# Permanent Q at IP as well as at the upstream

## - tunability e.g. waist scan and vibration -

Kyoto University
Y. Iwashita

# Introduction

- Standpoint - why do we need this?
  - ➡ anxiety on vibration of Sc-EM (straightforward)
  - ➡ tunability requested (fixed PMQ proven)
  - ➡ new device needs handling experience.
- Brief Review of the history
- What is left to do?

# Permanent Magnet Study Short History

## 2002~2005 First R&D program for FFQ

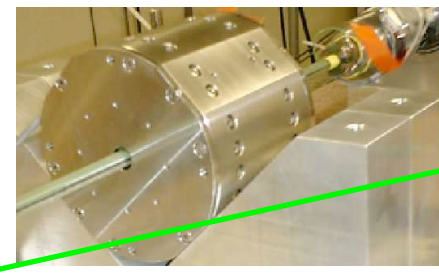
Permanent Magnet Quadrupole for Final Focus Lens in a Linear Collider

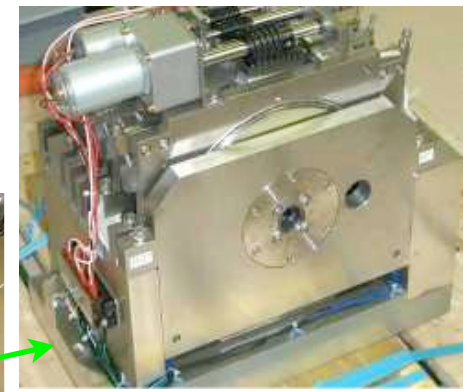
2002 Fixed strength PMQ

2003 Adjustable PMQ (double ring)

2004 Measurement and fine tuning

2005 Higher gradient at small bore





## 2006~2009 Second R&D program

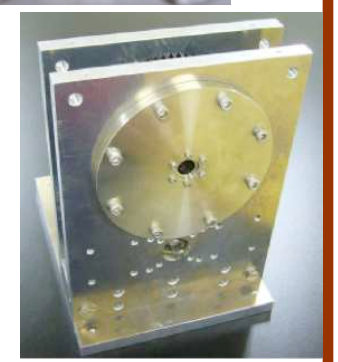
PMQ for Linear Collider and Neutron optics

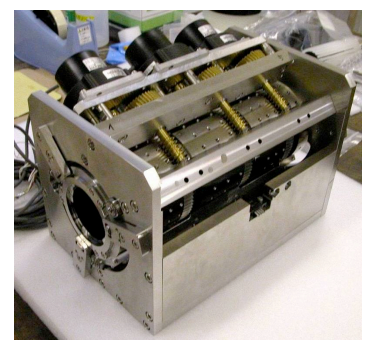
2006 Rapid Cycling Sextupole for neutron

2007 Adjustable PMQ (2nd model) started

2008 Assemble, Measurement and Adjustment

2009 Design and fabrication of Magnet mover





**No budget this year 2010!**

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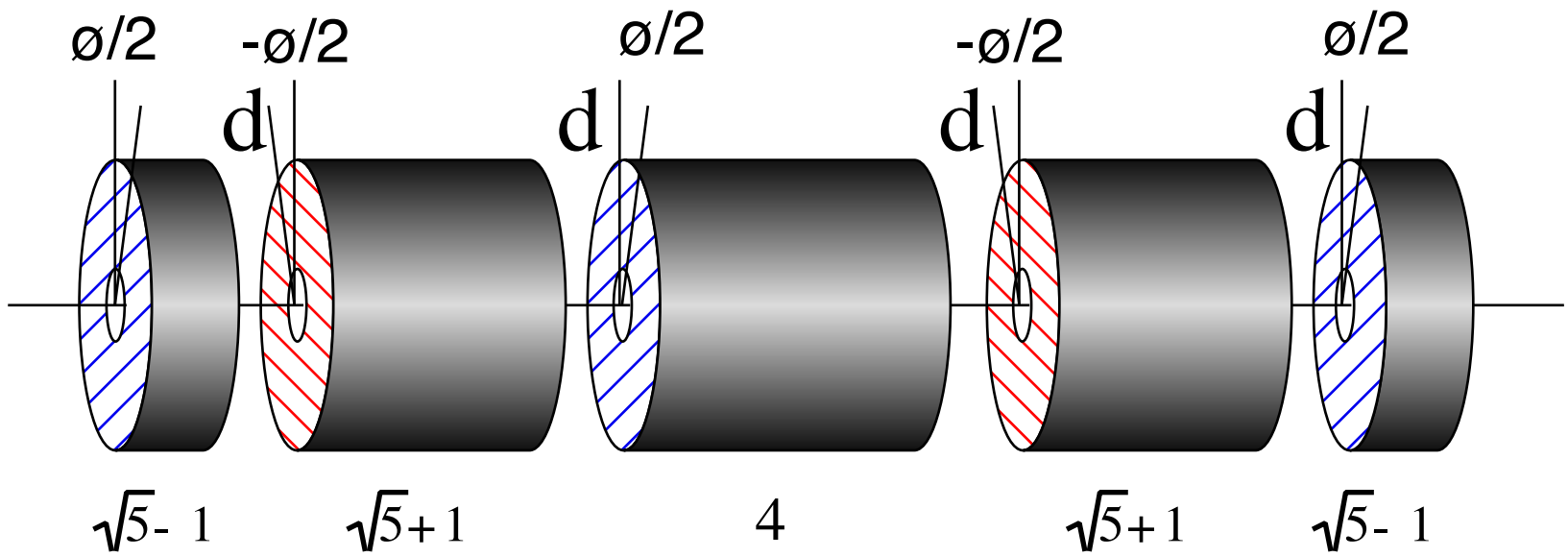
# Gluckstern's adjustable PMQ

# Gluckstern's skewless variable PMQ



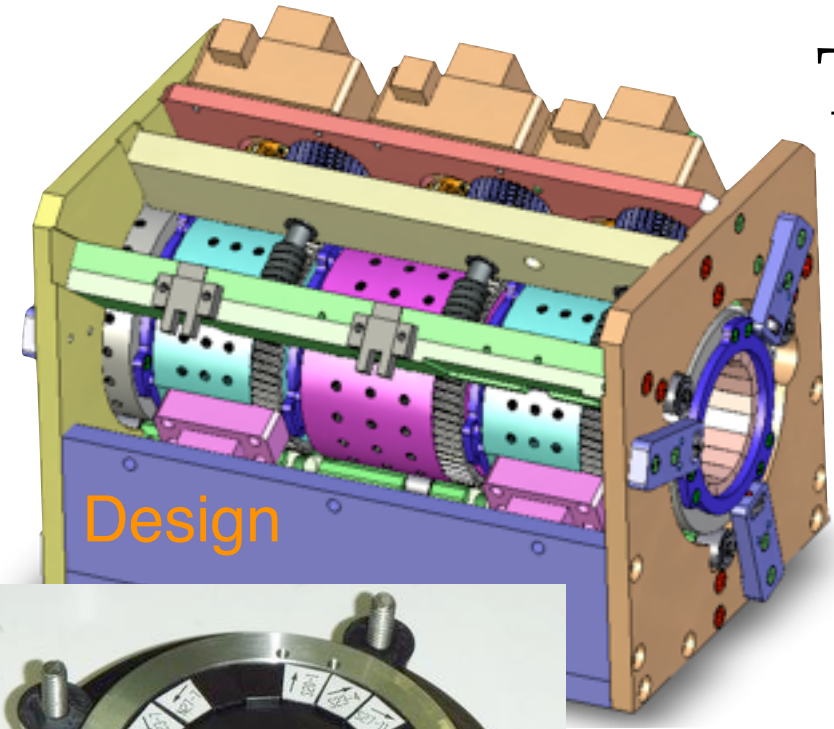

$$M = R \bullet M2 \bullet R^{-2} \bullet M1 \bullet R^{2} \bullet M0 \bullet R^{-2} \bullet M1 \bullet R^{2} \bullet M2 \bullet R^{-1}$$

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

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

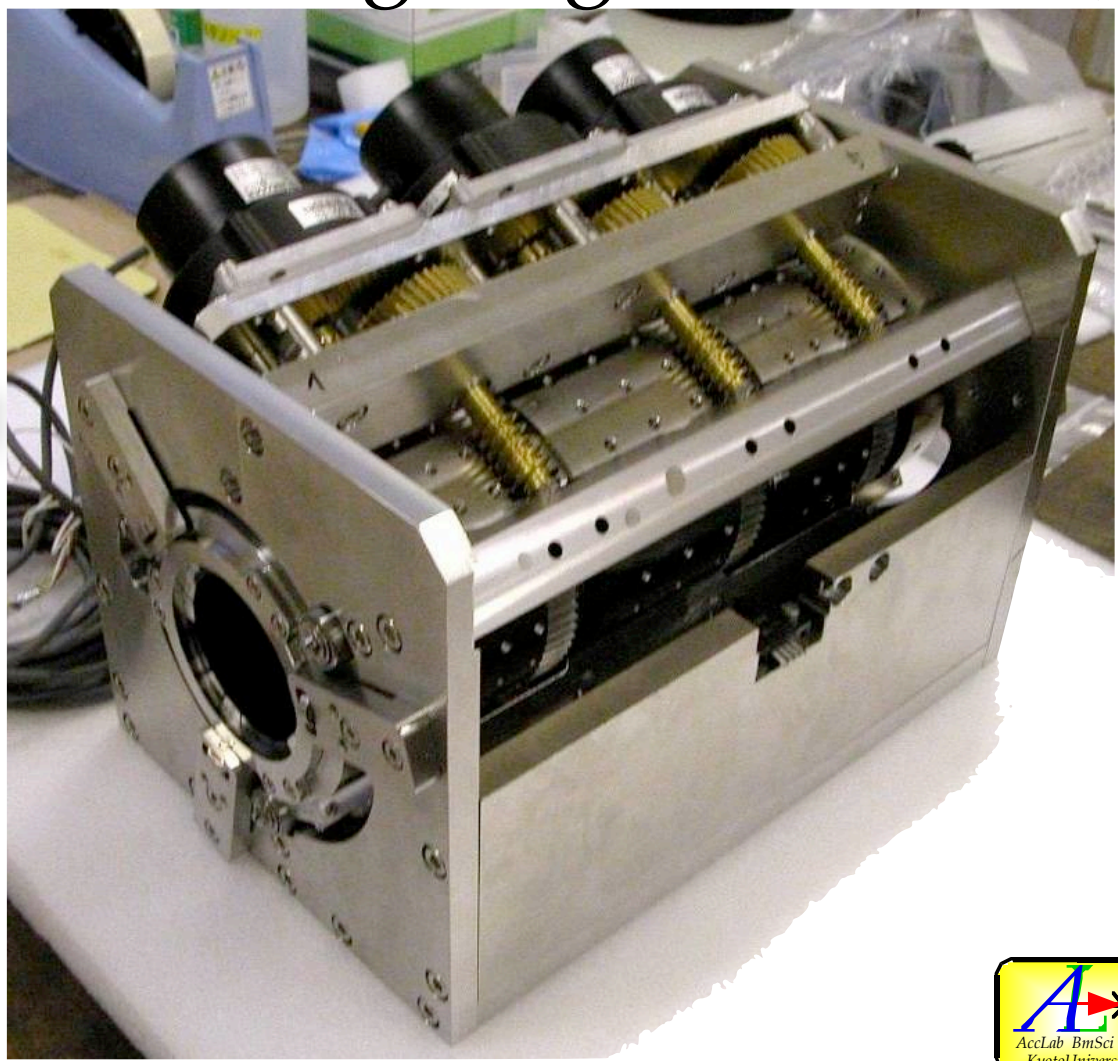
# Gluckstern's 5-ring PMQ Singlet(2):

## "Continuously Adjustable" PMQ fabricated




Disc(20mm)

## The 5-ring singlet PM-FFQ



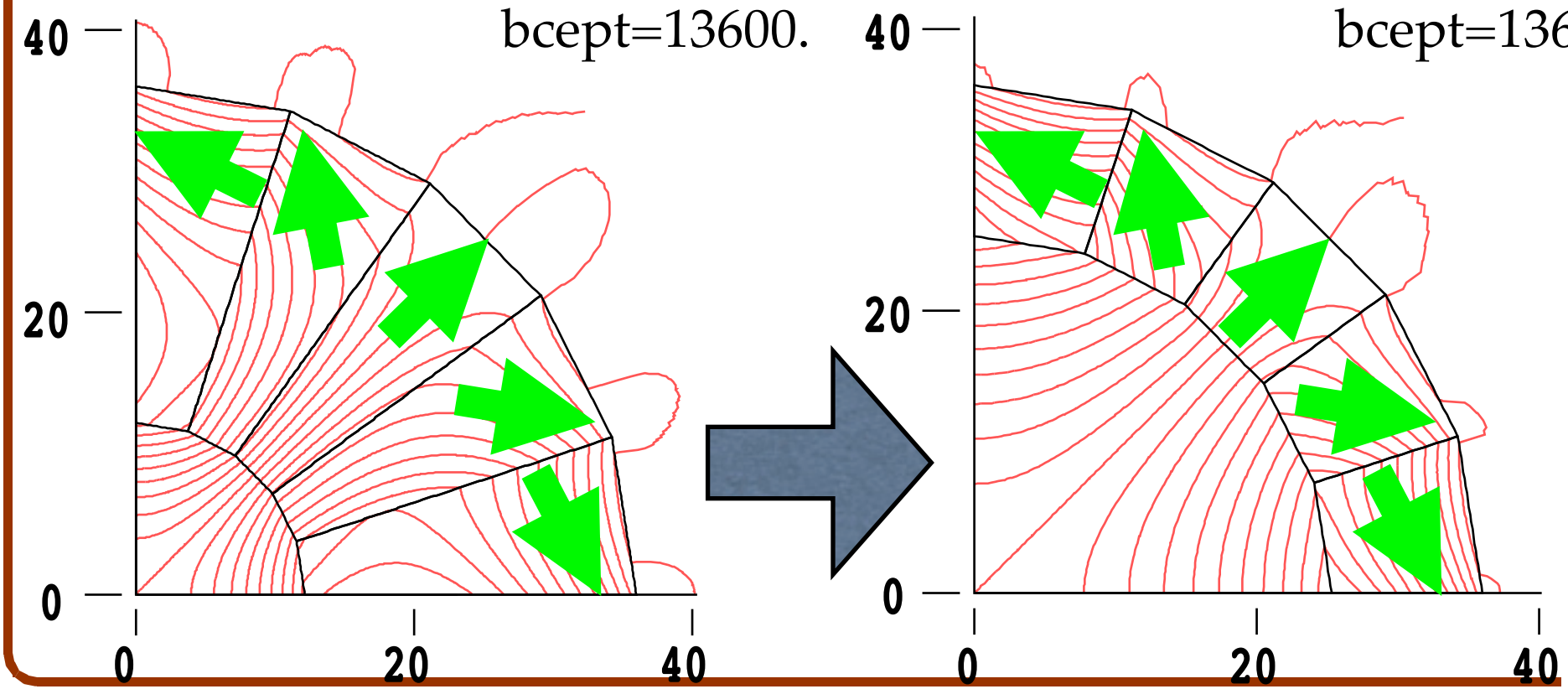
# Test at ATF2 – replace QD0

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

OD: ø72 (=2x(56-20))  GL=5.85 T

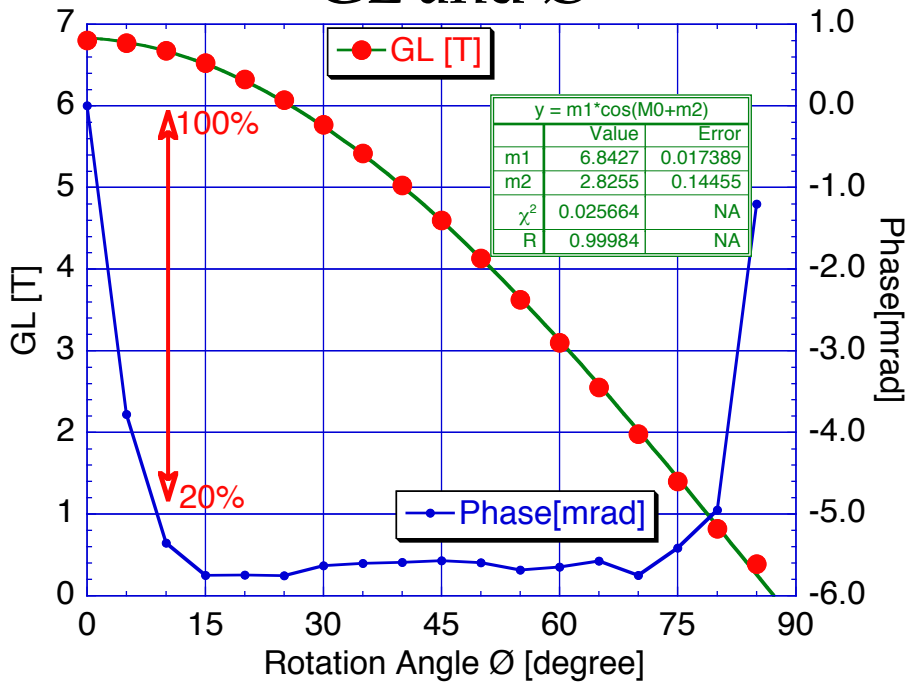
140T/m @ ø24  48H hcept=-12890, bcept=13600.

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

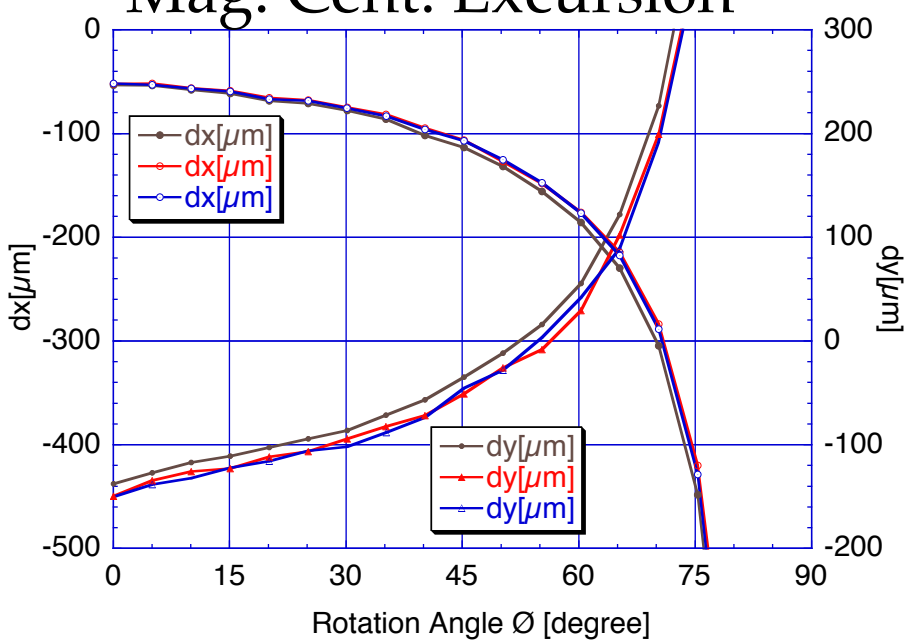


# Adjustment

## GL and Ø




## Mag. Cent. Excursion




# Observations

- GL (100~20%) can be covered.
- Angle adjustment needed.
- Reproducible magnet center excursion.
- But the value is big
  – needs adjustment.
- Minor mechanical modification will improve the excursion.

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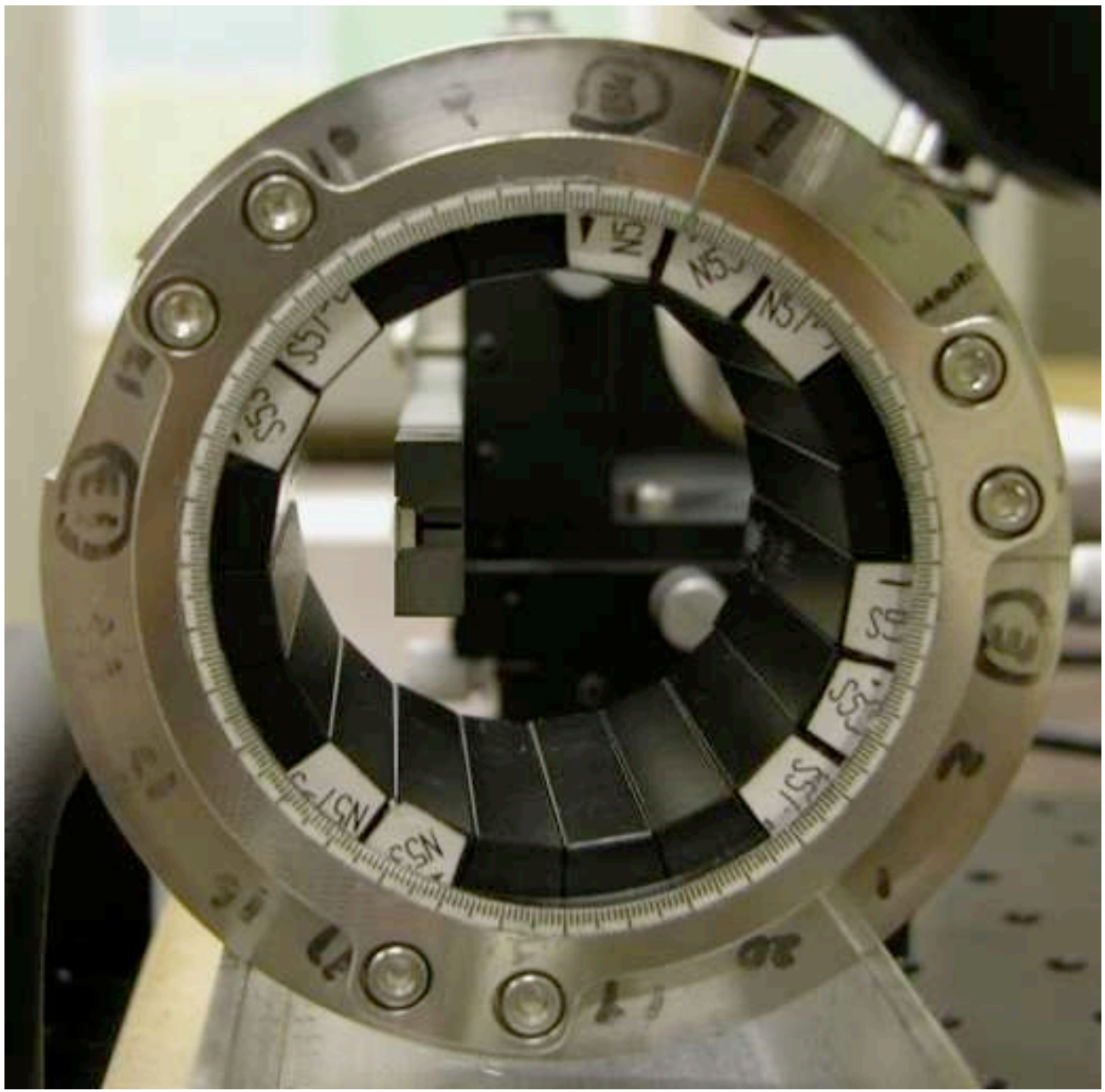
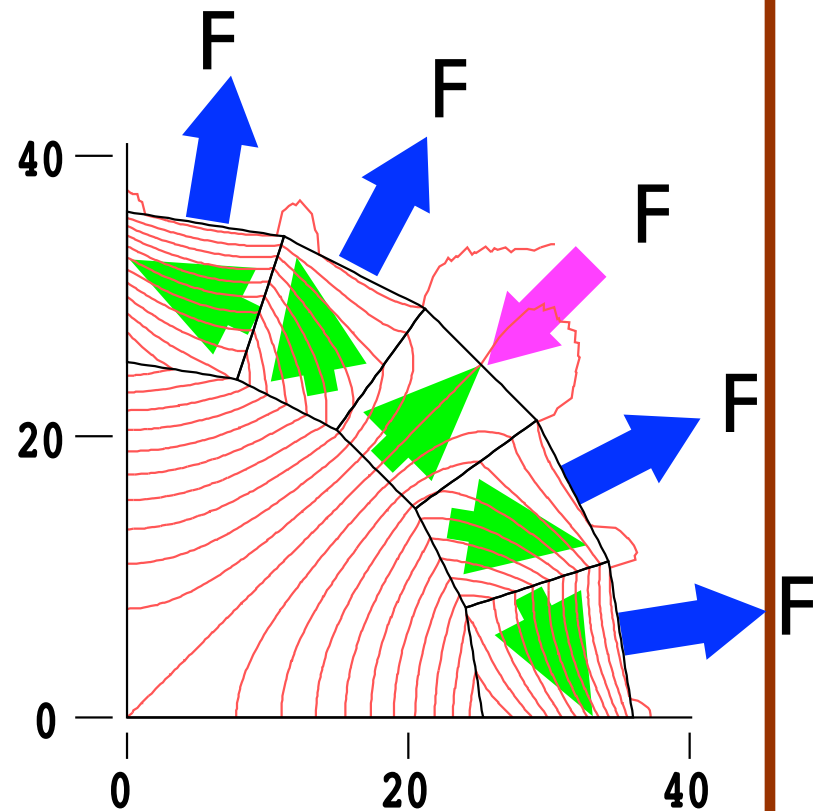
# Magnet Bore



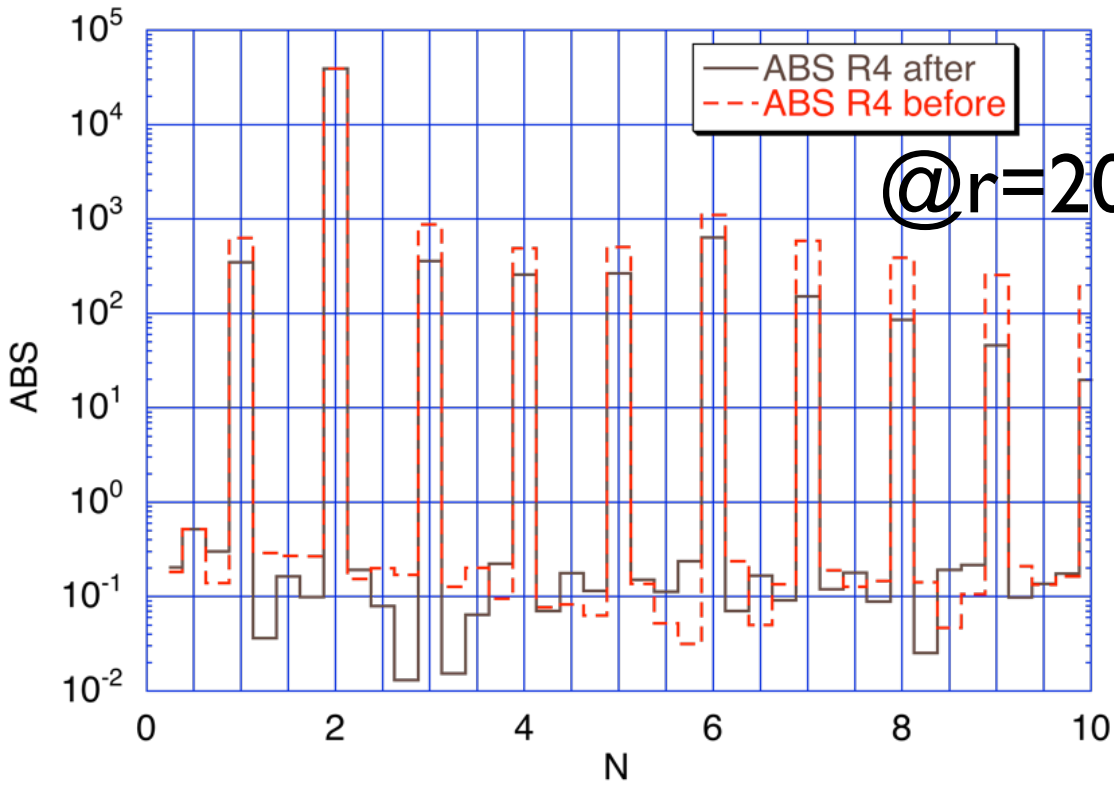
Pole magnets are attracted.




Others are repulsive.

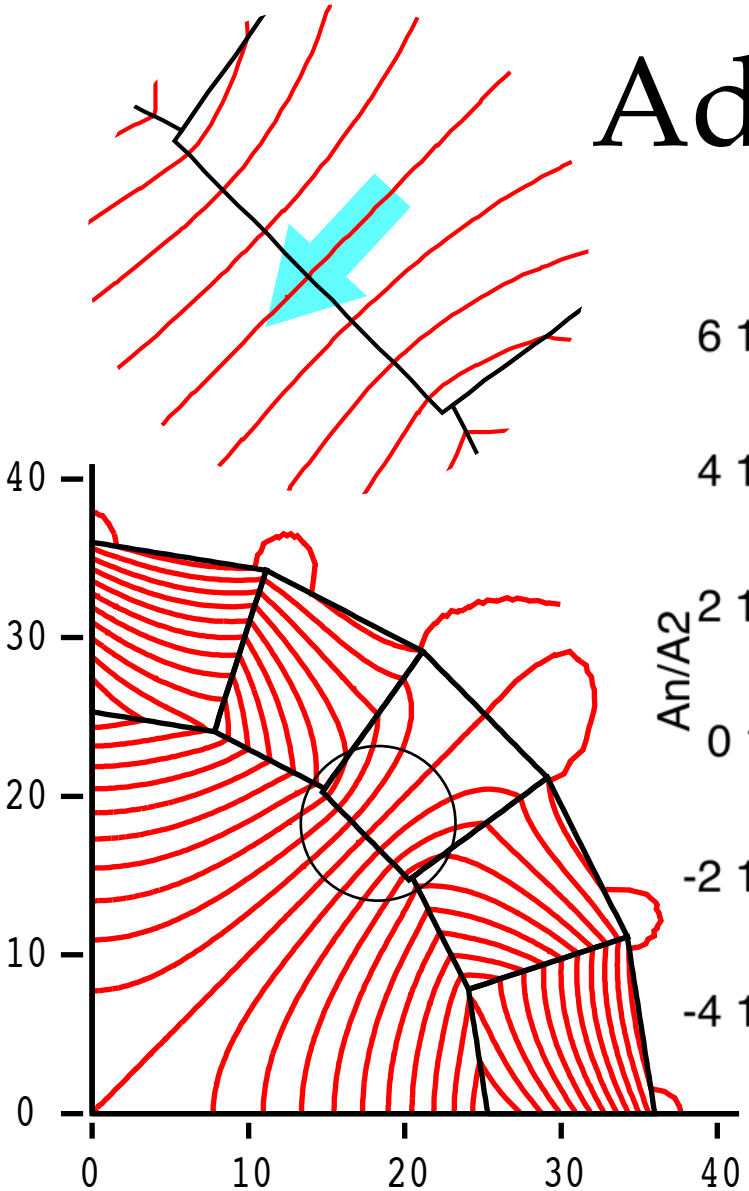
# Measurement on each PMQ

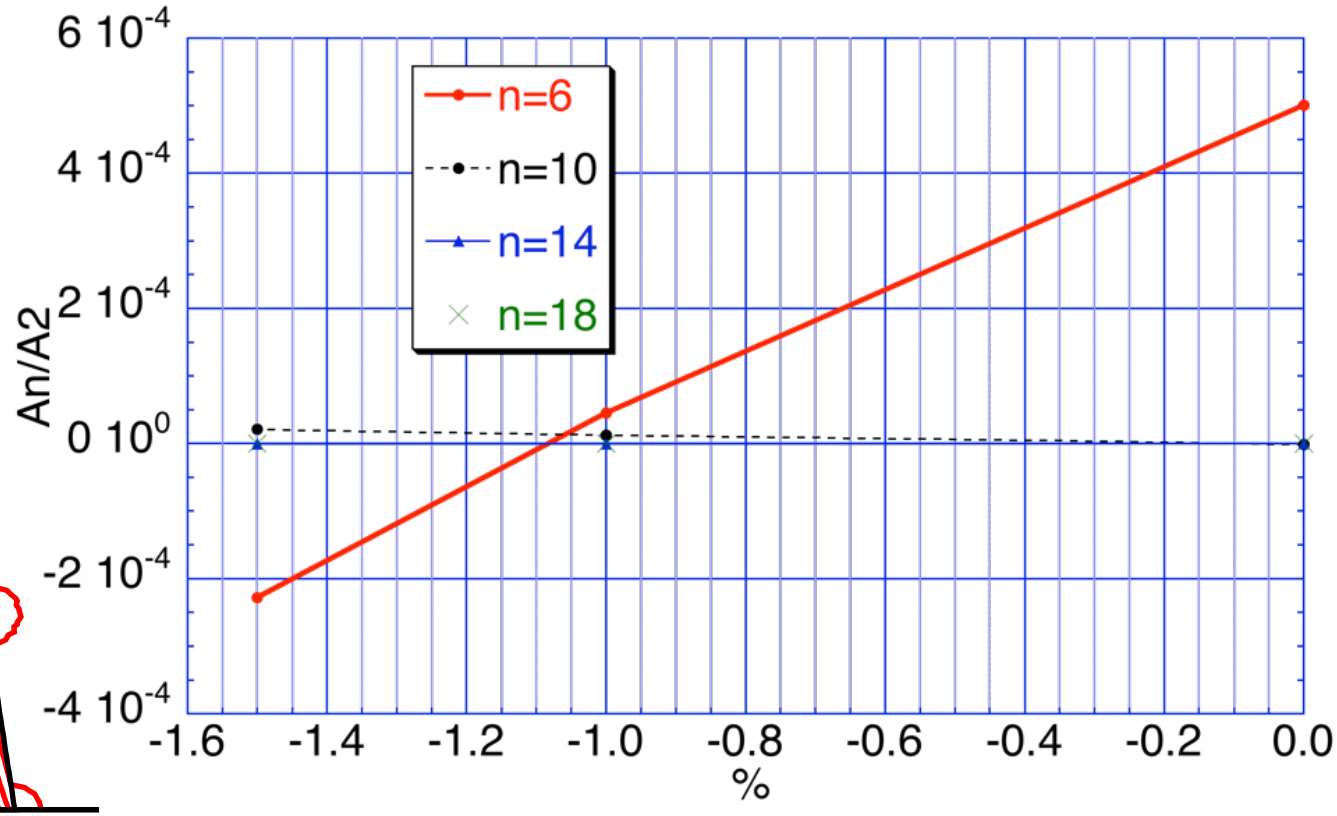
Just before and after a wrong magnet piece replacement




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

# Adjusting n=6




Displacing magnet pieces at pole positions (4 out of 20).

r=25mm -> 24.7mm

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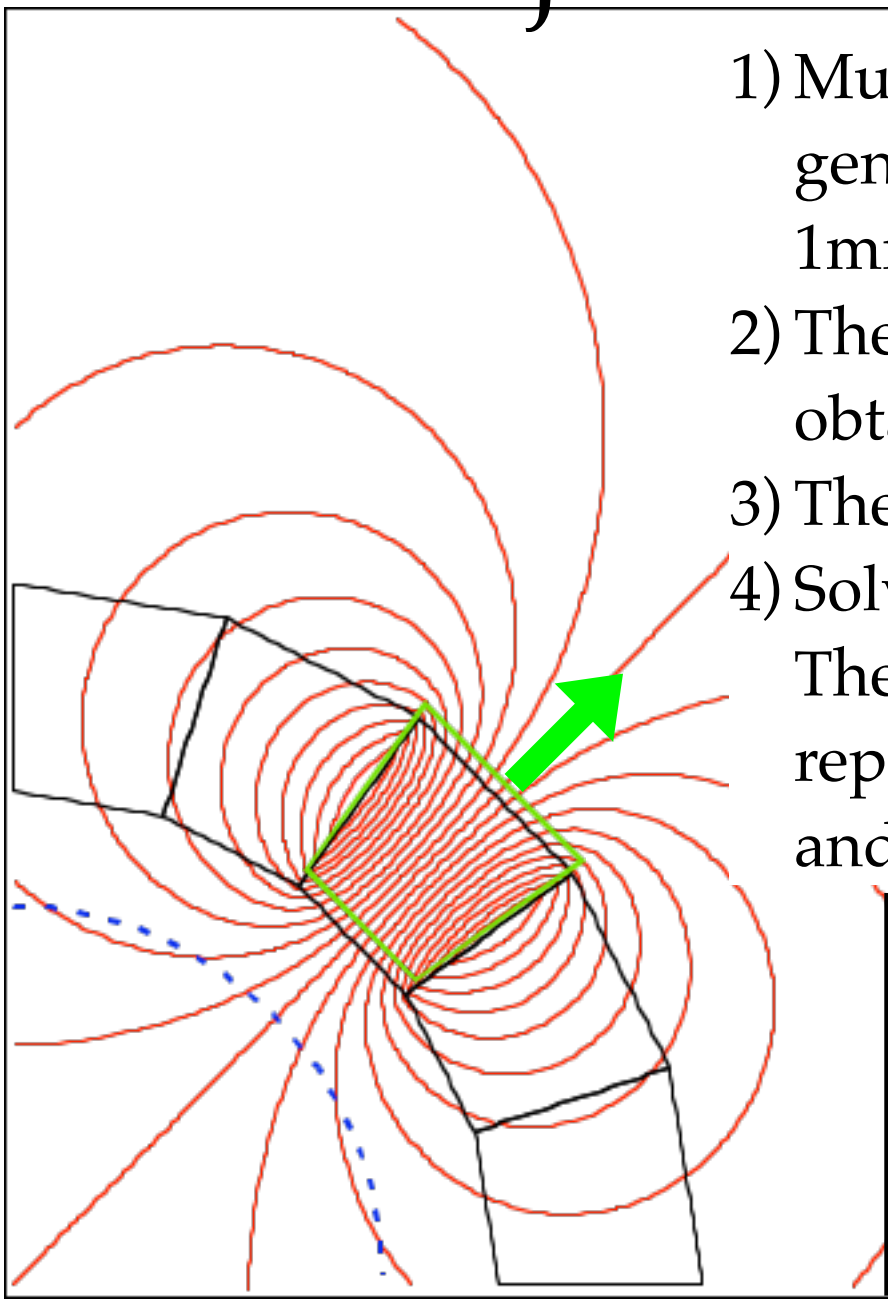
# Adjustment Algorithm



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 11$^{th}$.

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

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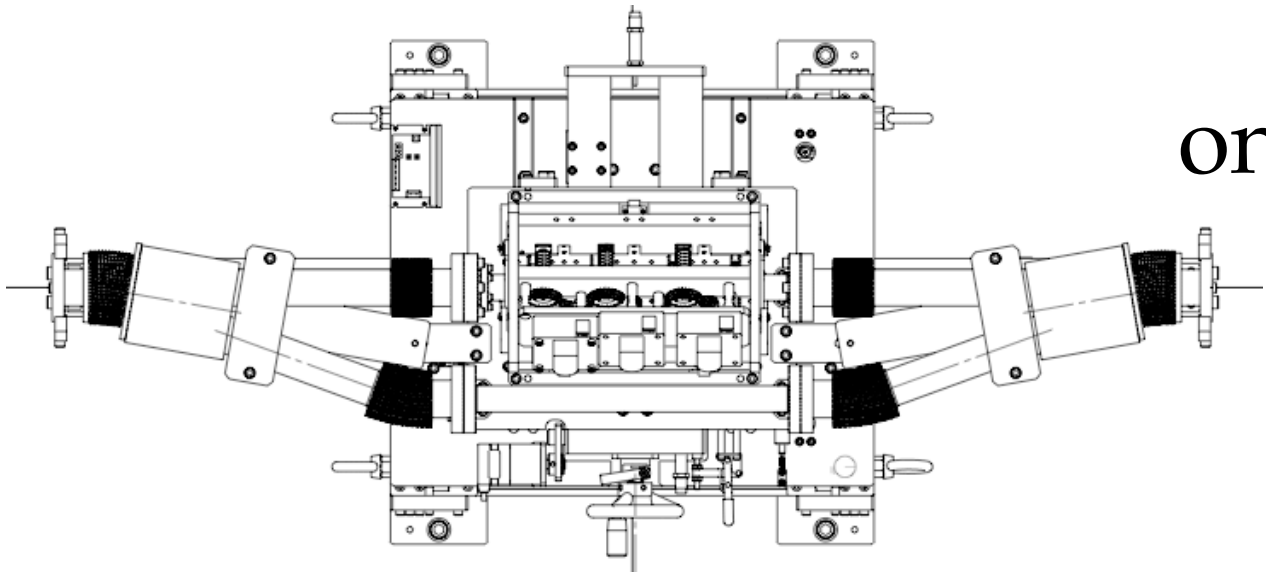
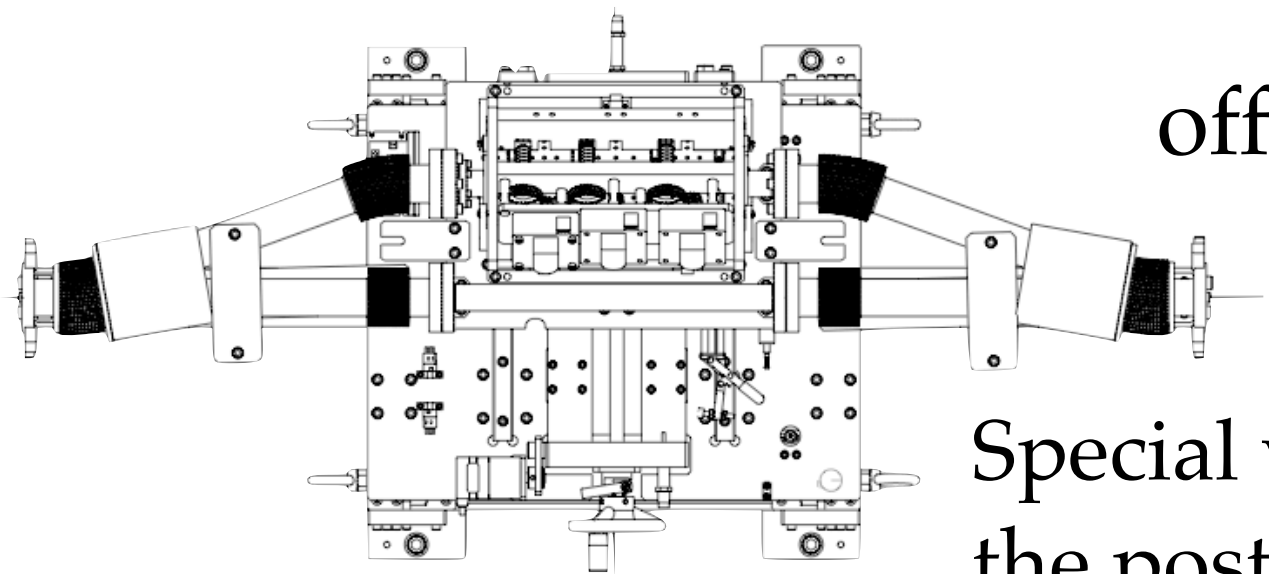
# Mover

# The push-pull Mover



on the Beam line



off the Beam line

Special vacuum flange for the post-fabrication.

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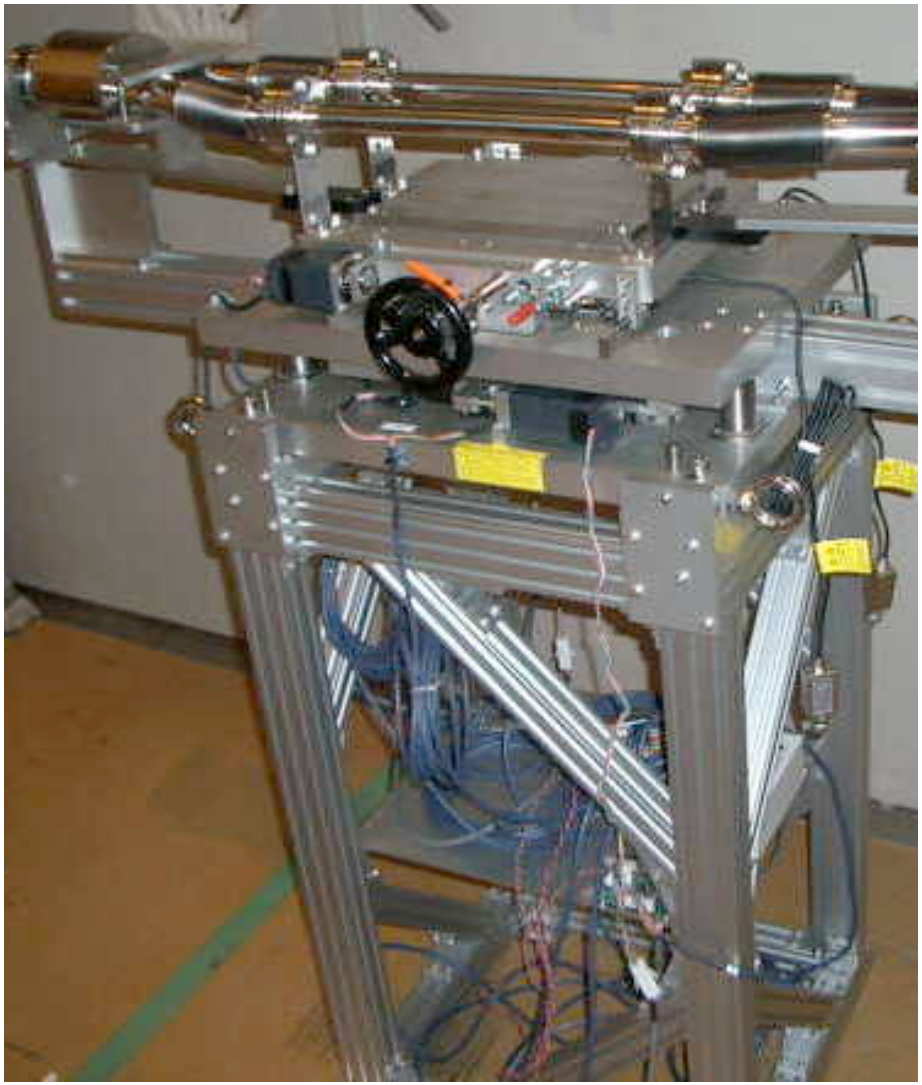
# Three DOF's



- Up-Down
- Left-Right
- Yawing
  (rotate around axis)

Remote control system delayed (next month?).

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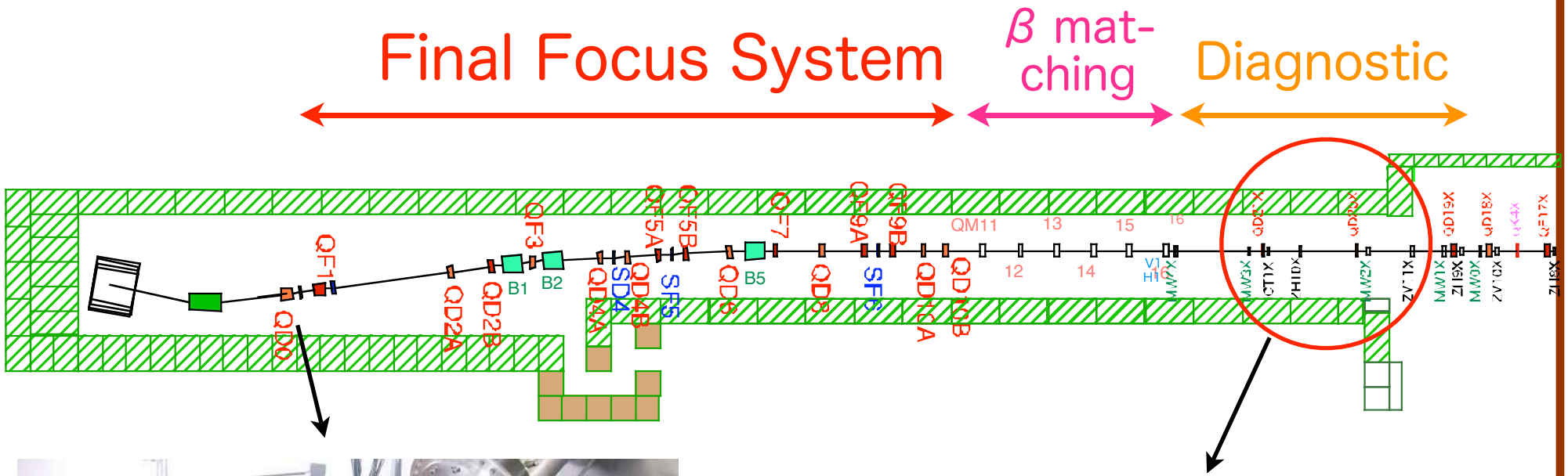
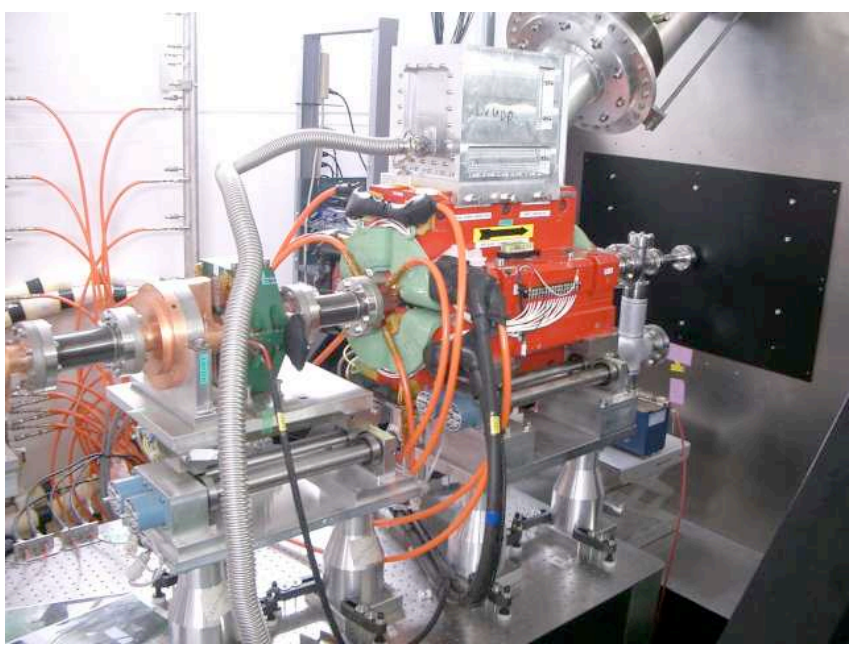
# Initial Test Position at ATF2 Beam Line

# Candidates for PMQ Location



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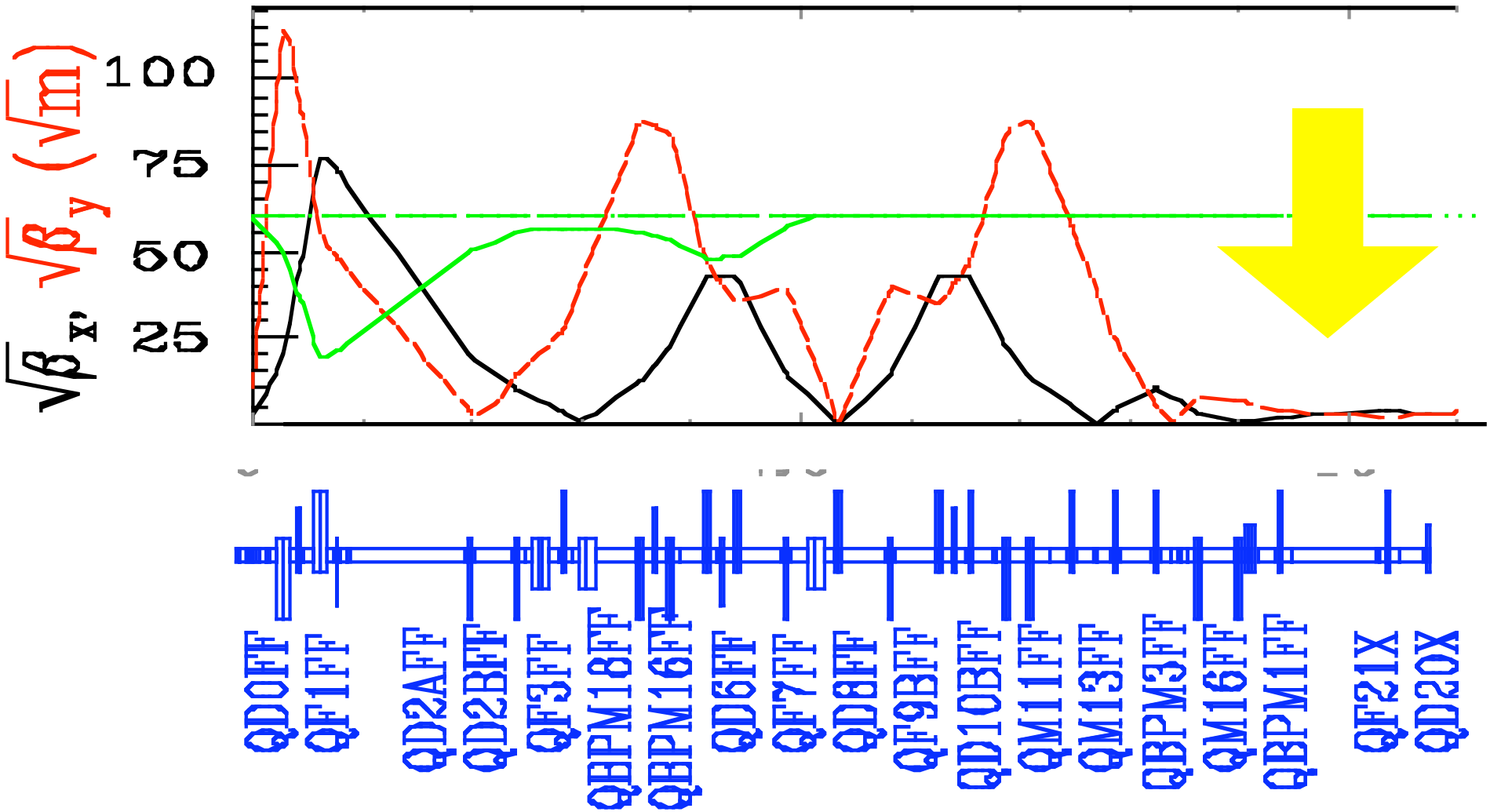
# Optics


$\sqrt{\beta_x}, \sqrt{\beta_y}$ ($\sqrt{m}$)
100
75
50
25
QD0FF
QF1FF
QD2AFF
QD2BFF
QF3FF
QBPM18FF
QBPM16FF
QD6FF
QF7FF
QD8FF
QF9BFF
QD10BFF
QM11FF
QM13FF
QBPM3FF
QM16FF
QBPM1FF
QF21X
QD20X

# What can be Tested?

- What can be monitored (with/without PMQ)?
  — Profile (size) by wire scanner
  — Position by BPM
  — (Size by Shintake Monitor downstream)
- Evaluation:
  x-y coupling, high order, stability ,
  Vibration evaluation (<50nm?),
  reproducibility, etc.
- Practical experience:
  handling, installation, stability...
- Comments ?!

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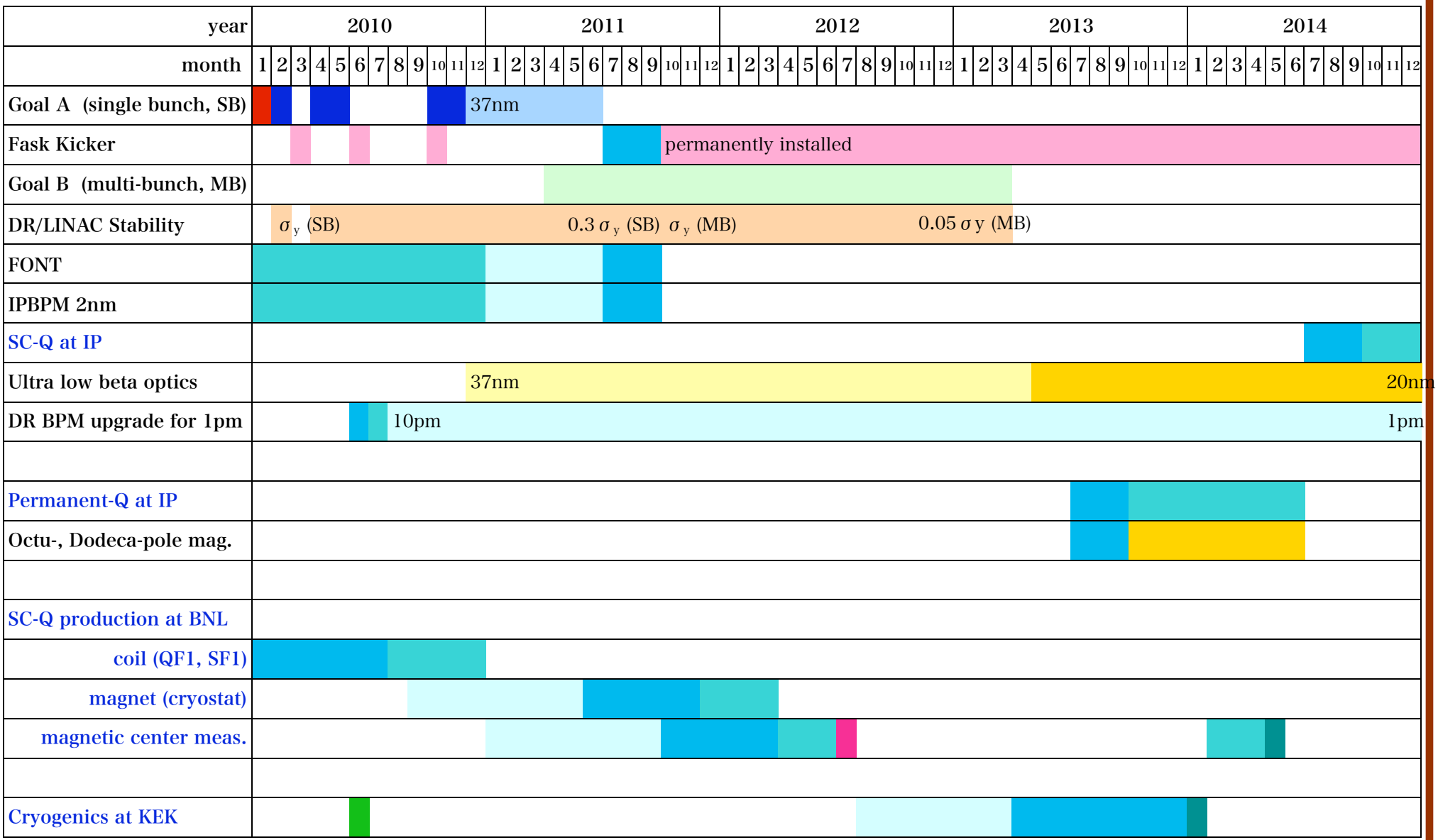


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# Appendix

# 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.

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