Low emittance tuning in ATF Damping Ring - Experience and plan

2008.03. Sendai GDE Meeting

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)

After this low emittance achievement

- New BPM electronics, which will give possibility of lower emittance.
  - Electronics for Some BPM were replaced. (mainly by colleagues from US). Will be replaced for remained BPM.
- Since then, basically no other improvement.
  - We have not really pursued lower emittance.
  - R&D of instrumentations were main tasks at ATF.

Vertical Emittance in ATF DR

- Emittance is large recently.
  20~30 pm (from 2006 ?) !!
- Why?
  - No clear answer.
  - Will be discussed later.
- We have to make it small again (smaller than before if possible)
  - For ATF2
  - For Fast Ion Instability study
  - Instrumentation development, which need small size beam.

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

(A) New BPM electronics

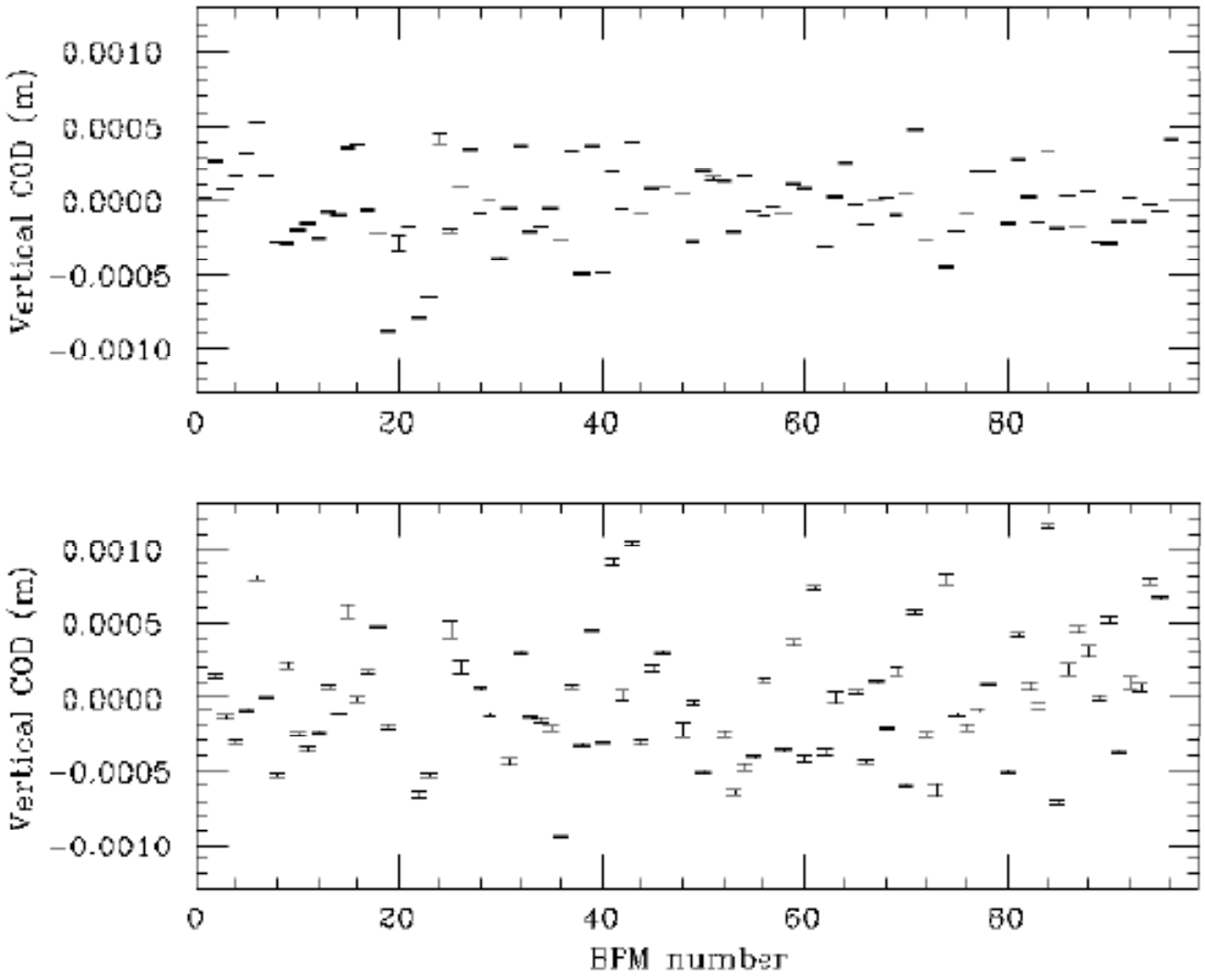
(B) Beam based BPM offset correction (BBA)

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

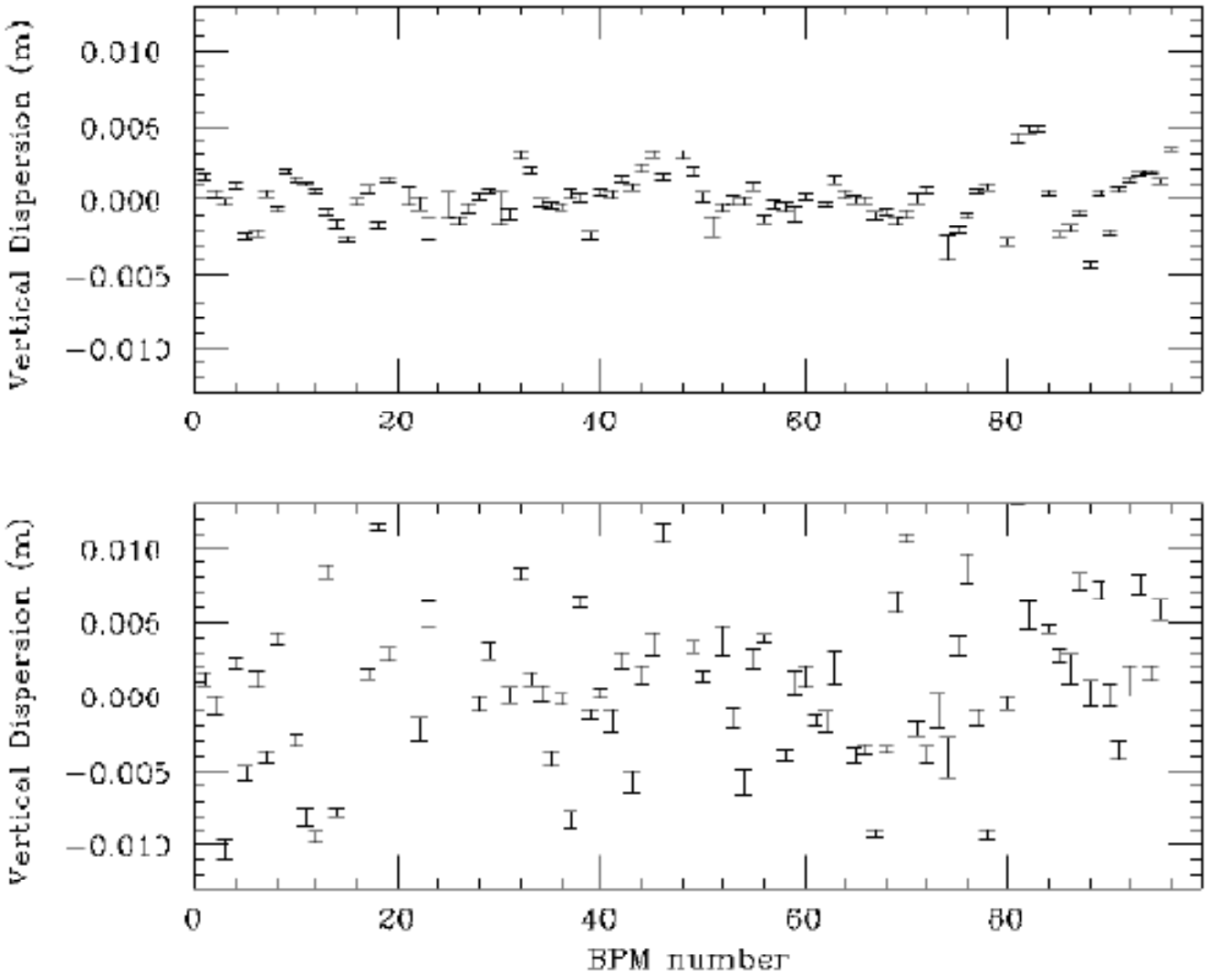
(D) Improved laser wire monitor

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

Vertical Orbit, May 2003 and Nov.2002

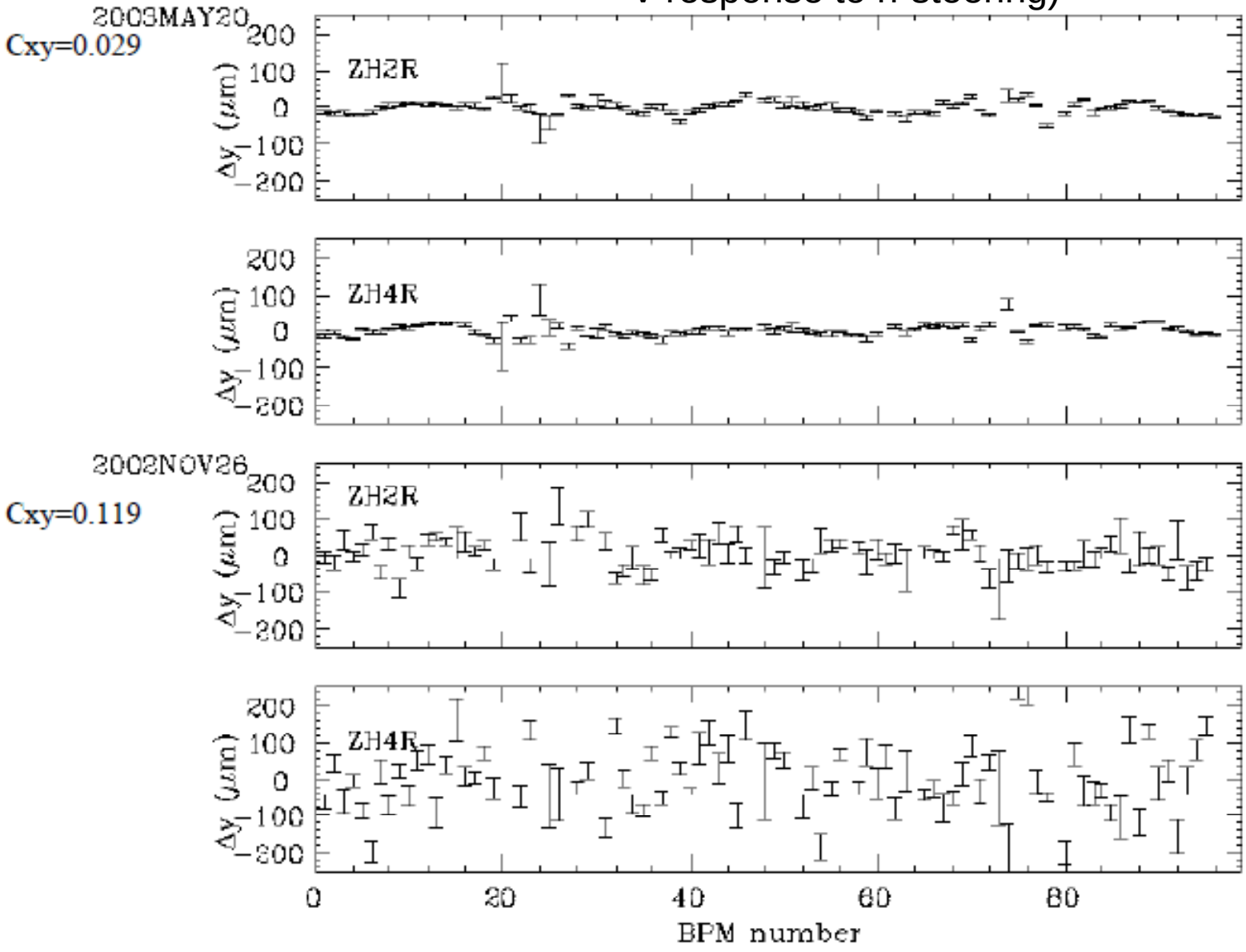


Vertical Dispersion, May 2003 and Nov.2002

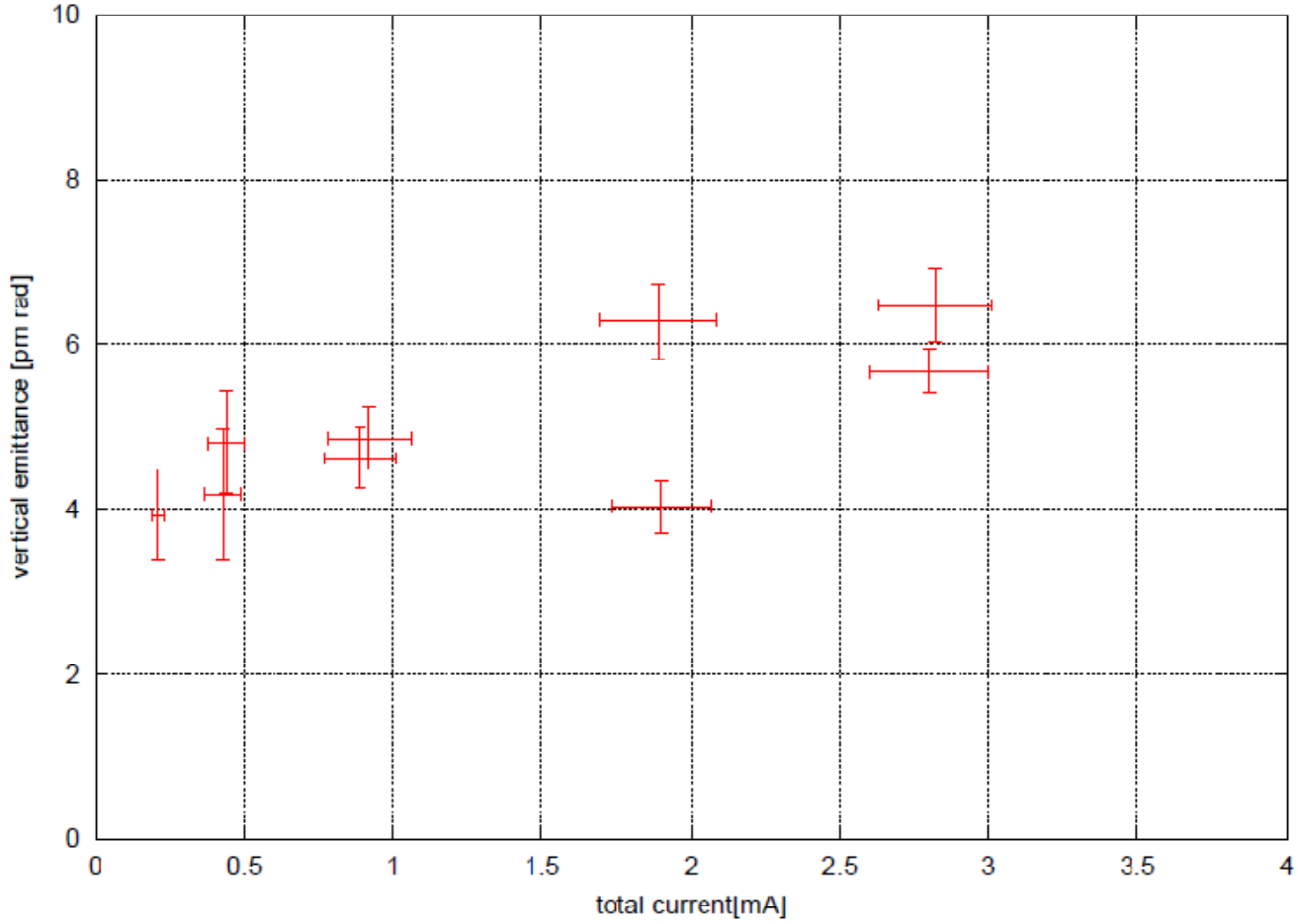


x-y Coupling May 2003 and Nov.2002

v-response to h-steering)



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



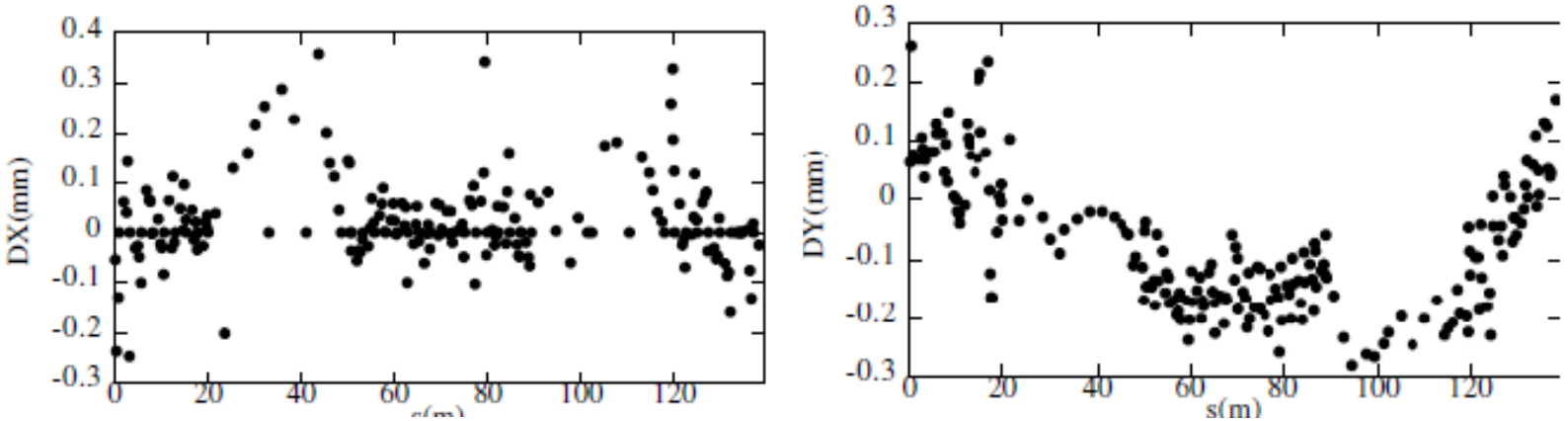
by Y.Honda

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

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

ηy: measured vertical dispersion.

r : weight factor = 0.05

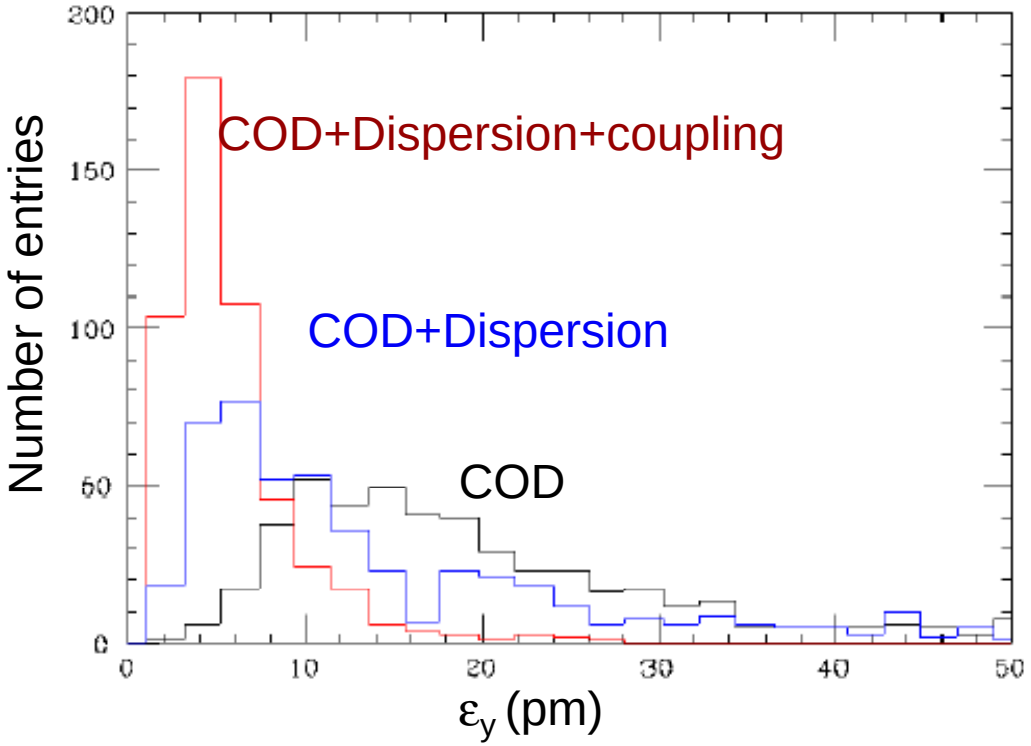
(c) Coupling correction: using skew quads, minimize

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

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

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

Simulated vertical emittance

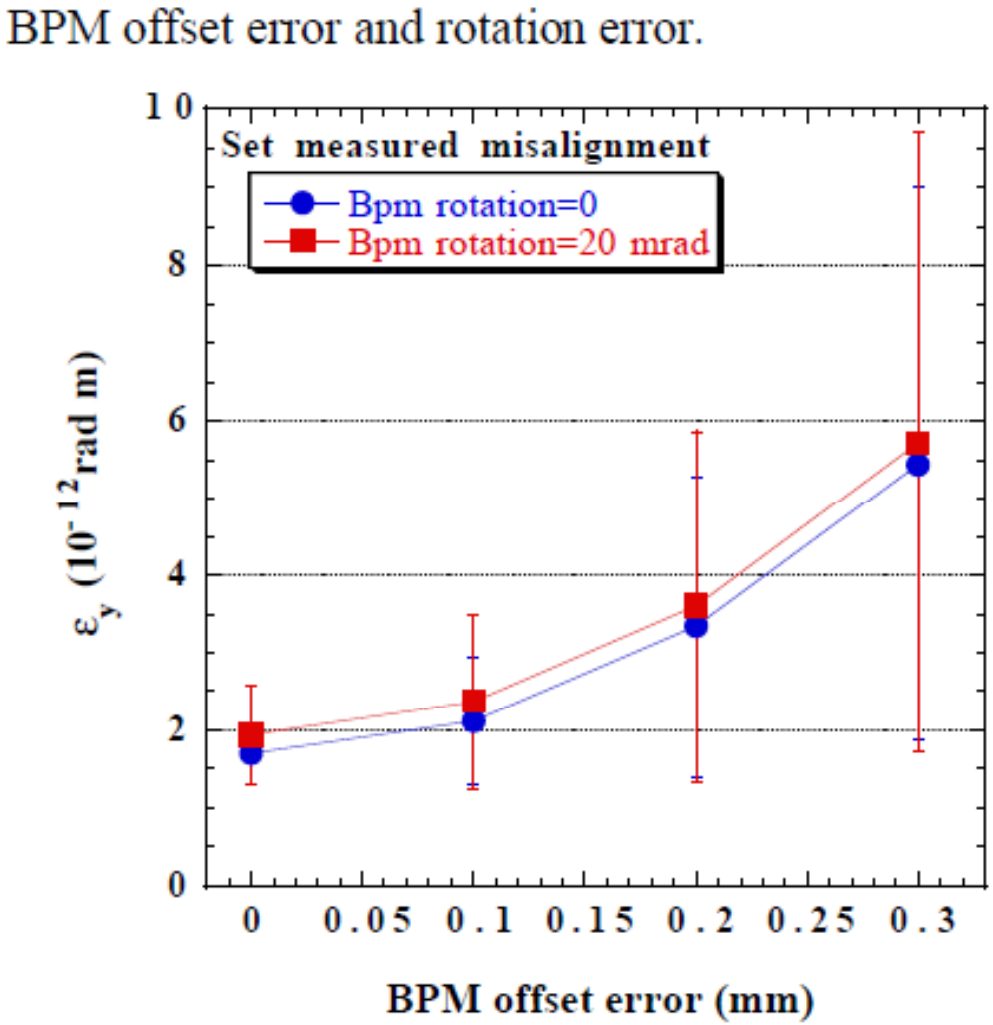


Distribution from
500 random seeds

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

For lower emittance

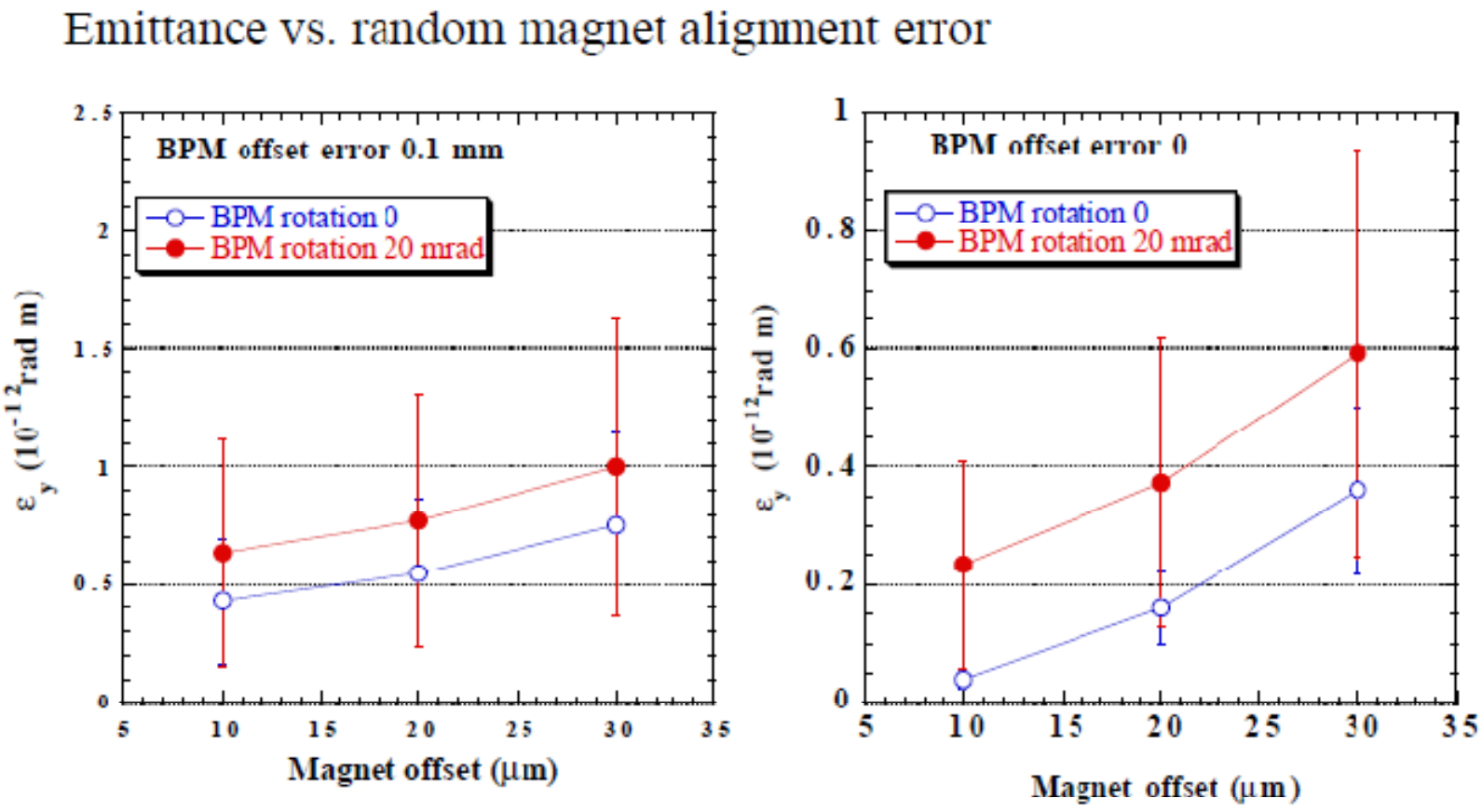
BPM offset error should be small (~100 μm)



Magnet alignments (< 30μm) are important,

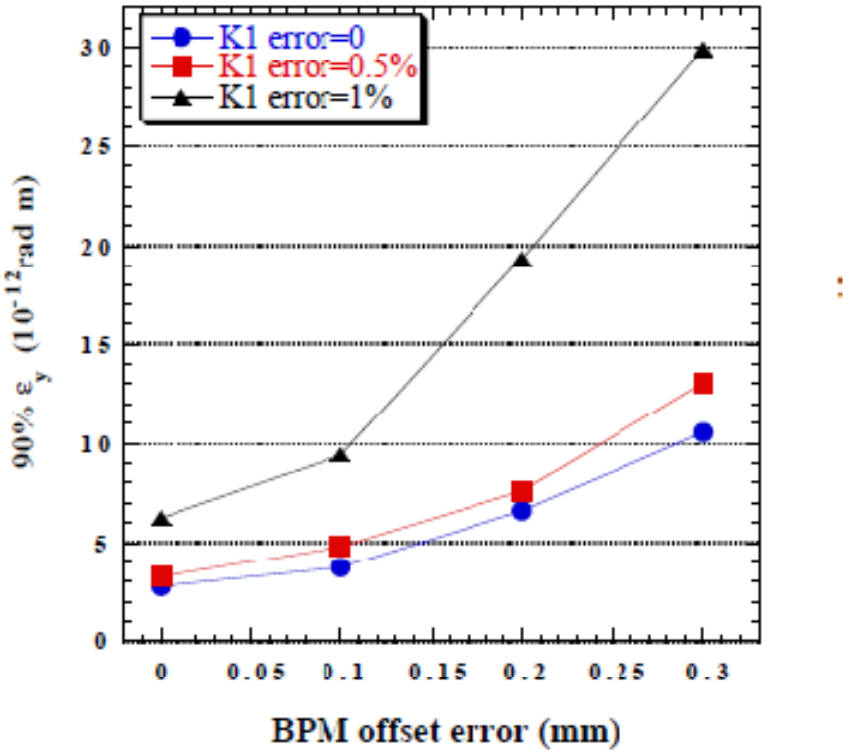
(only) if BPM offset error is small

and for very low emittance



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.)



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 ~5 pm emittance.

If we make more improvement, then ~2 pm will be possible.

- New BPM electronics
  - Better resolution and stability.
- Better BPM will make beam based corrections better, then
  - Reduce BPM offset error.
  - Reduce optics error

BUT. . . . .

Vertical emittance has become larger

- 5~10 pm had been constantly achieved after emittance tuning described here.
- Recently, about 20 pm at smallest, after the same procedure of the tuning.
- Apparent vertical dispersion and x-y coupling are worse. (? may not be always ?)
- Optics model looks bad. (e.g. tunes and orbit response to steering magnet do not fit with the calculation.)

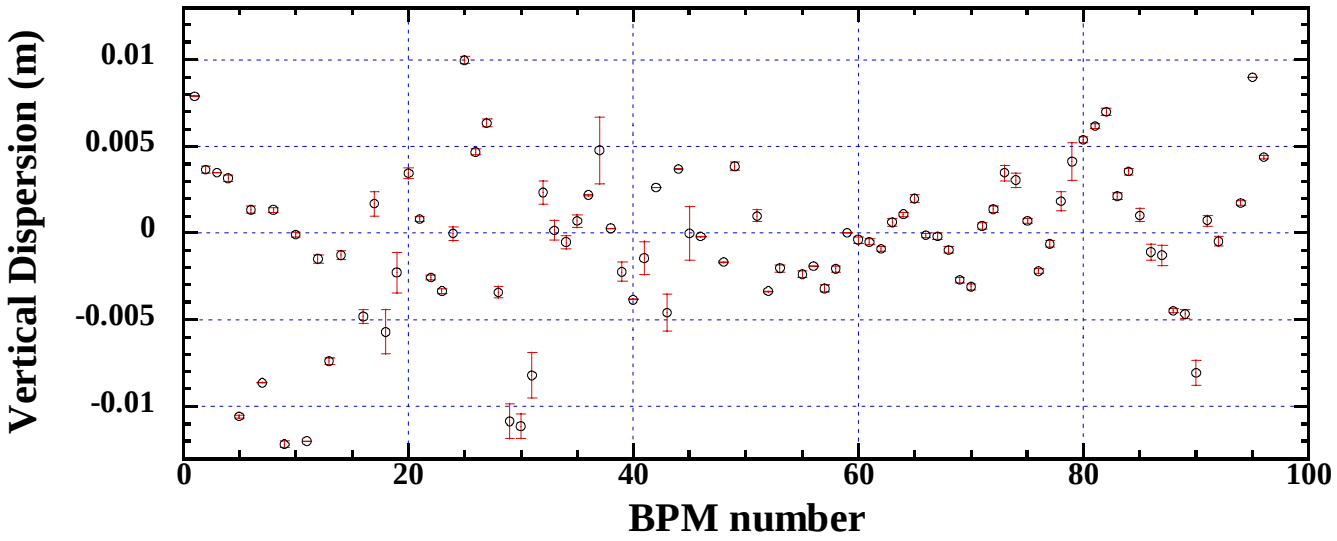
We need to solve the problem.

  - ATF2 assumes ~10 pm
  - Many instrumentation development need small beam size

Vertical dispersion, recent and old data

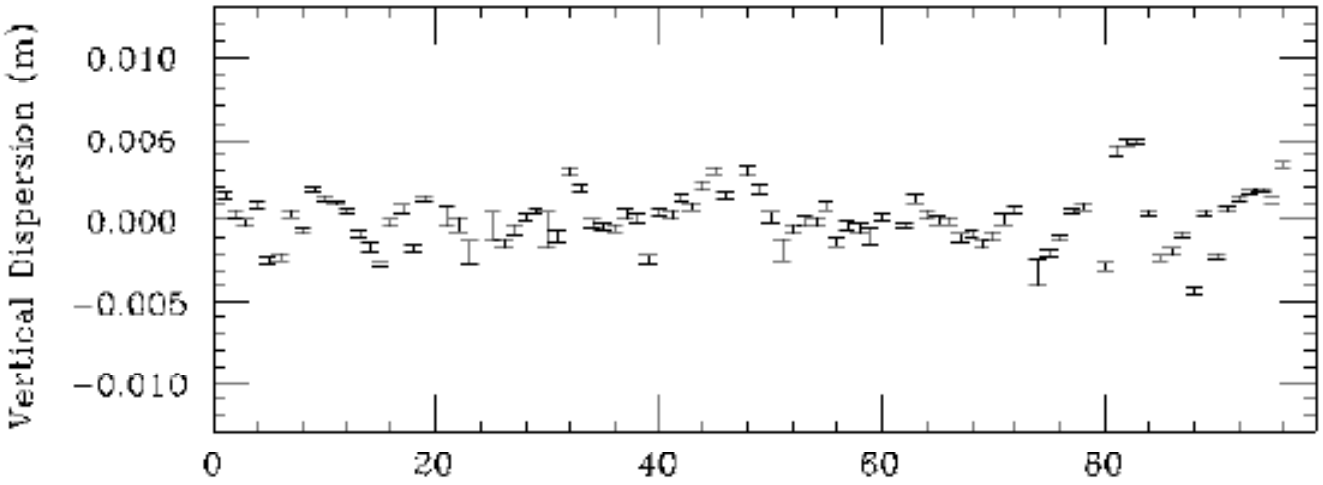
Feb.2008

RMS = 5 mm



May 2003

RMS = 3 mm

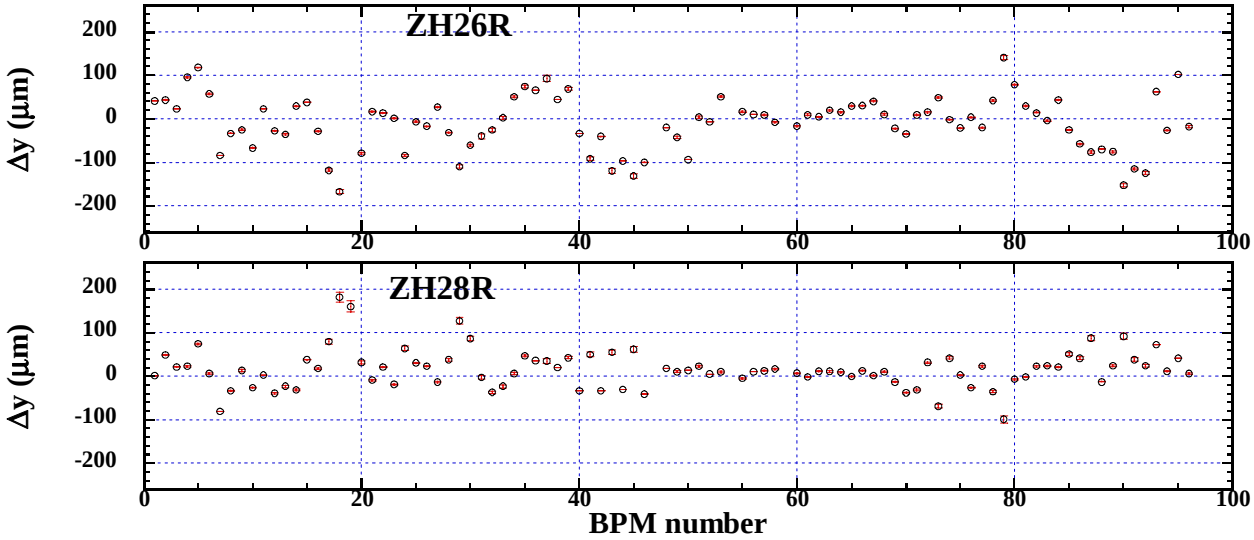


x-y Coupling, recent data

Feb.2008

Cxy=0.100

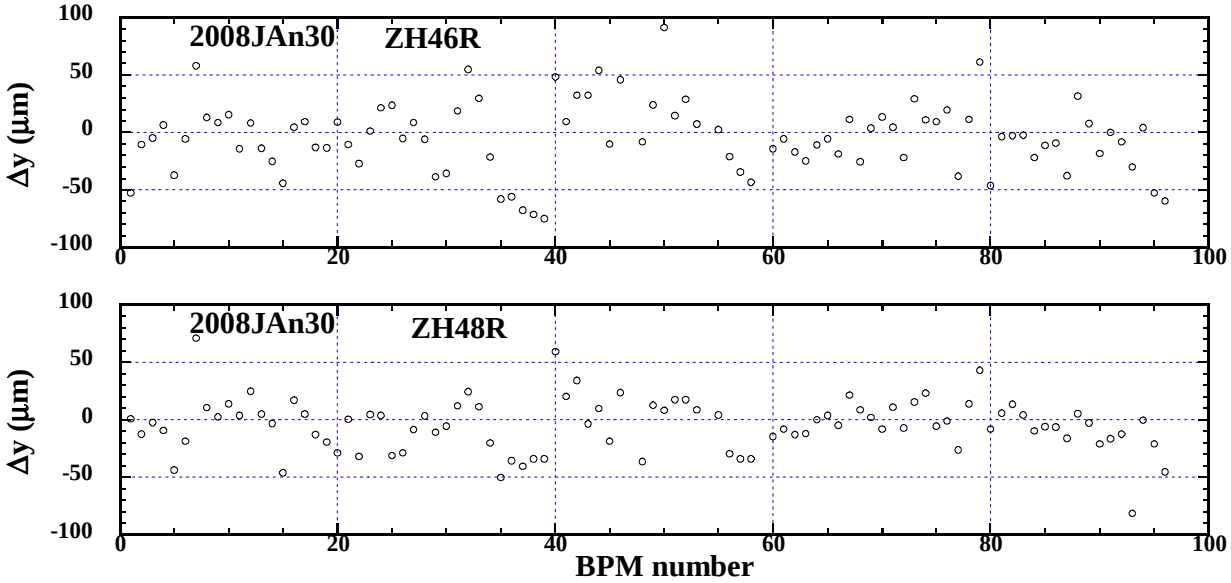
BAD!!



Jan.2008

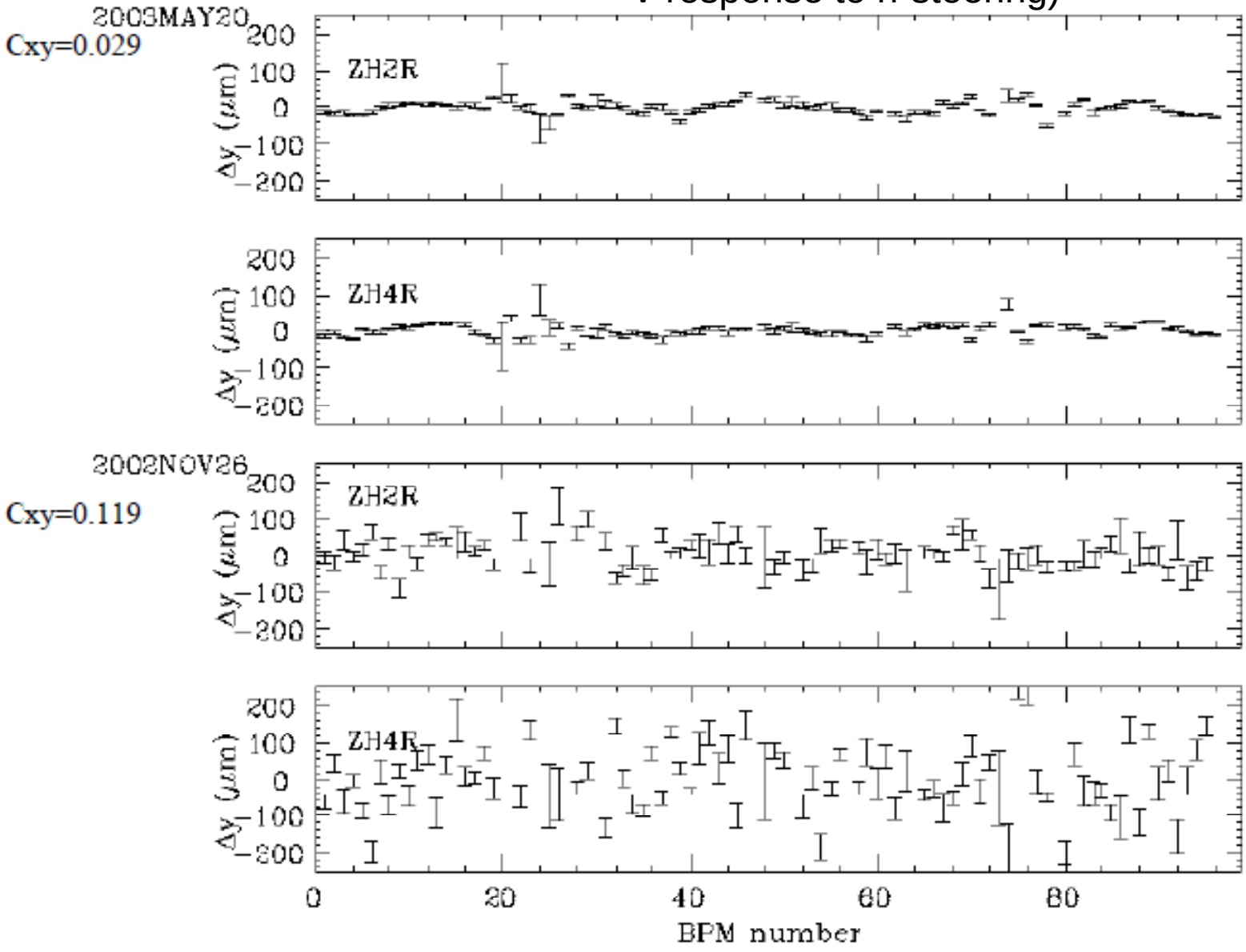
Cxy=0.037

NOT so BAD



x-y Coupling May 2003 and Nov.2002

v-response to h-steering)



What can be the source of large emittance? What to do? (1)

- Error of optics (strength error of quad magnet)?
  - Fit errors from orbit response to steerings. This had worked before but not worked last year. We should try again. There may be cleverer analysis.
- Magnets were moved ?
  - Check alignment. Re-align if necessary.
- BPM offset w.r.t. magnets.
  - BBA. It was done before for main quad magnets in vertical. Should be checked and be done again if necessary.

What can be the reason of large emittance? What to do? (2)

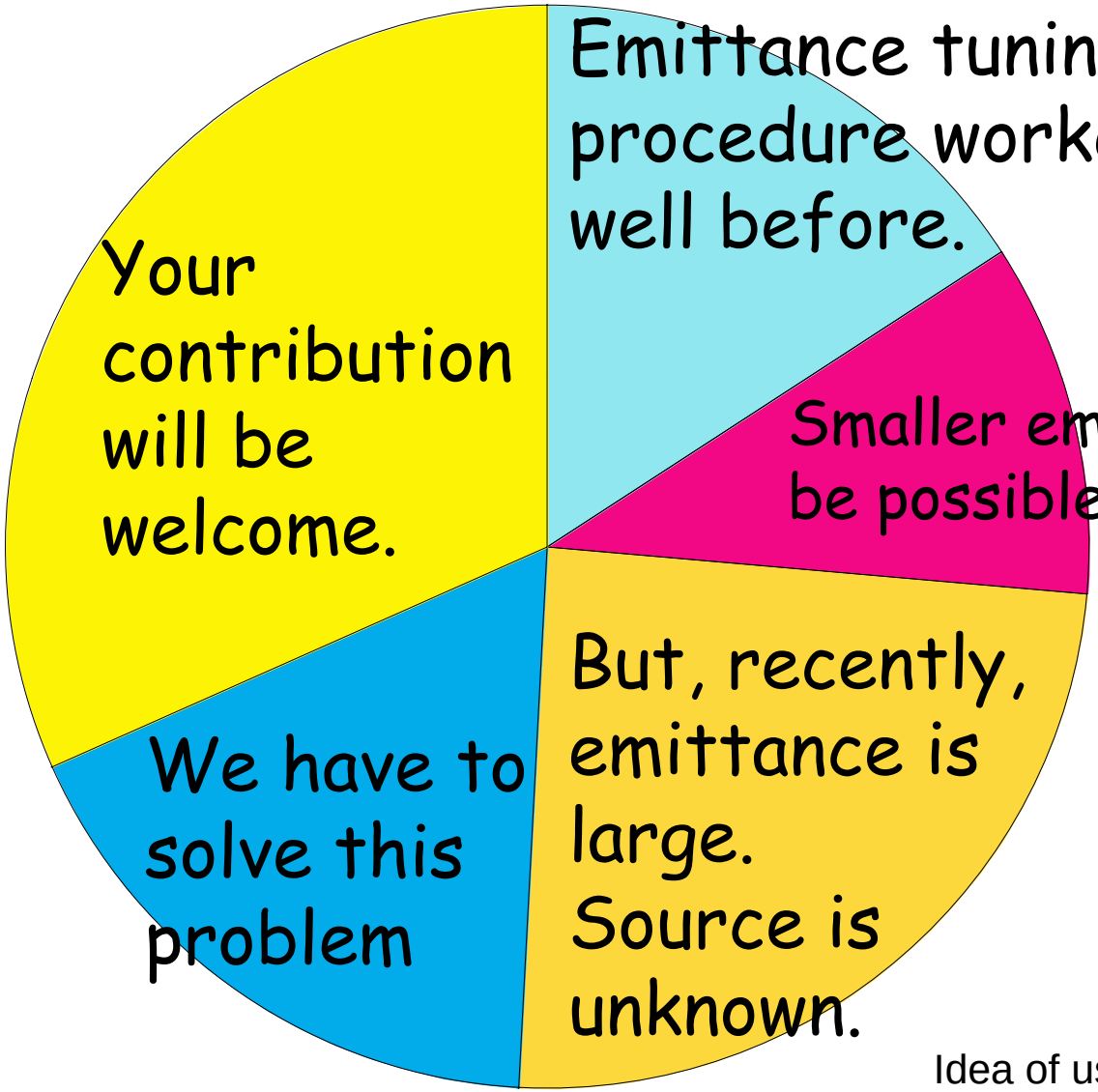
- BPM calibration (calib. factor, rotation)
  - How to calibrate?
- Mistakes (We found polarity error of some steering magnets.)
  - Make sure there is no more such mistakes.

- Something else?

We were and are working on these, but still more to do.

Your contribution will be welcome.

Summary of ATF DR emittance



Idea of using pi-chart is from:
http://portal.nifty.com/2007/03/17/a/