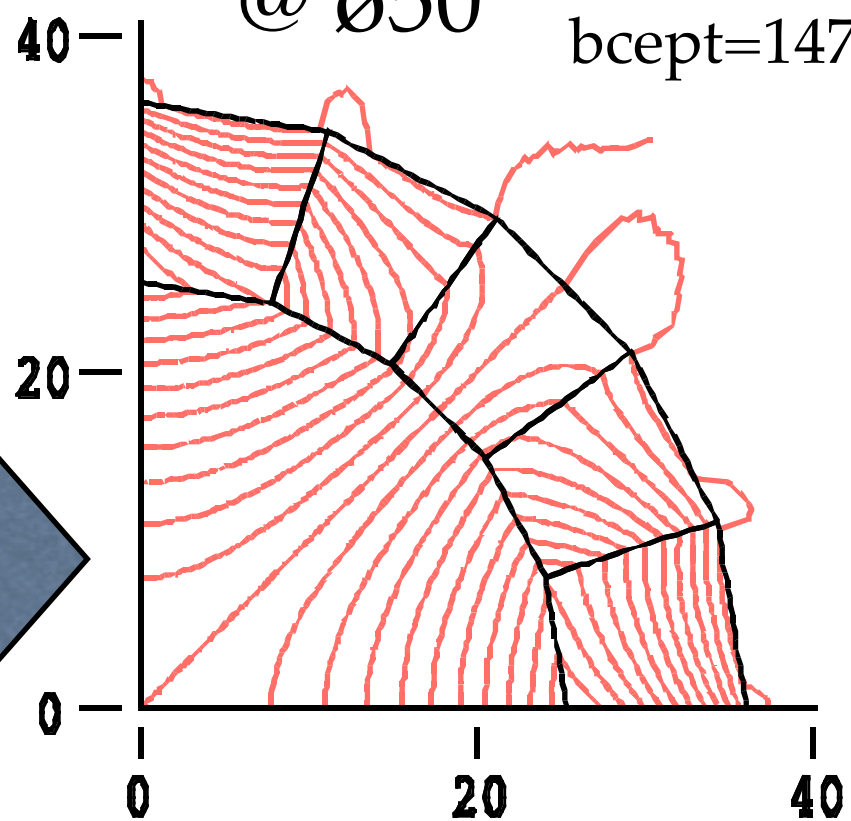
143T/m @ ø24

55AH
hcept=-12500,
bcept=14700.



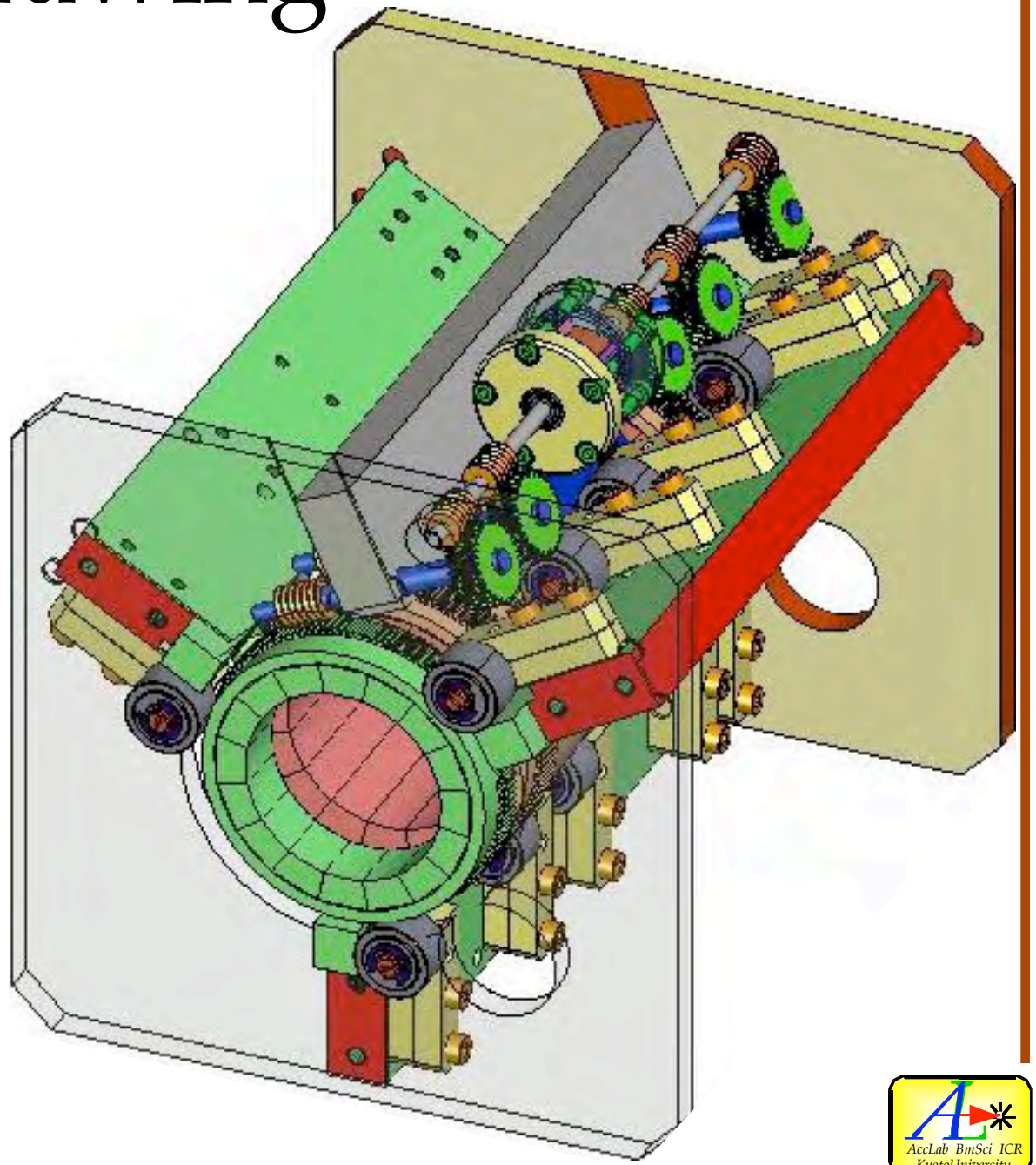
30T/m @ ø50

55AH
hcept=-12500,
bcept=14700.



Preliminary Drawing

Supersonic
Motor
(nonmagnetic)



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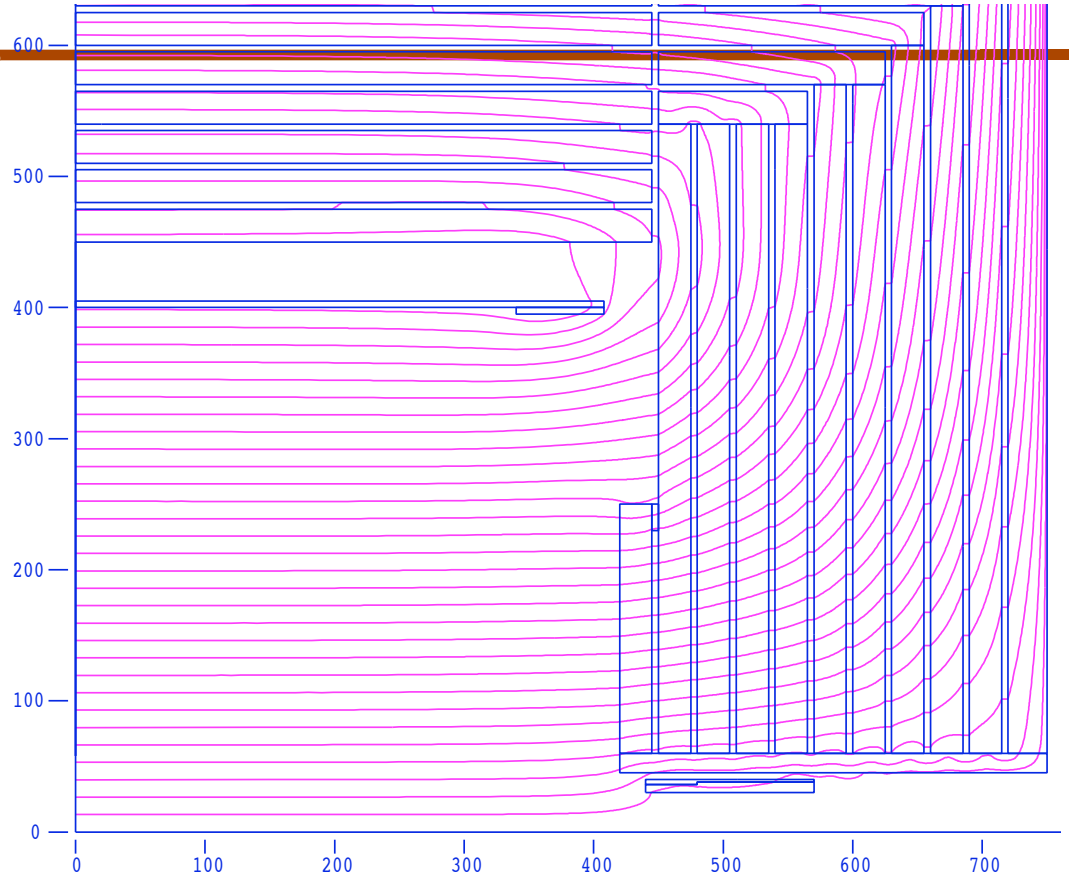
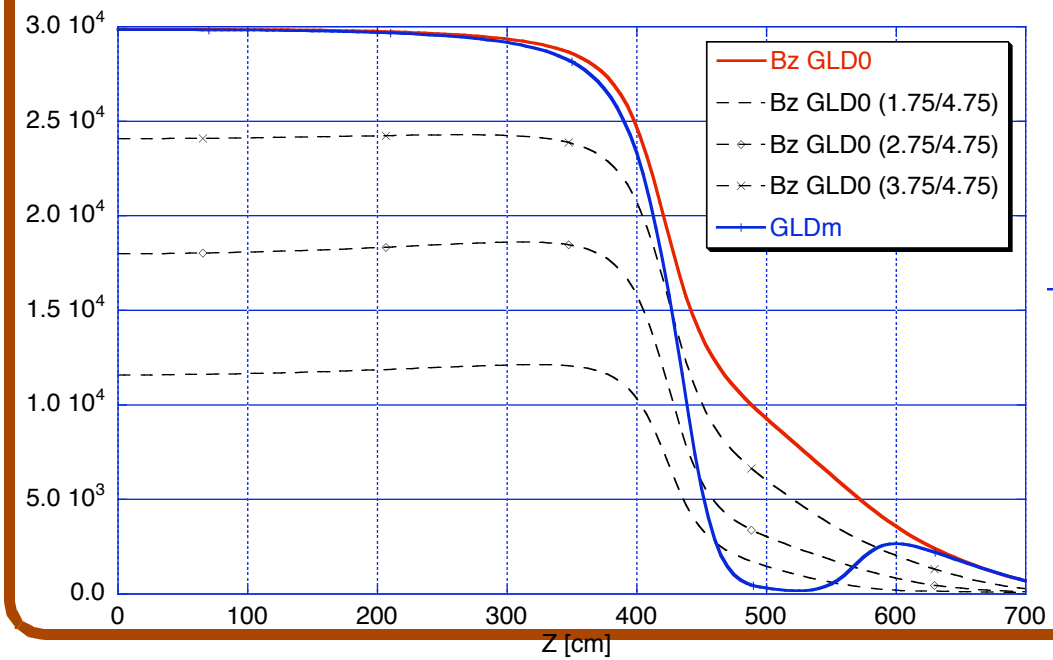
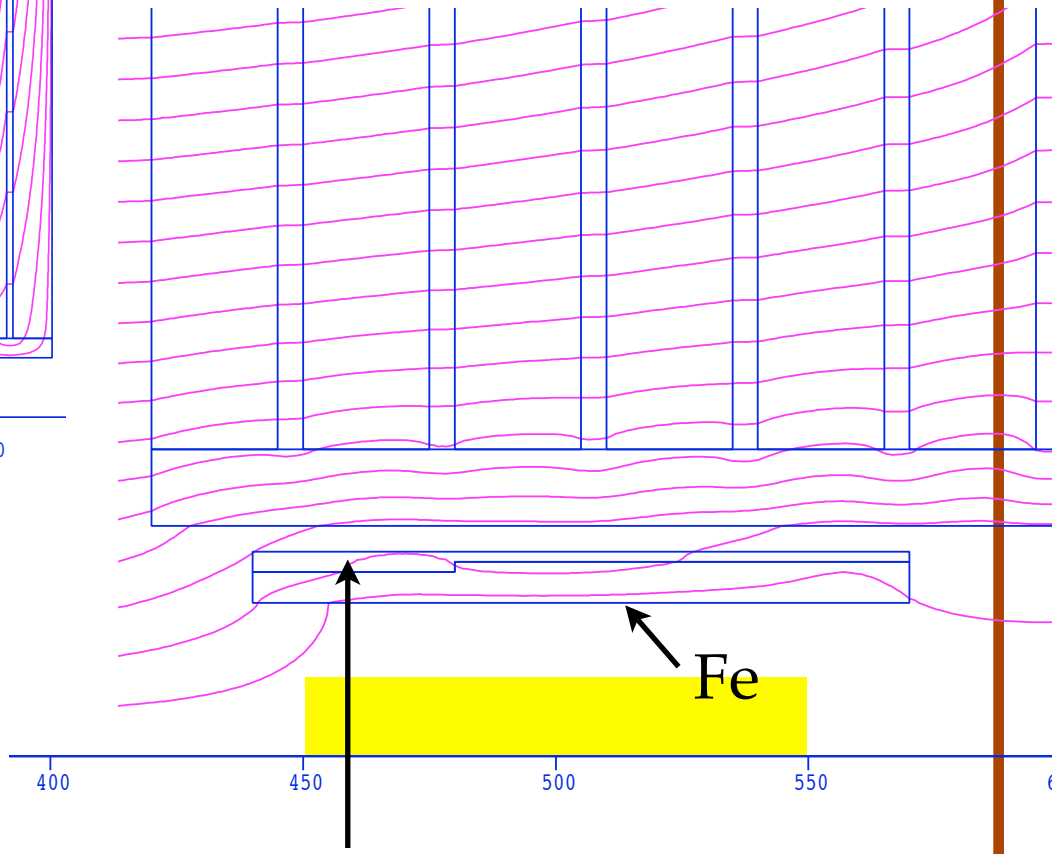
Magnetic Field around QD0







Antisolenoid: I = 3e4A / cm2

Force cancellation?

Summary

- 1st variable PMQ was based on double-ring structure (for 20mr) and evaluated.
- 2nd one (for 14mr) will have **5-ring-singlet structure**.
  - ➡ The strength can be changed **continuously**.
  - ➡ The **stray flux** outside PMQ can be small.
  - ➡ PM only structure **endure higher external field**.
- There is **no vibration source** in PMQ.
- A prototype will be fabricated this FY (ATF2 QD0?).
- Subjects to be investigated:
  Stability - Temp., Mag. center shift, Rad. damage, Antisolenoid, ...

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