# Simulation for Lower emittance in ATF Damping Ring

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Kiyoshi Kubo

Similar talk in DR WS in Frascati, May 2007

Most simulations were done several years ago.

# History of Low Emittance in ATF DR

- There were great efforts to achieve low vertical emittance since DR commissioning.
- From 2000 to 2002, we observed the lowest vertical emittance in DR about10 pm.
- After further improvement of hardware, with software and simulation works, we constantly achieved lower than 5 pm at low intensity (N →0), and lower than 8 pm at high intensity (N~1E10), which was lower than “designed” emittance (in 2003).
- Since then, basically no further improvement.
  - We have not really pursued lower emittance.
  - Basically no improvement of hardware for DR.
    - R&D of instrumentations were main tasks at ATF.
- Now, we are planning new BPM electronics (to be reported afternoon), which can give possibility of lower emittance.

# Improvement in ATF Damping Ring from 2001 to 2003 for low vertical emittance

(A) New BPM electronics

(B) Beam based BPM offset correction (BBA)

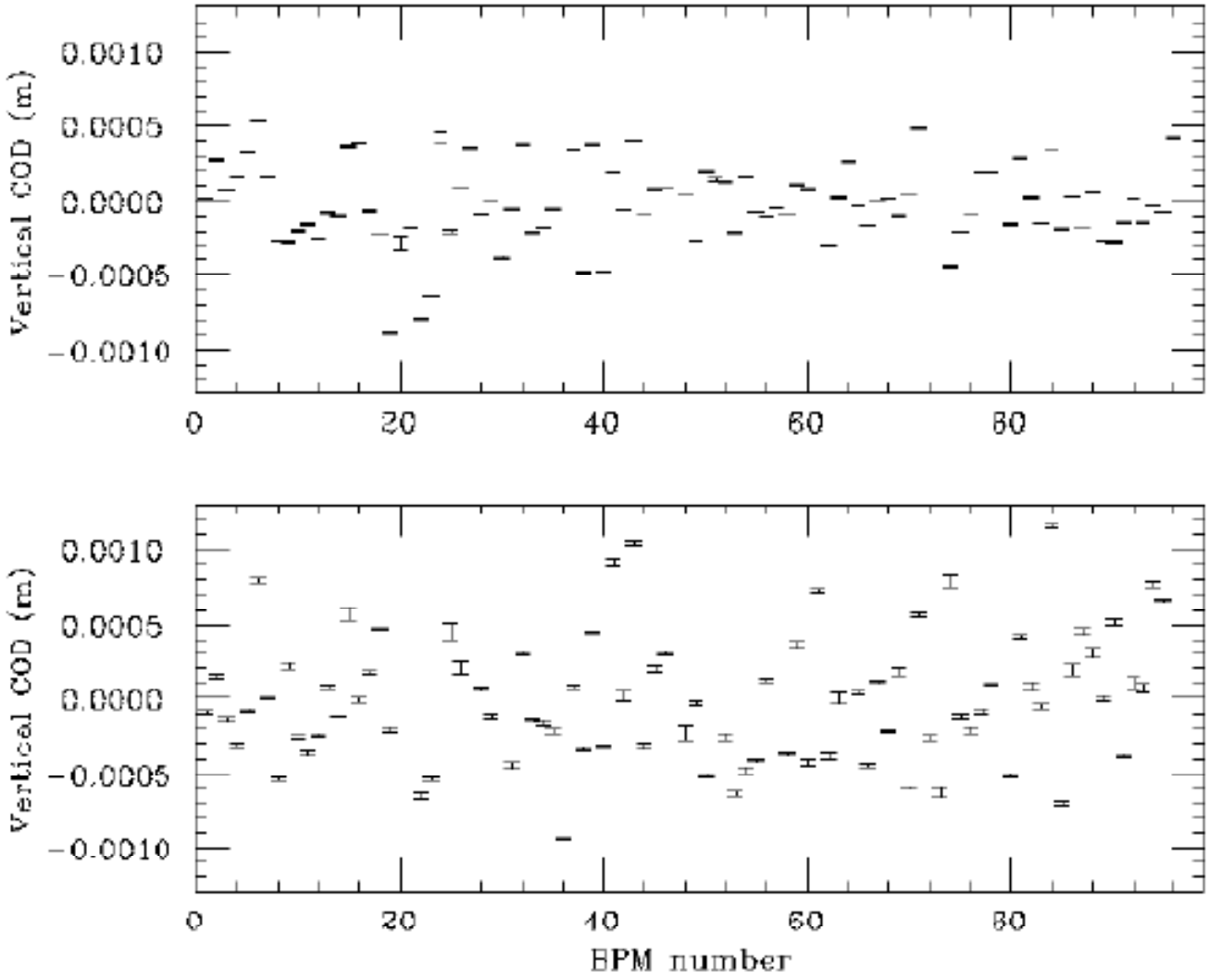
(C) Beam based optics correction (based on BPM - steering magnet COD Response Matrix)

(D) Improved laser wire monitor

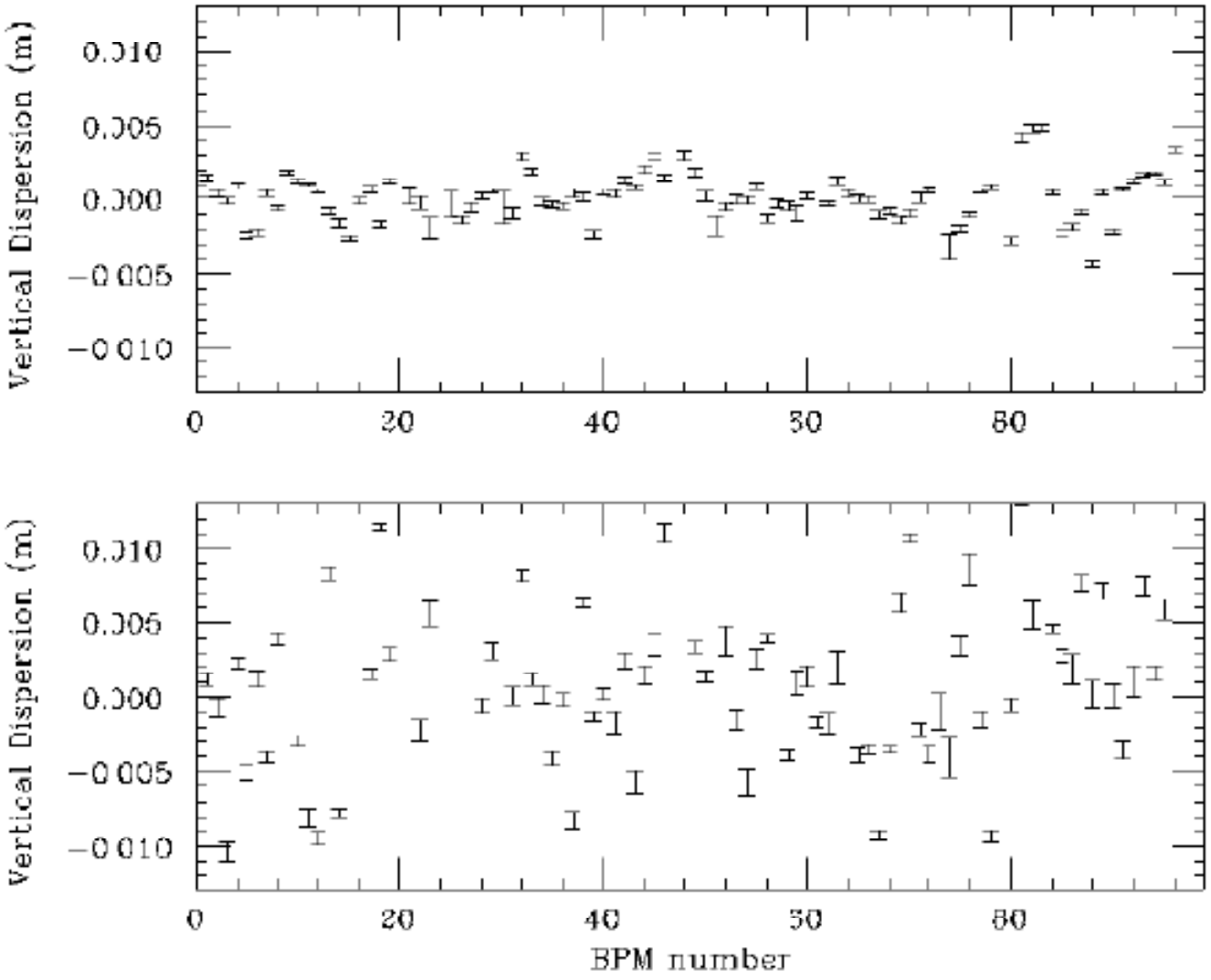
**Improved (B) and (C) became possible because of (A).**

**-- Further improvement of BPM system is going and we expect better (B) and (C).**

# Vertical Orbit, May 2003 and Nov.2002

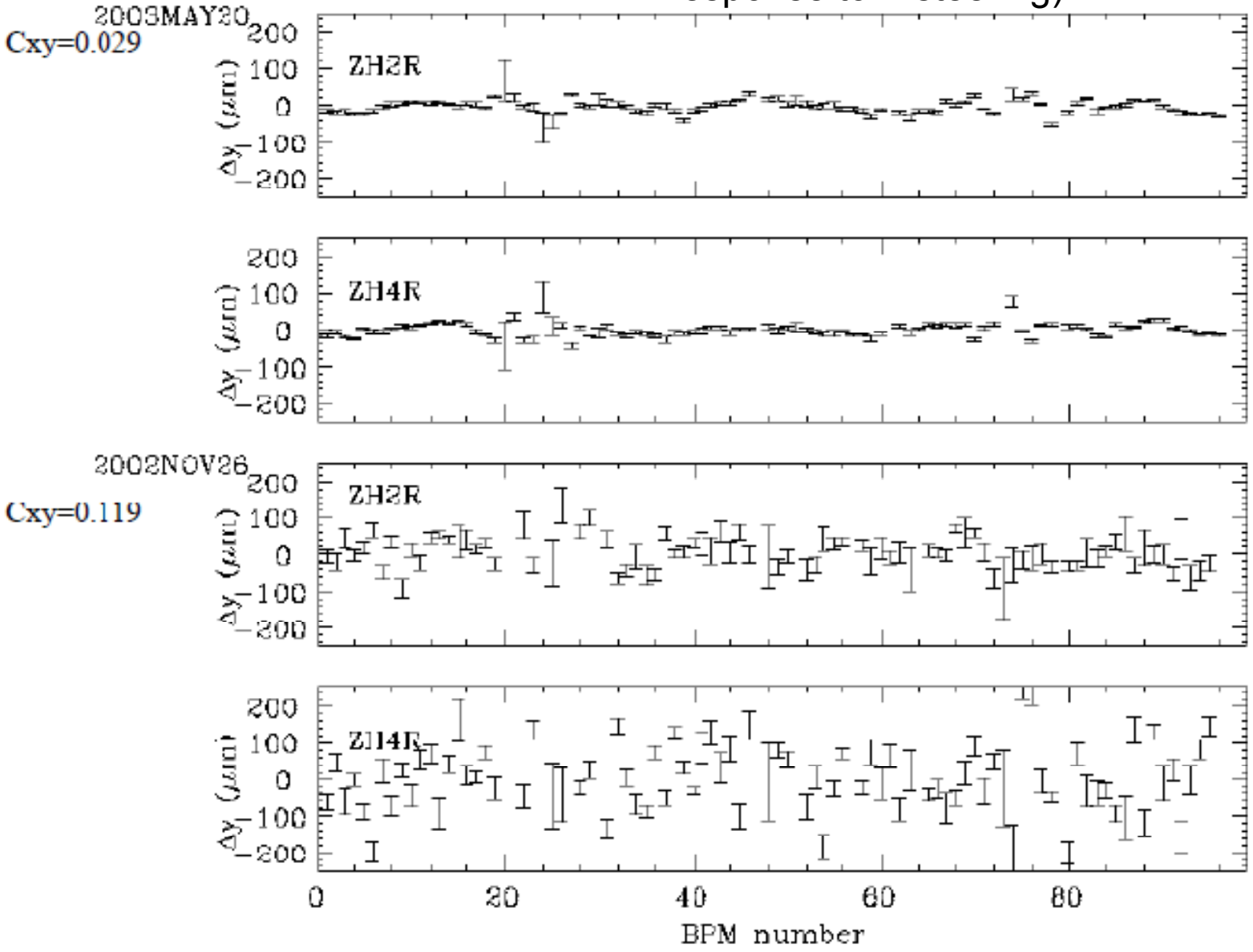


# Vertical Dispersion, May 2003 and Nov.2002

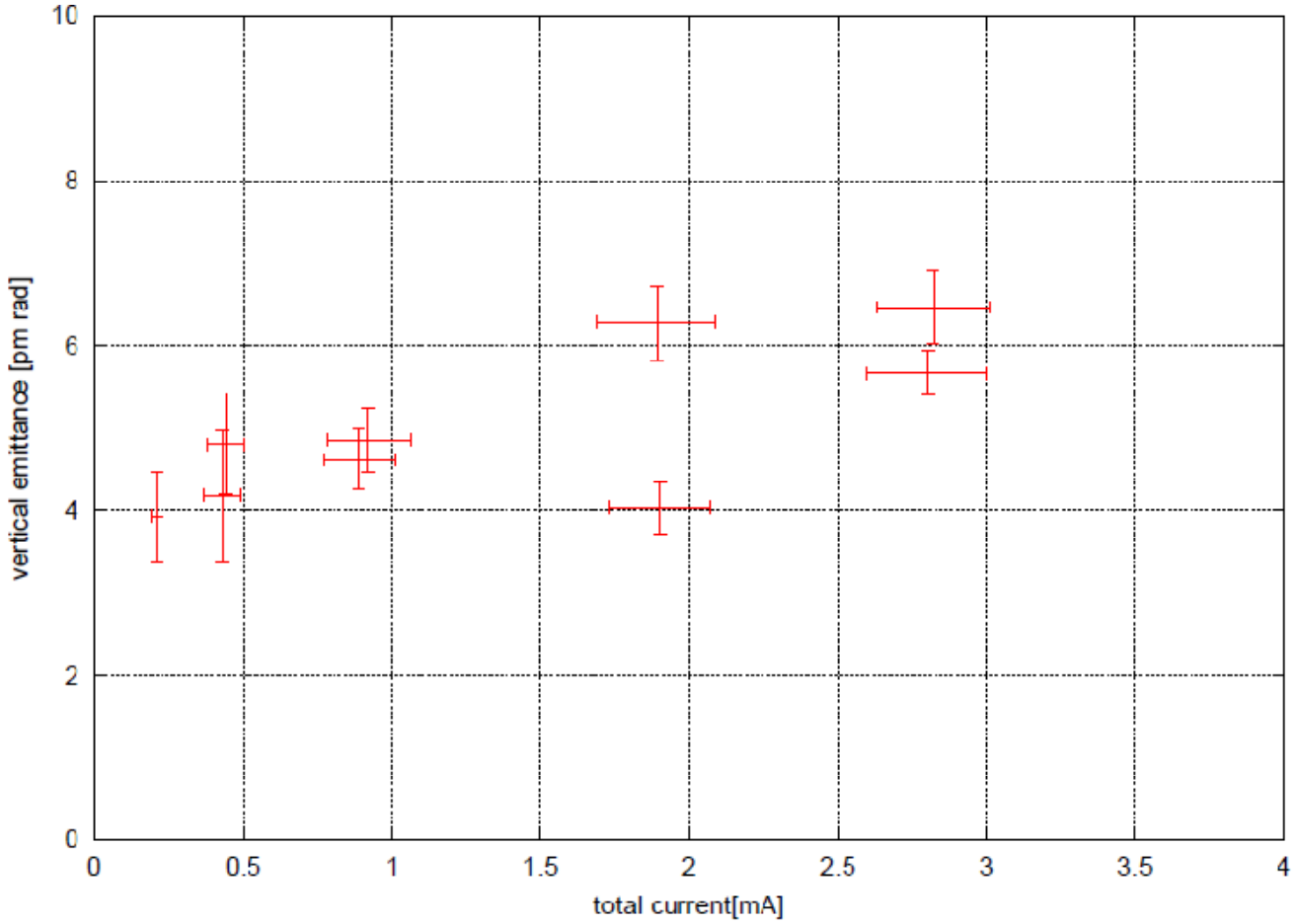


# x-y Coupling May 2003 and Nov.2002

v-response to h-steering)



# Vertical emittance measured by Laser Wire (April 16, 2003)



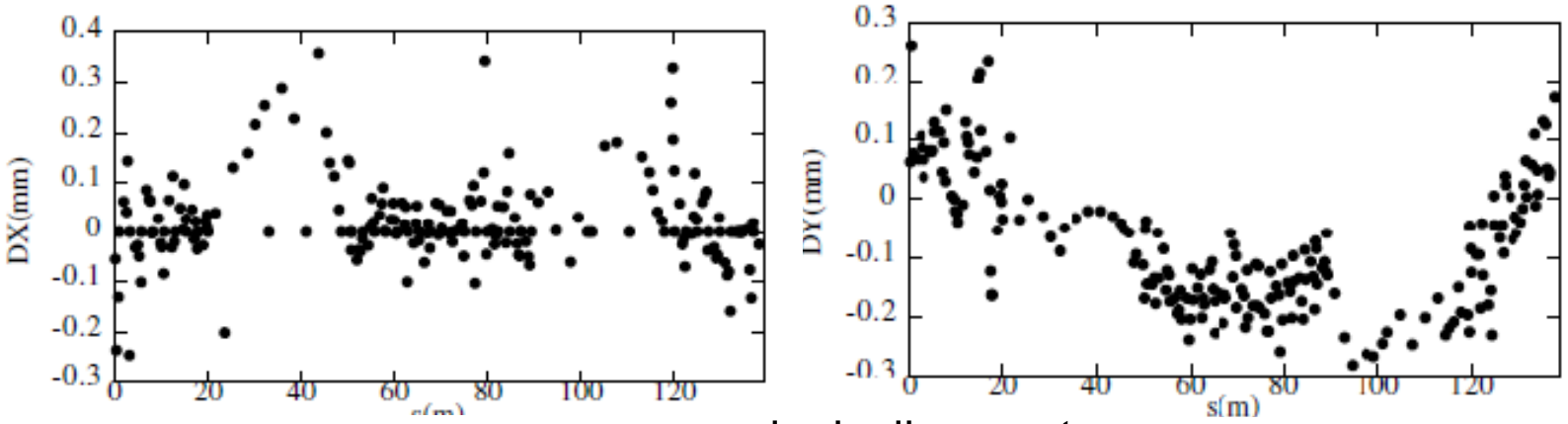

by Y.Honda

# Old simulation of ATF DR emittance tuning

## ERRORS:

(tried to reproduce actual condition, not confirmed)

- Misalignment of magnets: as measured




measured misalignment

+ random 30 micron offset

+ random 0.3 mrad. rotation

- BPM error : offset 300 micron wrt nearest magnet, rotation 0.02 rad.

# Simulation - correction(1)

**Three consecutive corrections**:

Simulate actual procedure

Monitor:

BPM (total 96)

Corrector:

Steering magnets (47 horizontal and 51 vertical)

Skew Qauds (trim coils of sextupole magnets, total 72)

- COD correction
- Vertical COD-dispersion correction
- Coupling correction

# Simulation - correction(2)

(a) COD correction: using steering magnets, minimize

$\sum_{\mathrm{BPM}} x^2$ and $\sum_{\mathrm{BPM}} y^2$, :*x(y)*: horizontal (vertical) BPM reading.

(b) V-COD-dispersion correction: using steering magnets, minimize

$\sum_{\mathrm{BPM}} y^2 + r^2 \sum_{\mathrm{BPM}} \eta_y^2$

$\eta y$: measured vertical dispersion.

$r$ : weight factor = 0.05

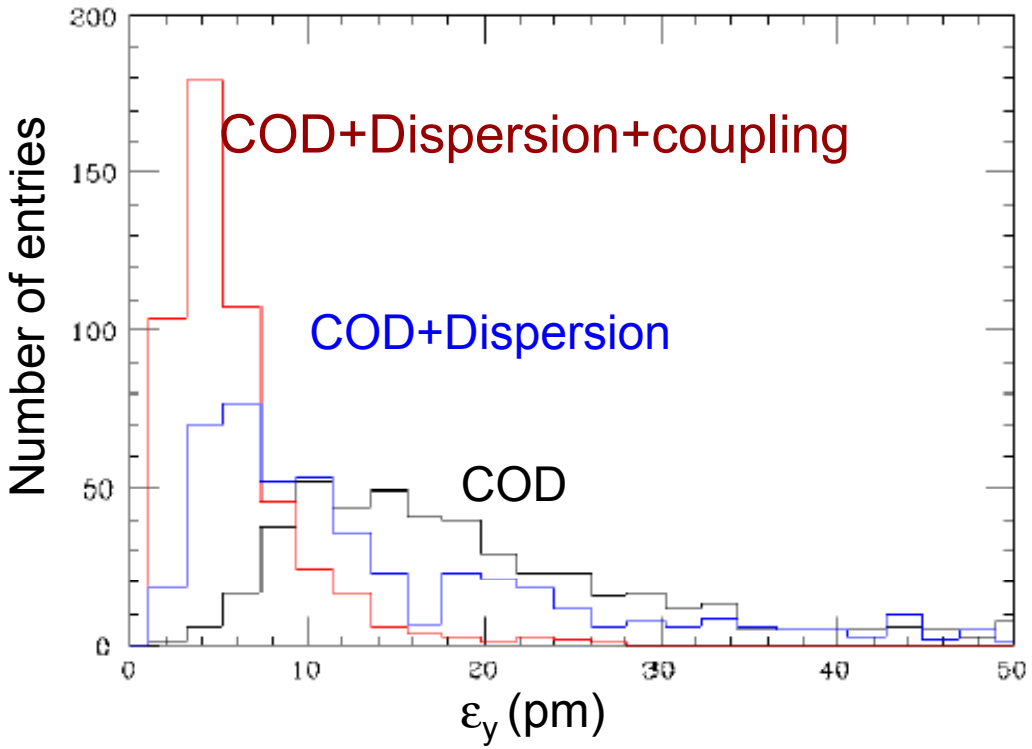
(c) Coupling correction: using skew quads, minimize

$$C_{xy} \equiv \sqrt{\sum_{\mathrm{H-steers}} \left( \sum_{\mathrm{BPM}} \Delta y^2 \Big/ \sum_{\mathrm{BPM}} \Delta x^2 \right)} \Big/ N_{\mathrm{steer}}$$

$\Delta x(\Delta y)$: horizontal (vertical) position change at BPM due to excitation of a horizontal steering magnet.

Two horizontal steering magnets were used (*N*steer=2). About (n+1/2)$\pi$ phase advance between the two.

# Simulated vertical emittance

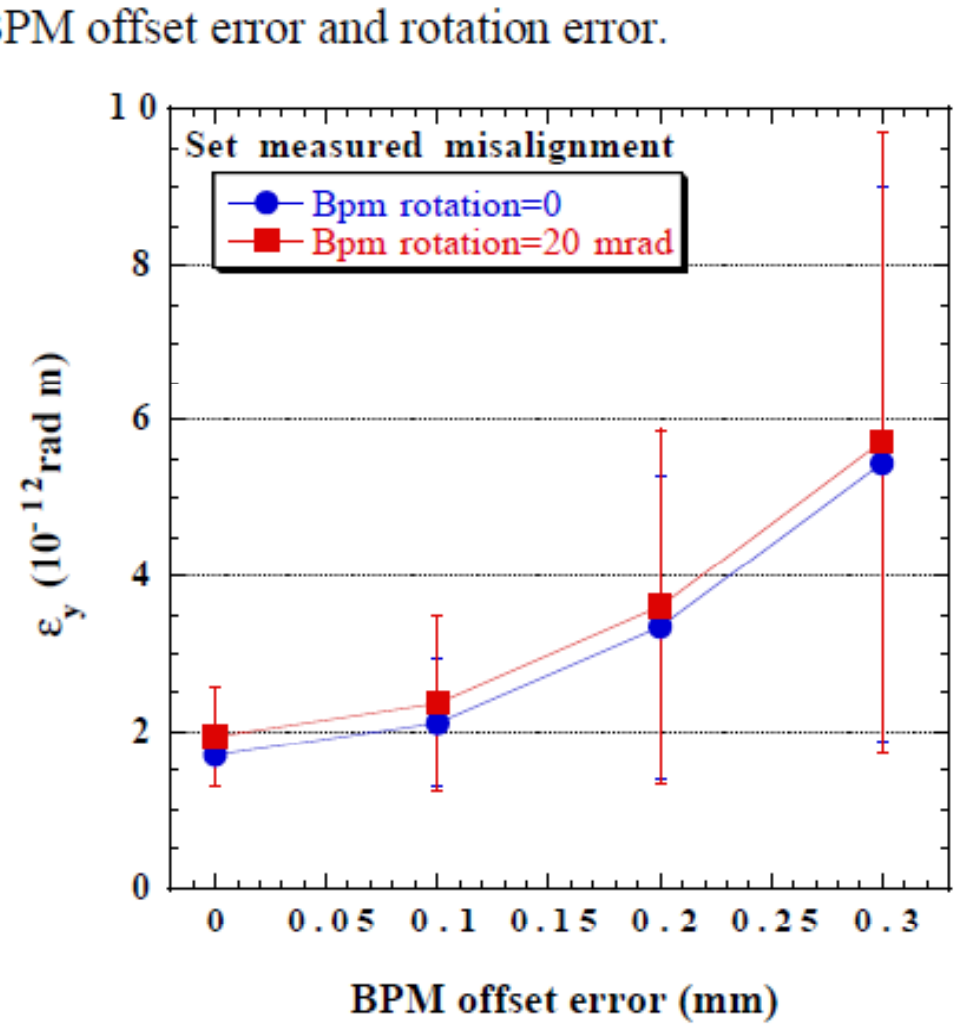



Distribution from
500 random seeds

| Corrections | Average | Ratio of target (11pm) |
|---|---|---|
| COD | 23 pm | 20% |
| + Dispersion | 16 pm | 51% |
| + Coupling | 5.8 pm | 91% |

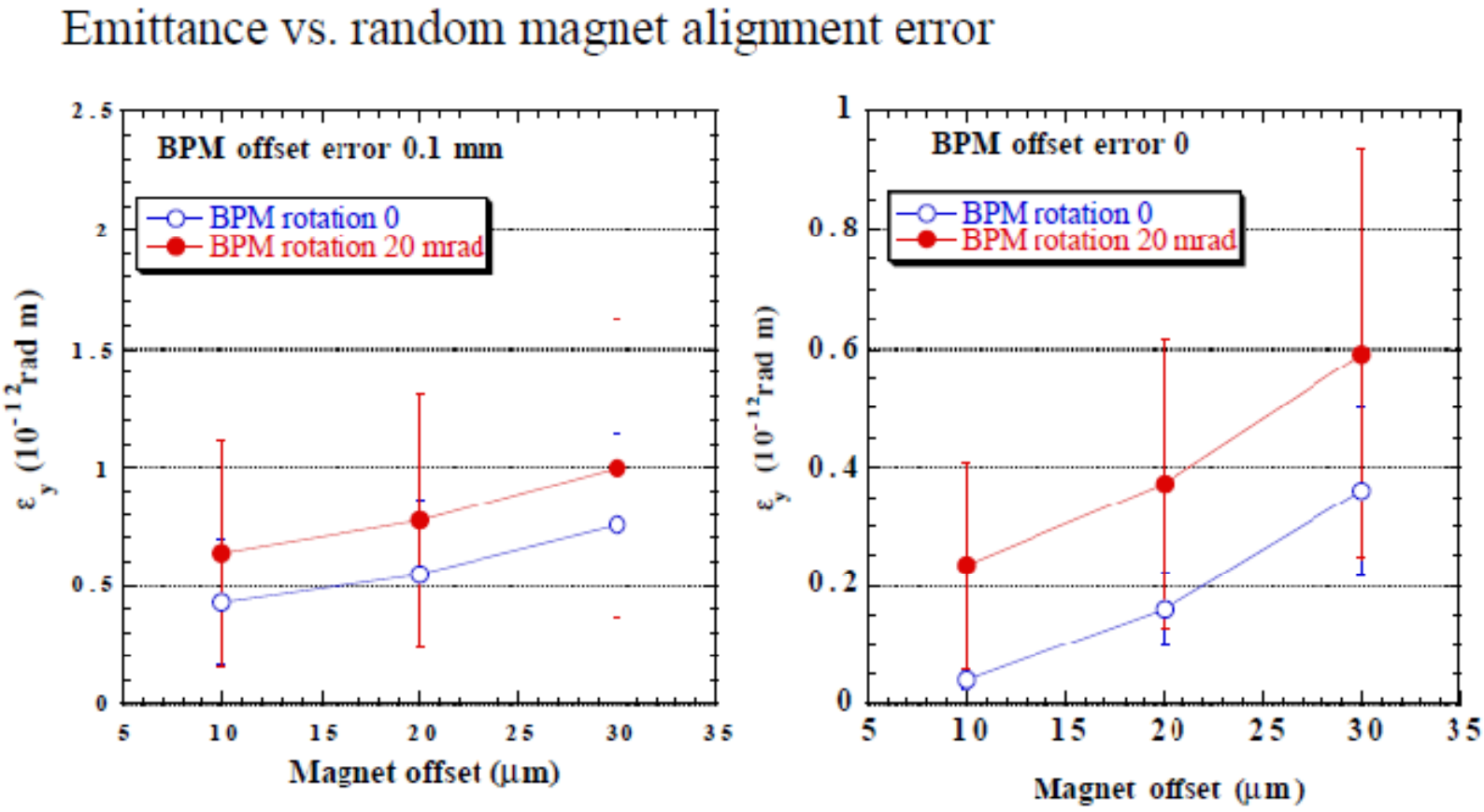
# For lower emittance

Small BPM offset error w.r.t. nearest magnet is important



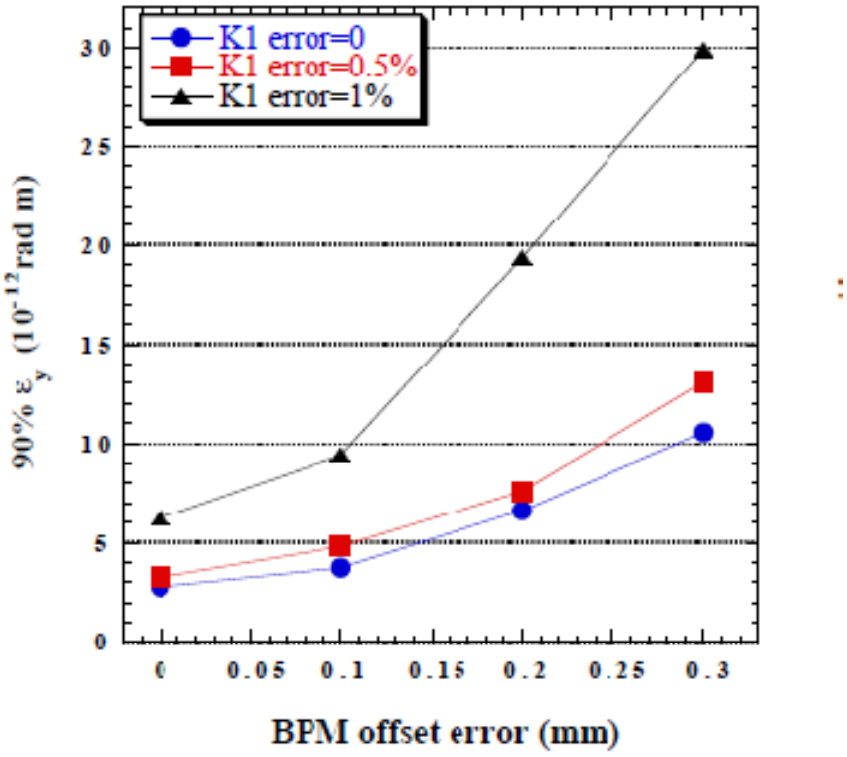
# Magnet alignment (< 30μm) is not very important,

## if BPM offset error (w.r.t. nearest magnet) is not very small or we do not need very very low emittance



# Quad strength error (optics error) should be small (<0.5%)

This figure shows 90% CL emittance,
Emittance, 90% random seeds give lower than that.
(A few seeds give extremely large emittances which make plots of average useless.)



# For lower emittance

We did some improvements to achieve ~5 pm emittance.

- Reduction of BPM offset error wrt. nearest magnet
- Reduction of optics error (magnet strength error)

Now, we need more improvement for ~2 pm.

- Further reduction of BPM offset error will be the first priority.
- New BPM electronics, is being tested.
- Better resolution and stability. Then,
  - Reduce BPM offset error w.r.t. magnets from improved data for Beam Based Alignment.
  - Reduce optics error from improved response matrix data
- Better BBA has been demonstrated for a few (? one) quadrupole magnet- BPM pairs, recently.
- But,detailed simulations of BBA and Optics Test have not done yet.

# SUMMARY

Simulation showed:

- BPM offset error (w.r.t. nearest magnet) < 0.1 mm.
  - Beam based alignment measurement using good BPM system will make it possible.
  - Then, $\varepsilon_y$ ~ 2 pm will be achieved.
- Magnet re-alignment, RMS < 30 μm.
  - Then, εy ~ 1 pm will be achieved.
  - But we do not have a plan.
- Quad strength error should be 0.5% or smaller
  - It may have been achieved already, but not confirmed.
  - Beam based optics measurement (Orbit Response Matrix) with good BPM system is important.

What we need:

- New BPM system, which is now being tested.
- More simulations and data taking tools, analysis for BBA, optics diagnostics etc.
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