Low emittance tuning in ATF Damping Ring
- Experience and future plan

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Kiyoshi Kubo

History of Low Emittance in ATF DR

- There were great efforts to achieve low vertical emittance since DR commissioning.
- From the end of 2000 to 2002, we observed the lowest vertical emittance in DR about 10 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. (2003)
- Since then, basically no farther 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, which will give possibility of lower emittance.
  - The new system is being tested (mainly by colleagues from US).

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

(A) New BPM electronics

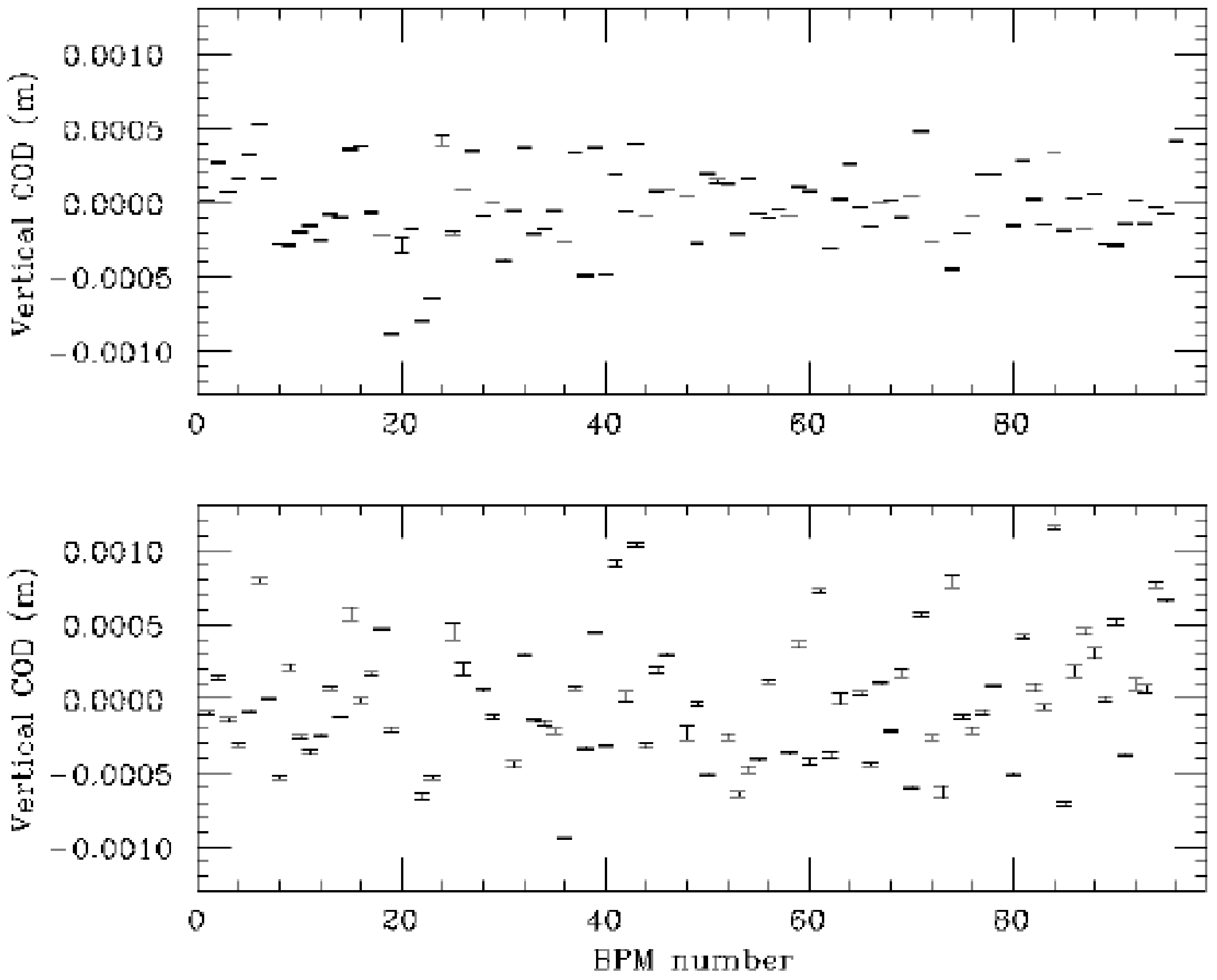
(B) Beam based BPM offset correction (BBA)

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

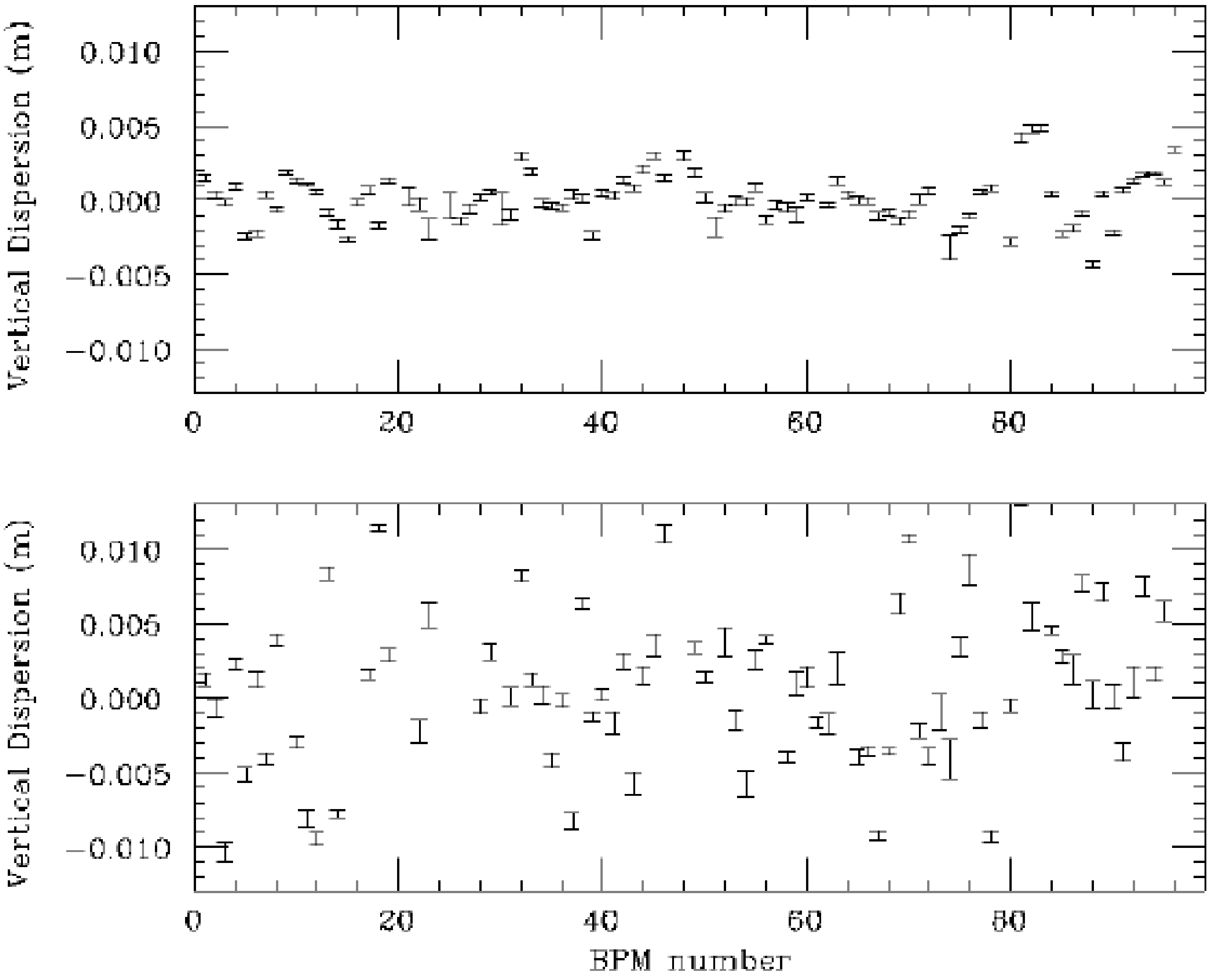
(D) Improved laser wire monitor

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

Vertical Orbit, May 2003 and Nov.2002



Vertical Dispersion, May 2003 and Nov.2002

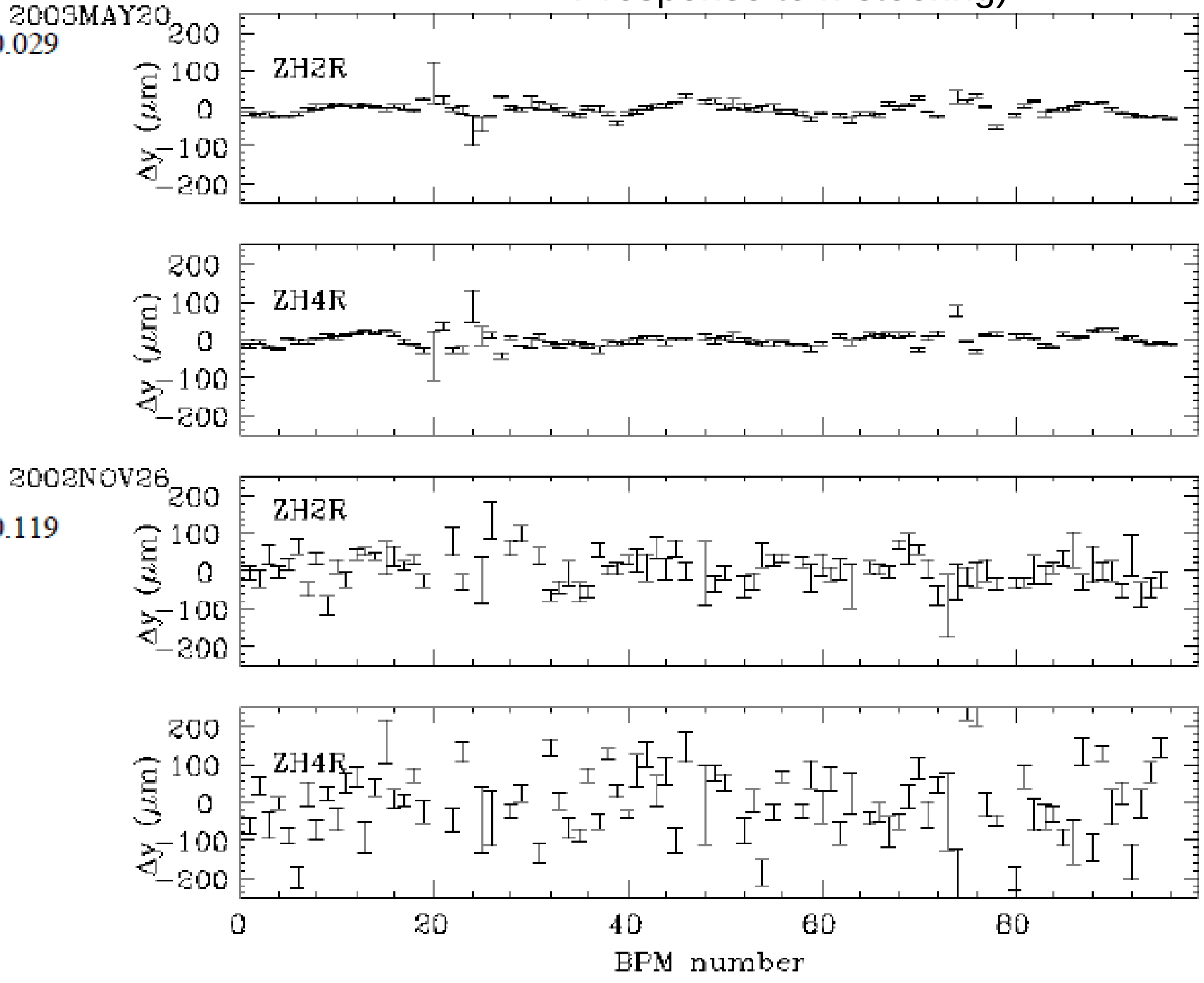


x-y Coupling May 2003 and Nov.2002

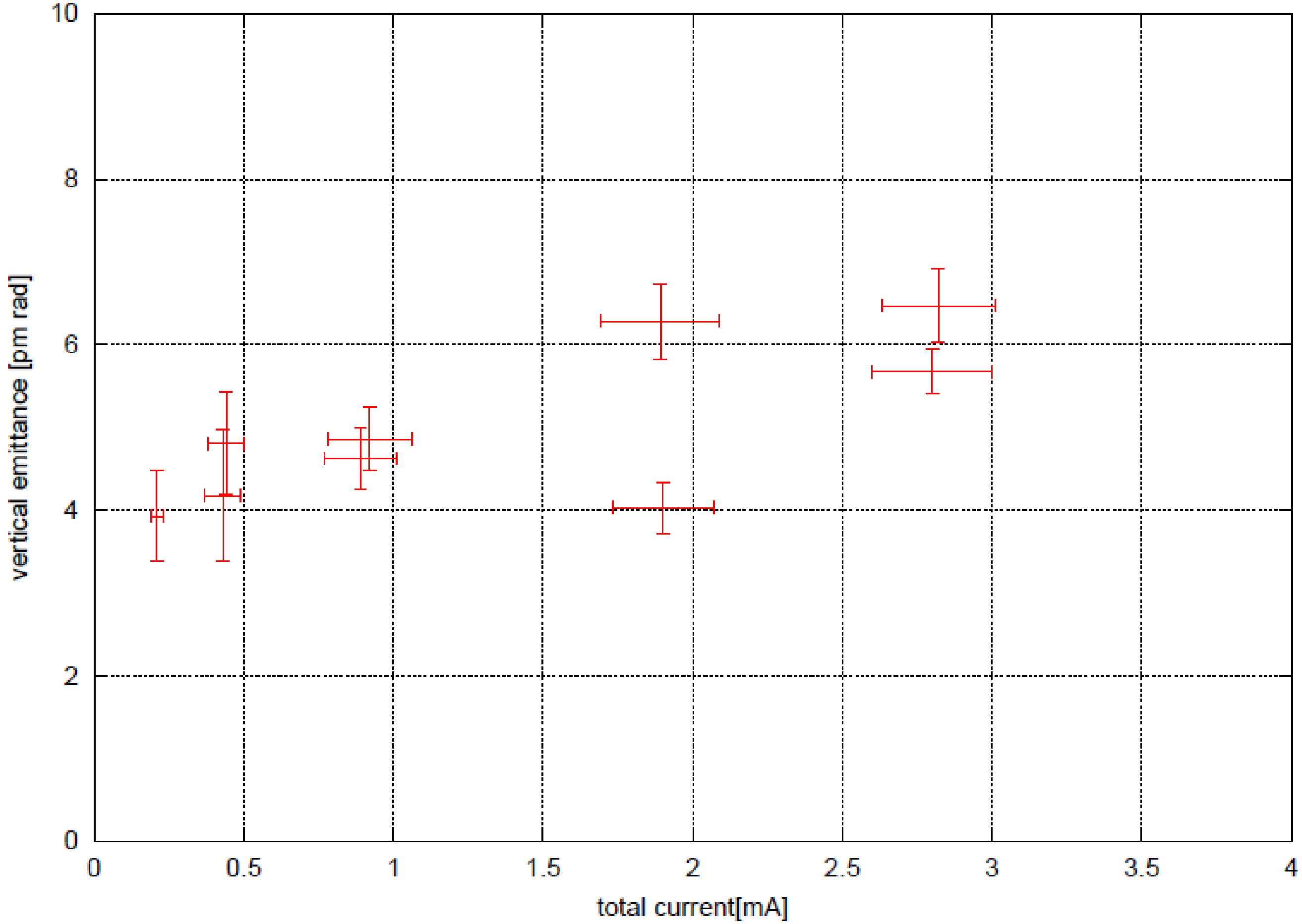
v-response to h-steering)

Cxy=0.029

Cxy=0.119



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



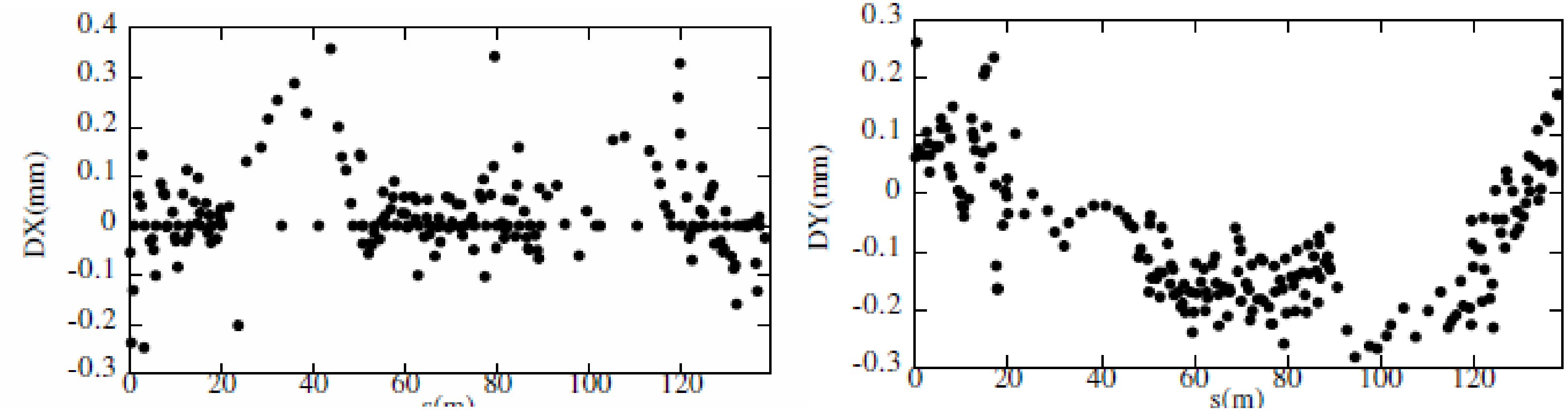
by Y.Honda

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

Corrector:

Steering magnets

Skew Qauds (trim coils of sextupole megnets)

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

Simulation - correction(2)

(a) COD correction: using steering magnets, minimize

$$\sum_{\mathrm{BPM}} x^2 \quad \text{and} \quad \sum_{\mathrm{BPM}} y^2,$$

:*x(y)*: horizontal (vertical) BPM reading.

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

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

ηy: measured vertical dispersion.

r : weight factor = 0.05

(c) Coupling correction: using skew quads, minimize

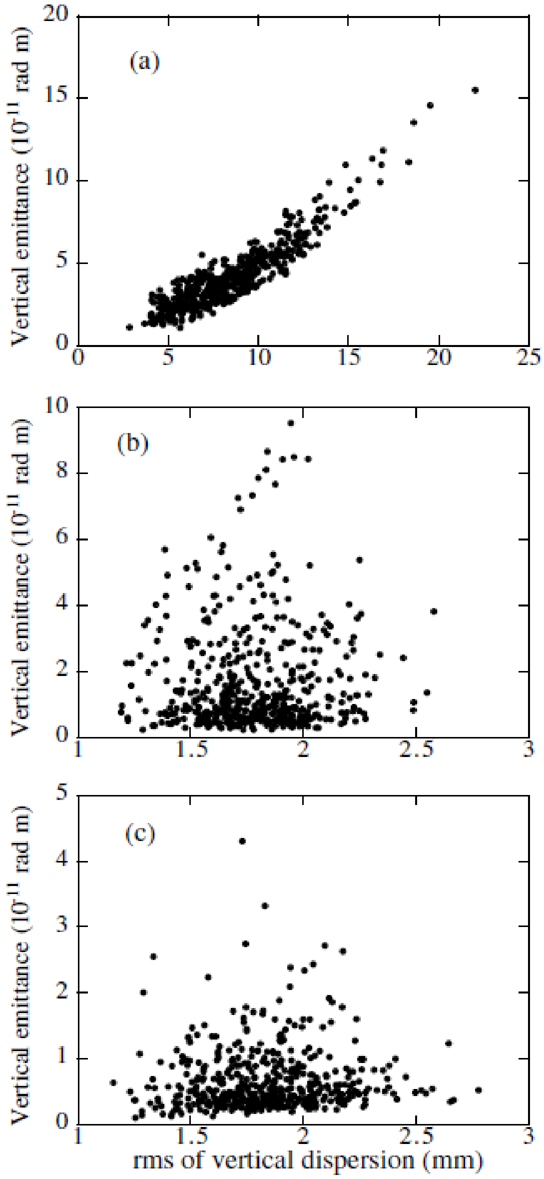
$$C_{xy} \equiv \sqrt{\sum_{\mathrm{H-steers}} \left(\sum_{\mathrm{BPM}} \Delta y^2 \Big/ \sum_{\mathrm{BPM}} \Delta x^2 \right) \Big/ N_{\mathrm{steer}}}$$

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

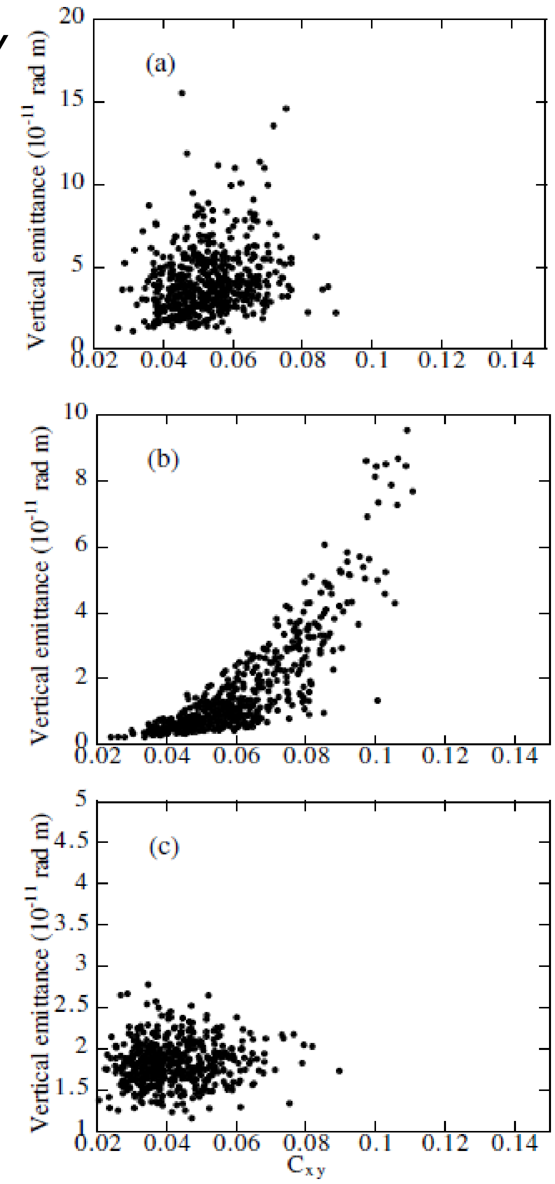
Two horizontal steering magnets were used, (Nsteer=2).

Emmitace, dispersion and coupling of each stage

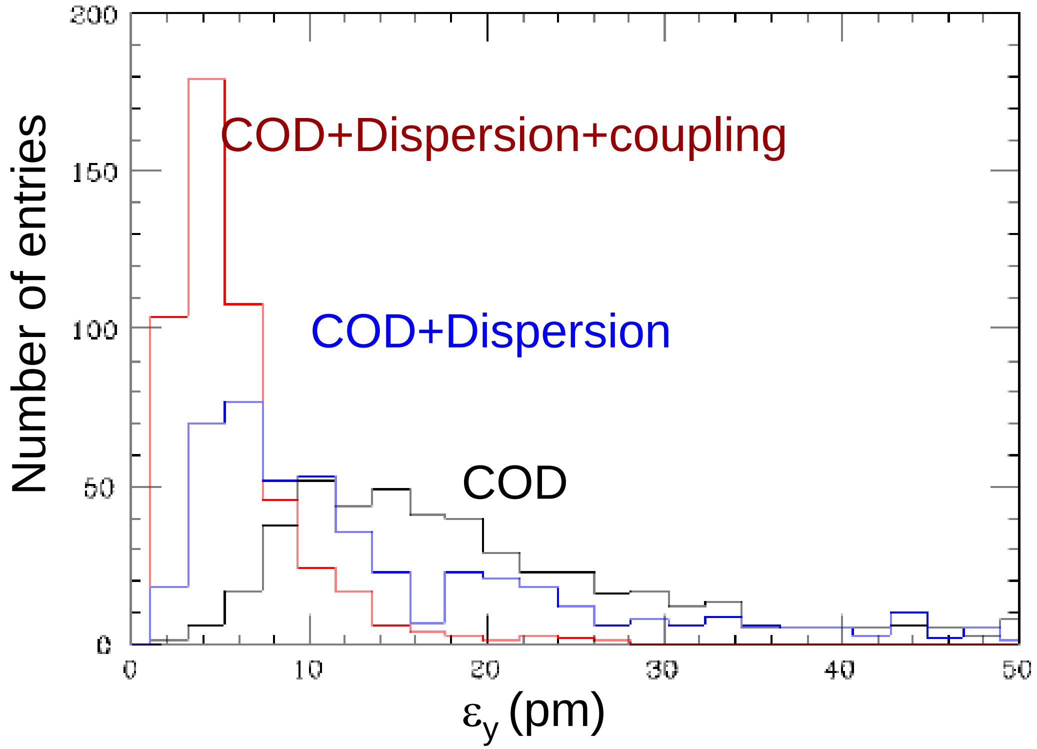
ε_y vs. rms of vertical dispersion



ε_y vs. C_xy



Simulated vertical emittance



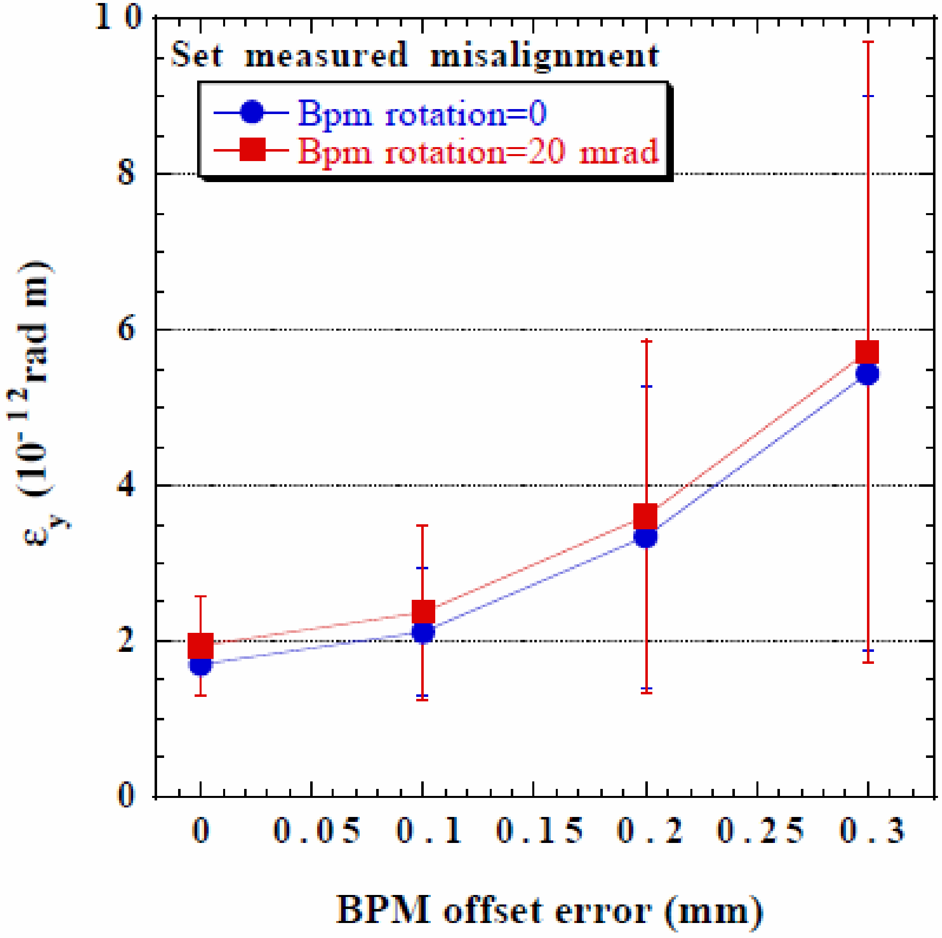
Distribution from 500 random seeds

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

For lower emittance

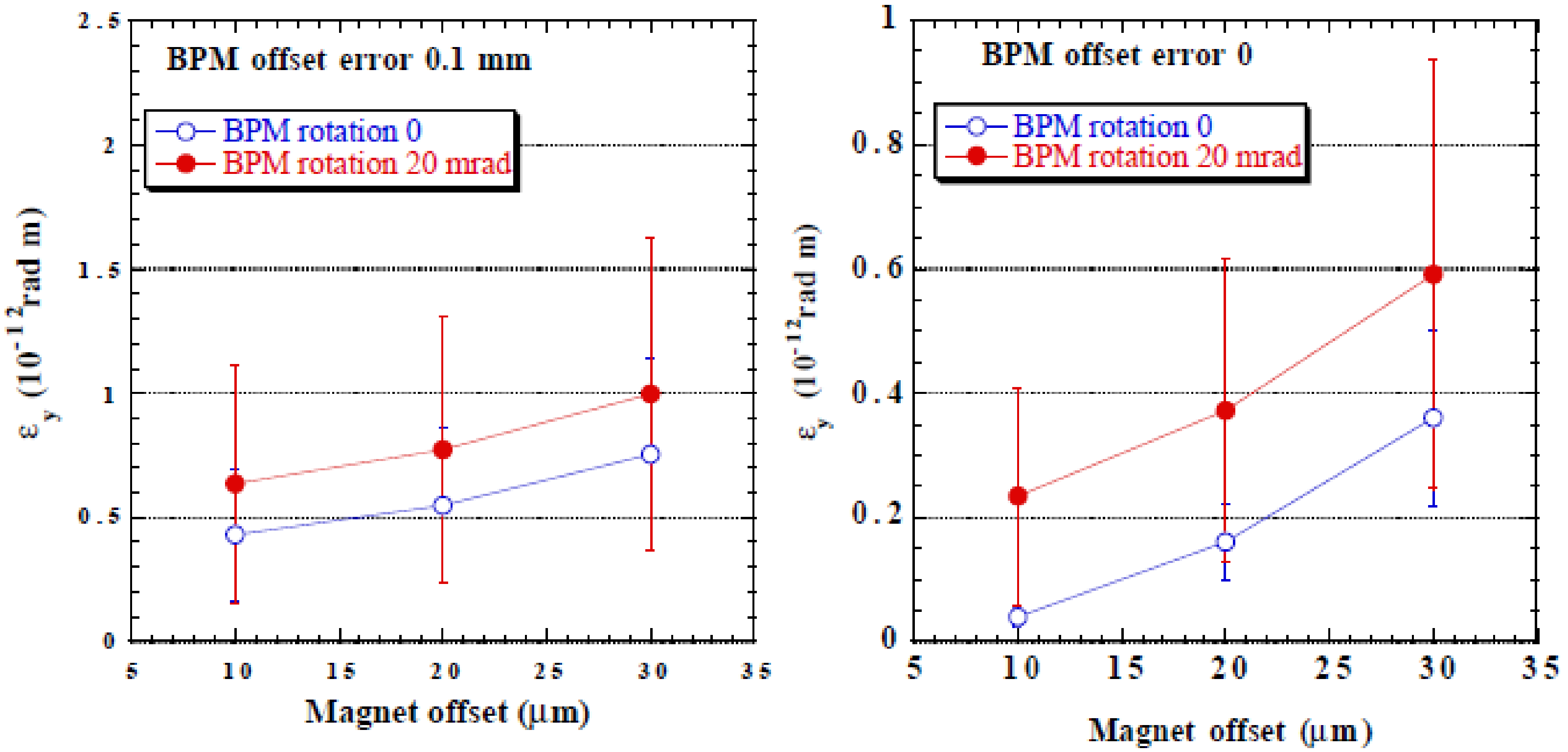
BPM offset error should be small (~100 μm)

BPM offset error and rotation error.



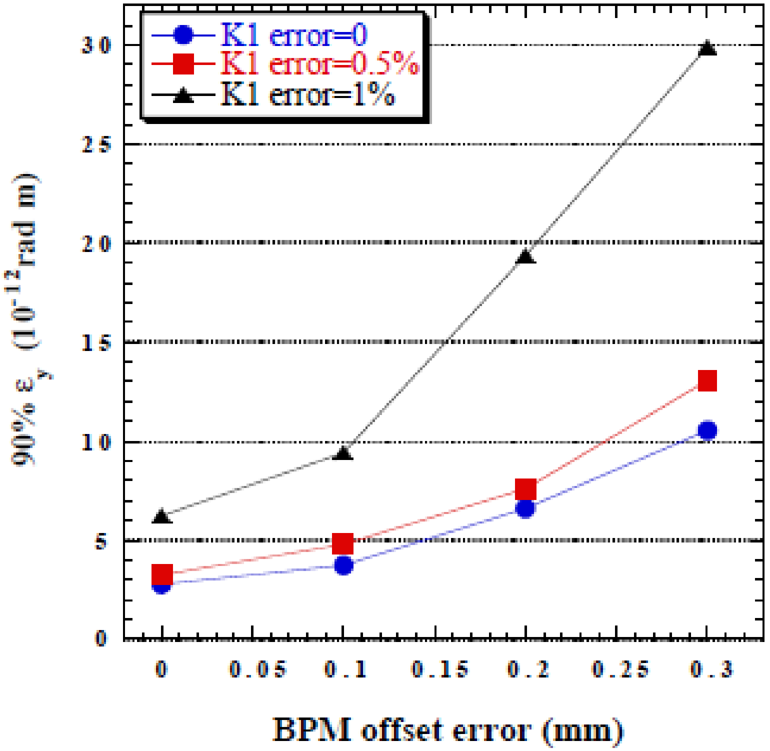
Magnet alignments (< 30μm) are important,
(only) if BPM offset error is small
and for very low emittance

Emittance vs. random magnet alignment error

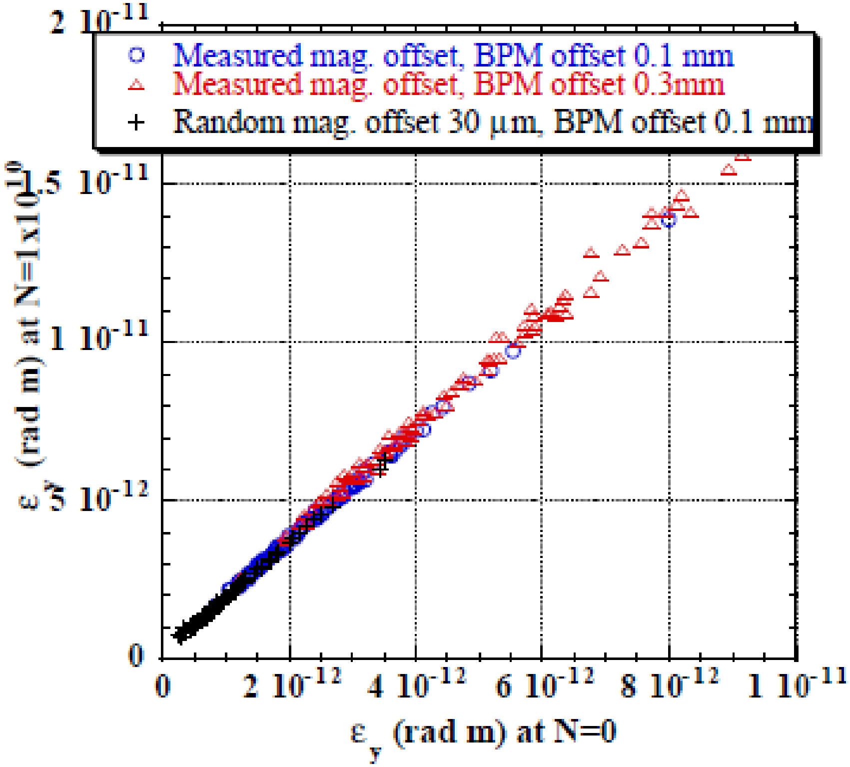


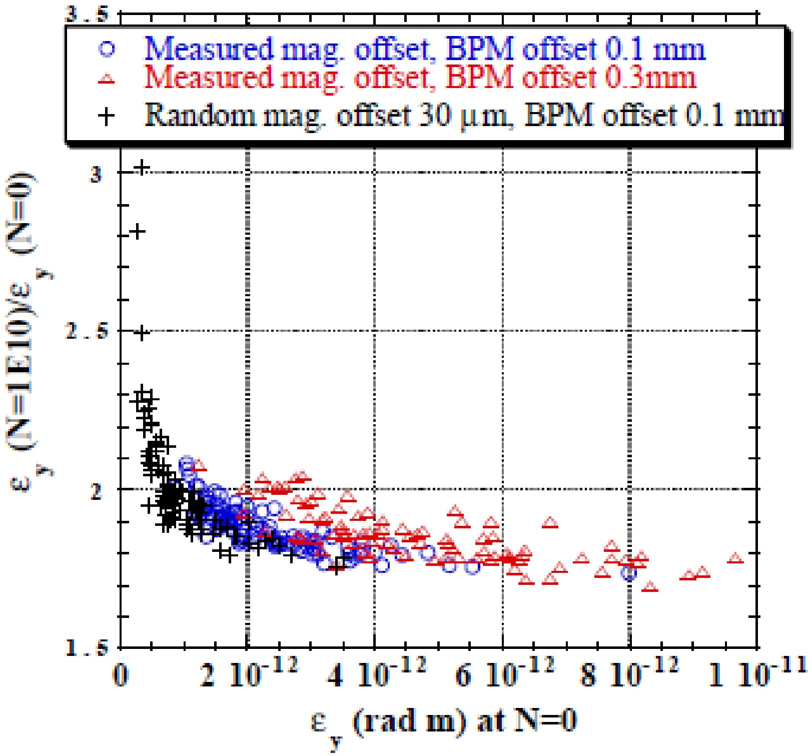
Quad strength error should be small (<0.5%)

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



Effect of intrabeam scattering





IBS makes vertical emittance at N=1E10 about factor 2 larger than emittance at N=0, for ε(N=0) >1 pm.

The factor rapidly increases for ε(N=0) < 1pm

For lower emittance

- Improve BPM offset error wrt. nearest magnet
- Improve magnet alignment
- Improve optics error (magnet strength error)

These are what we did to achieve ~10 pm emittance.

Now, we need even more improvement for ~2 pm.

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, ε_y ~ 2 pm will be achieved.
- Magnet re-alignment, RMS < 30 μm.
  - Then, ε y ~ 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 will make (or, already have made) it possible.

What we need:

- New BPM system, which is now being tested.
- More simulations for BBA etc.
- Software tools for
  - Analysis of measured data
  - and for using the results for corrections
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