For Lower emittance in DR

2012.1.

Kiyoshi Kubo

Three consecutive corrections:

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

correction

(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

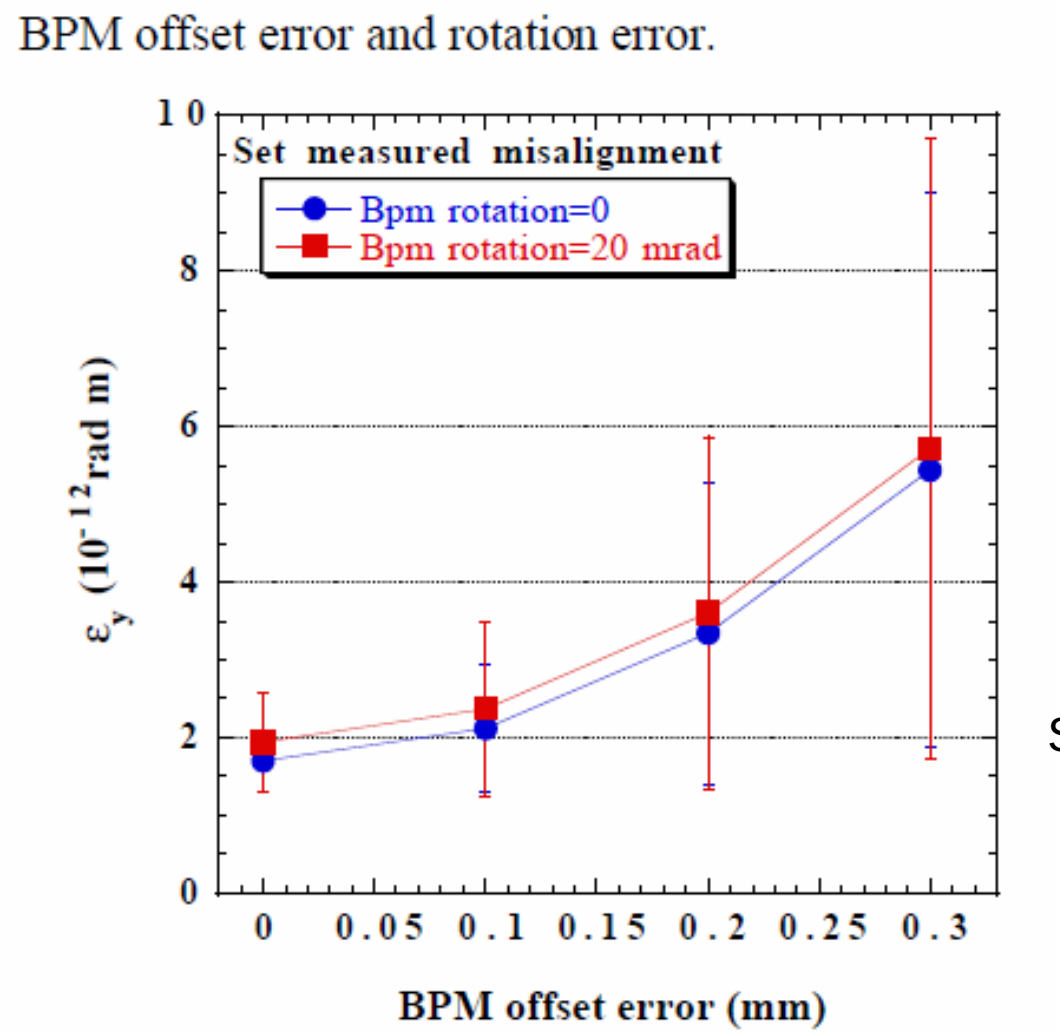
(c) Coupling correction: using skew quads, minimize

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

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

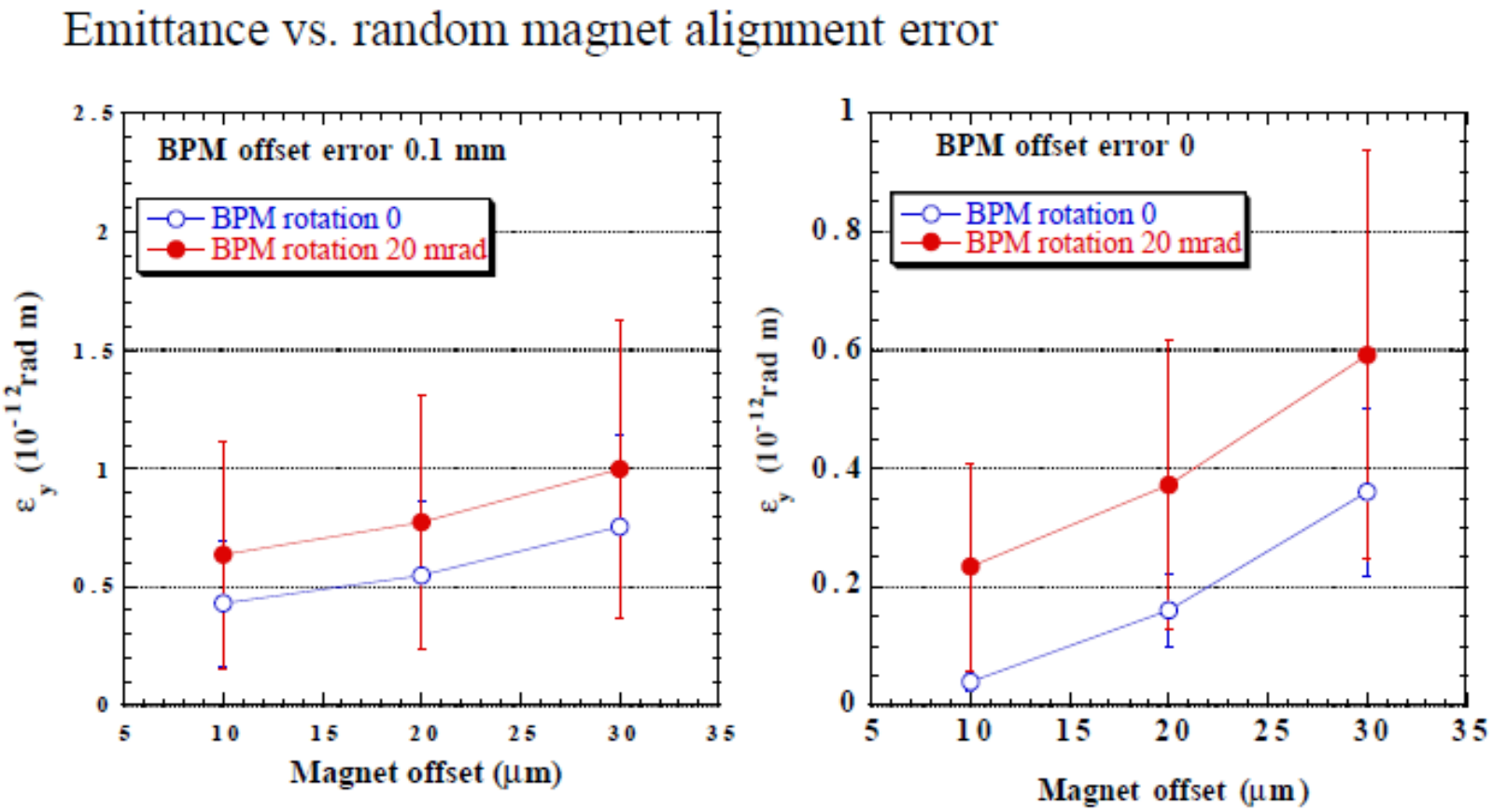
Two horizontal steering magnets were used (*N*steer=2). About (n+1/2)π phase advance between the two.

For lower emittance
BPM offset error should be small (~100 μm)



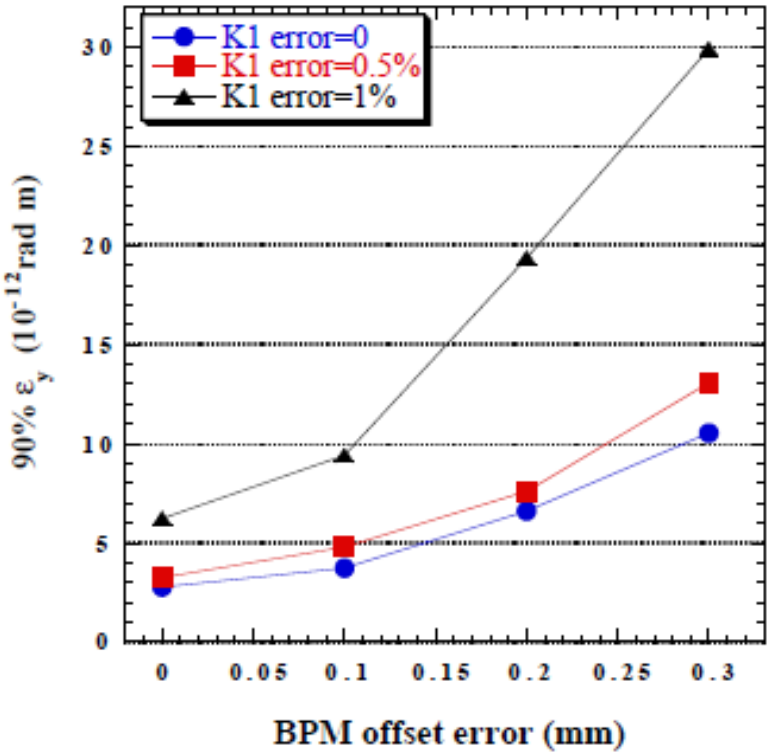
Set old measured misalignment

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

From Simulations:

1, Improve magnet alignment

2, Improve BPM offset error wrt. nearest magnet

3, Improve optics error (magnet strength error)

Now, we are trying to achieve ~2 pm (or 1?).

1, Re-alignment after the earth quake

2,3, Beam Based Alignment and Optics Correction

- Using improved BPM electronics system
- Orbit response to Quad strength change
- Orbit response to Steering

Other correction methods using turn-by-turn orbit data may improve emittance. (?)

- Need detailed simulations.

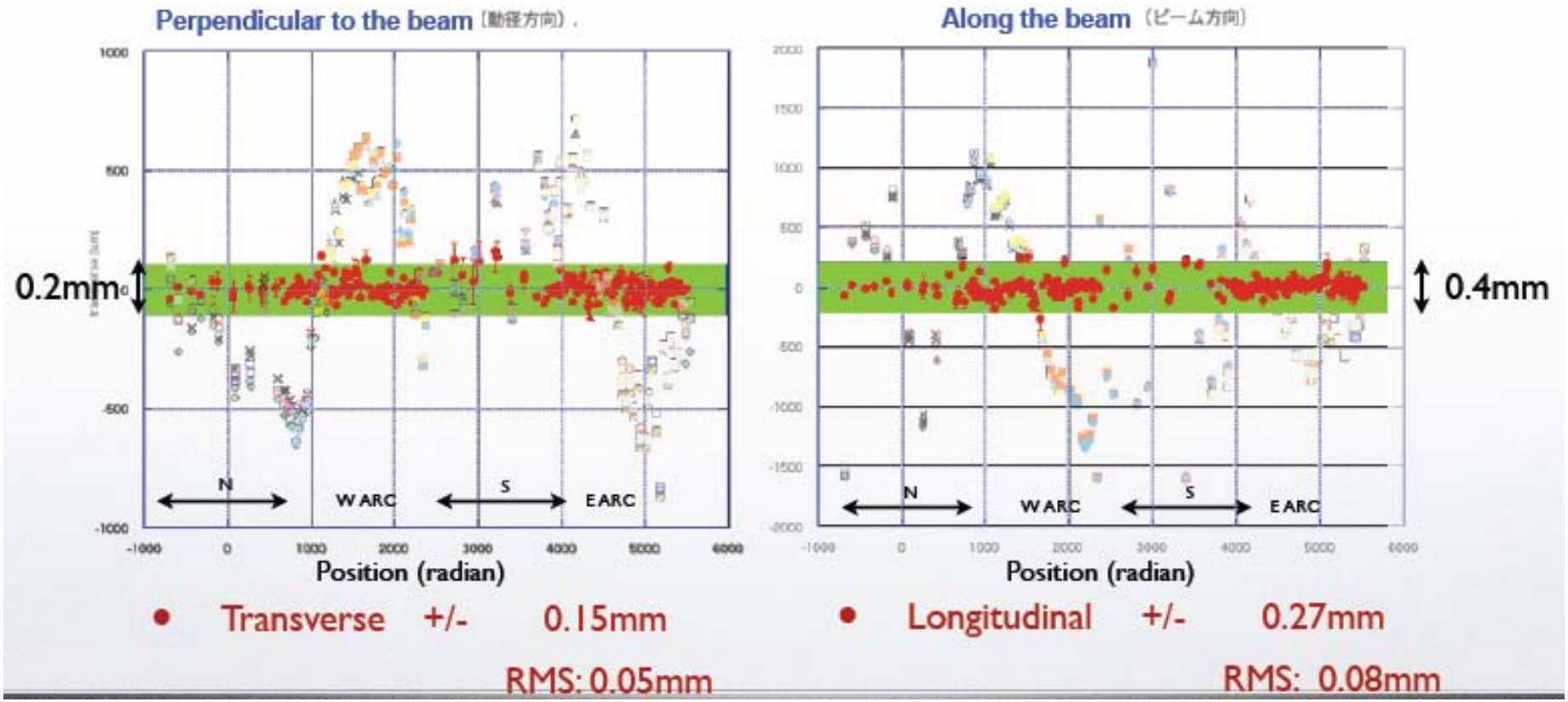
Magnet Alignment

- From simulations:
  - RMS <30 um is desirable,
  - RMS <50 um may be acceptable (?)

- It is not easy to tell whether present alignment is good enough for 1~2 pm. But OK for ~10 pm.
- Need simulation with actual misalignment.

DR survey

- after alignment (september)



- Transverse +/- 0.15mm
  RMS: 0.05mm
- Longitudinal +/- 0.27mm
  RMS: 0.08mm

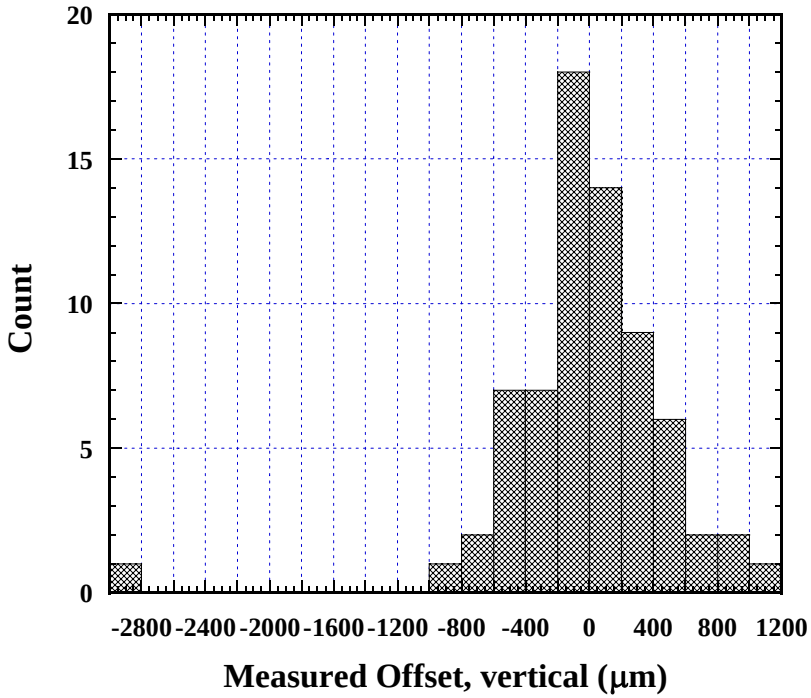
Araki's presentation in ATF2 Proj. meeting Wednesday

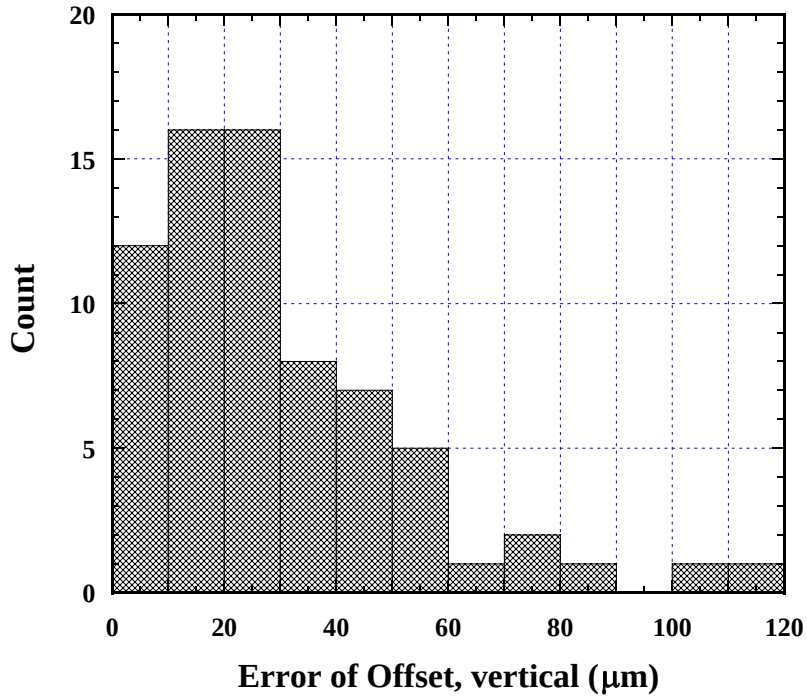
BBA: BPM offset wrt. nearest magnet

- Offset error RMS < 100 um required
- Measured as orbit change due to quad strength change.
  - Not automated. Beam lost with large field change.
- Accuracy is estimated to be much smaller than 100 um.
  - ~ (BPM resolution)/sqrt(Number of BPMs)/(change of K1)/(beta-function)
  - BPM resolution (pulse to pulse fluctuation) < 1 um with new BPM system by FNAL Group
  - But, with some maintenance by experts. How to keep the system reliable?

(See Okugi's presentation in ATF2 Proj. meeting Wednesday)

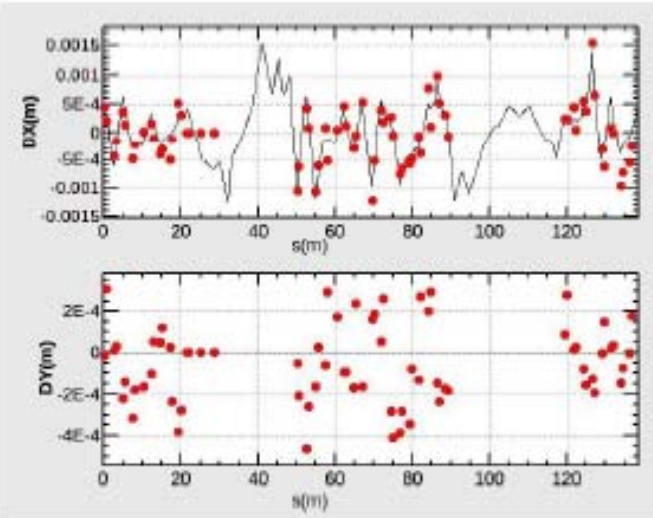
BBA result

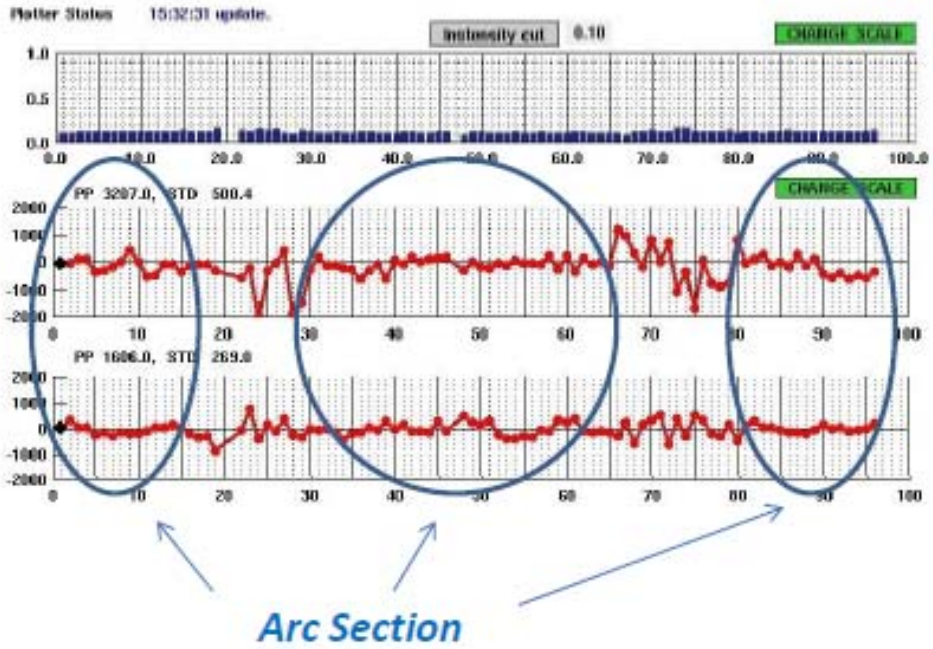




Data by Okugi

Horizontal Orbit Correction





We could make the horizontal orbit of arc section flat by orbit correction program, when we applied the BBA data

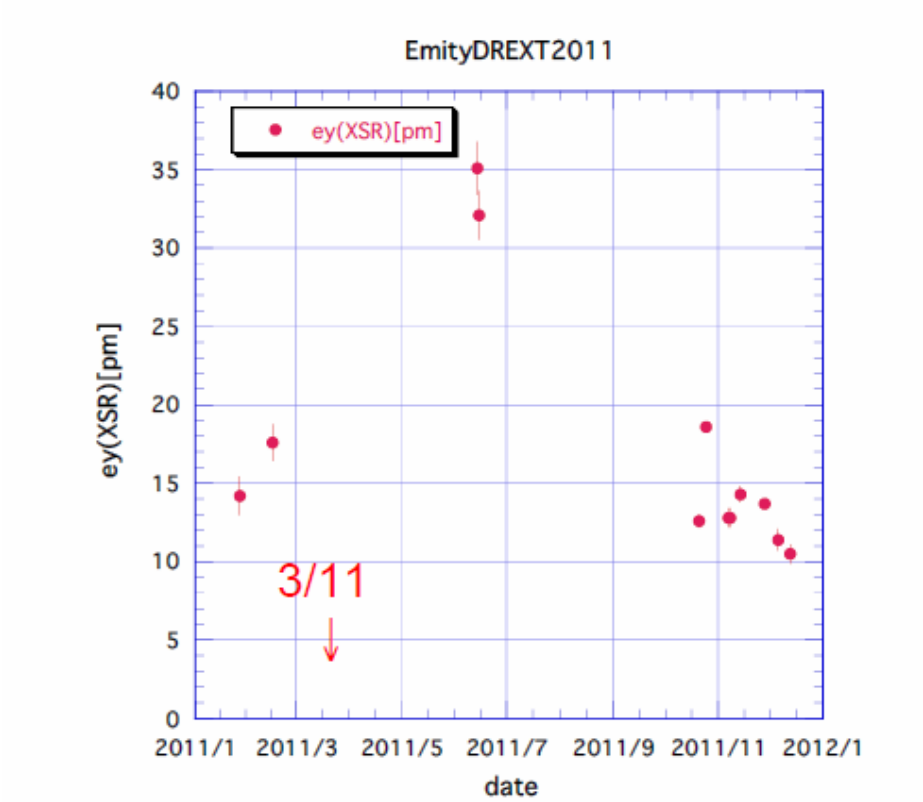
From Okugi's presentation in ATF2 Proj. meeting Wednesday

Optics measurement/correction

- Quad strength error RMS <0.5%, if error is random.
  - Adjusting tunes can make the requirement looser
- Correction Based on ORM (orbit response to steering magnets) analysis will be good enough.
  - But it has not been well confirmed.
  - Need good BPM system.
    - Present system seems good enough (after maintenance by experts).

(See Kubo's presentation in ATF2 Proj. meeting Wednesday)

Recent DR emittance



(From Kuroda's presentation in ATF2 Proj. meeting Wednesday)

Measured emittance is OK for present ATF2 study, but far from 1~2 pm.

Problems? What to do

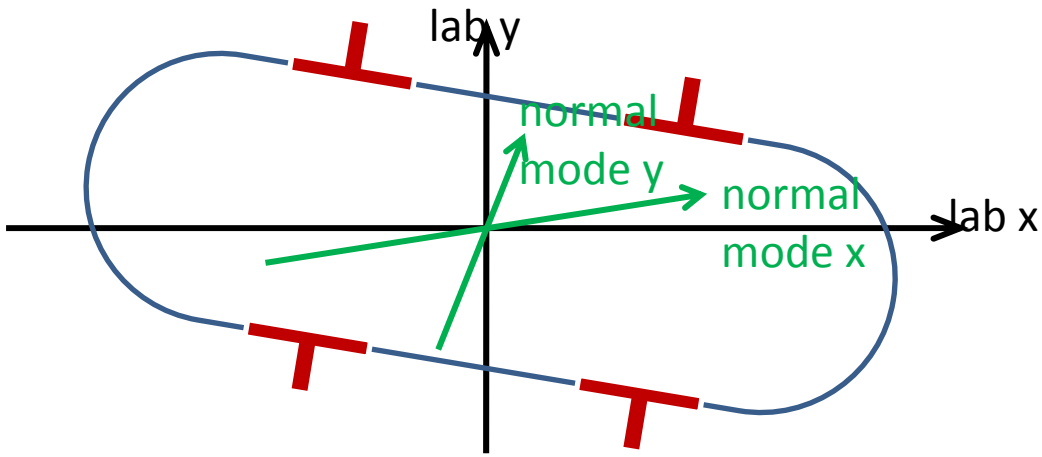
- BPM system work well (at least with some maintenance by experts)
- BBA (offset) seems good enough.
- Magnet alignment seems fine but effects of actual misalignment not fully checked.
- Accuracy of X-SR beam size monitor?

What to do

- Keep BPM always reliable. (Communication between tuning team and BPM group)
- Need BBA for rotation (or x-y coupling) of BPM?
- Check effects of misalignment. More alignment if needed.
- DR Laser wire monitor for confirmation of emittance.
- ?

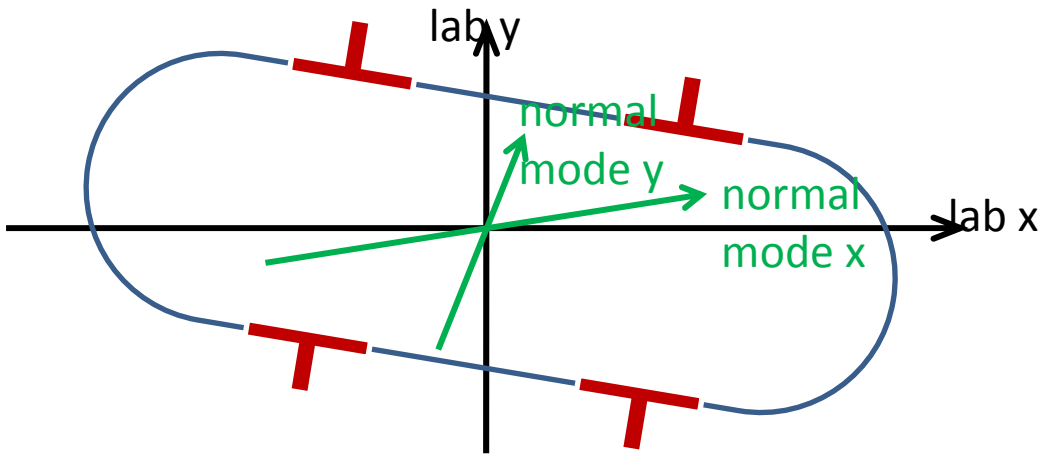
Tuning method
Using turn-by-turn BPM Data

- To “calibrate” a BPM, we can observe turn-by-turn normal mode motion on the beam, e.g. by “shaking” the beam first at one betatron frequency, then at the other.
- This allows us to determine the components of beam motion along the normal mode axes, regardless of any gain errors.
- If the dispersion is parallel to the “horizontal” normal mode, then quantum excitation will not excite any motion in the “vertical” normal mode: this is the optimum condition for minimising the vertical emittance.
- The effects of dispersion and coupling are fixed simultaneously.

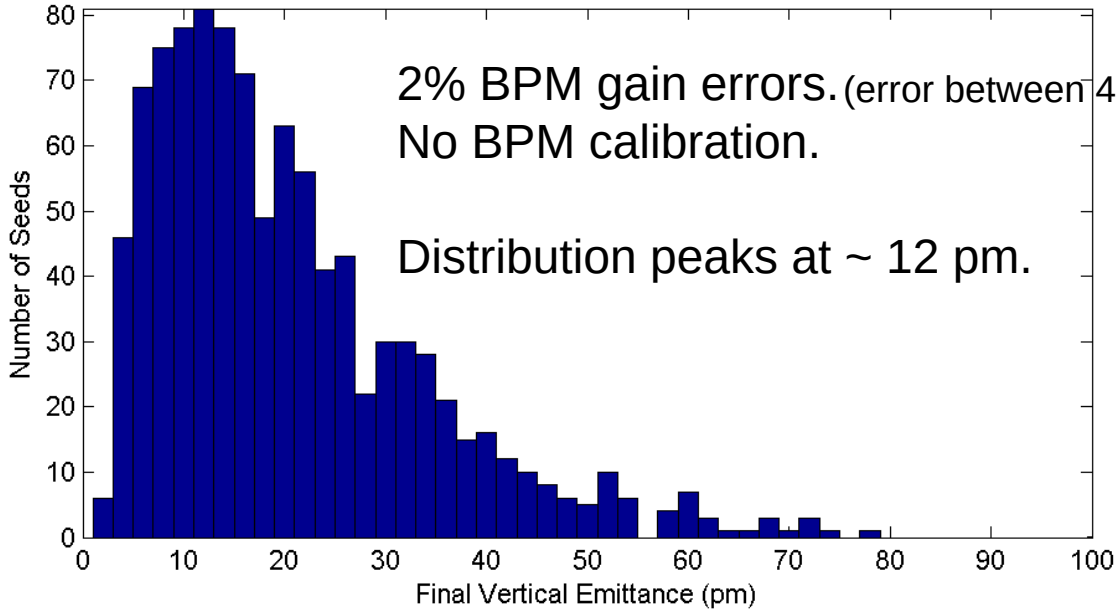


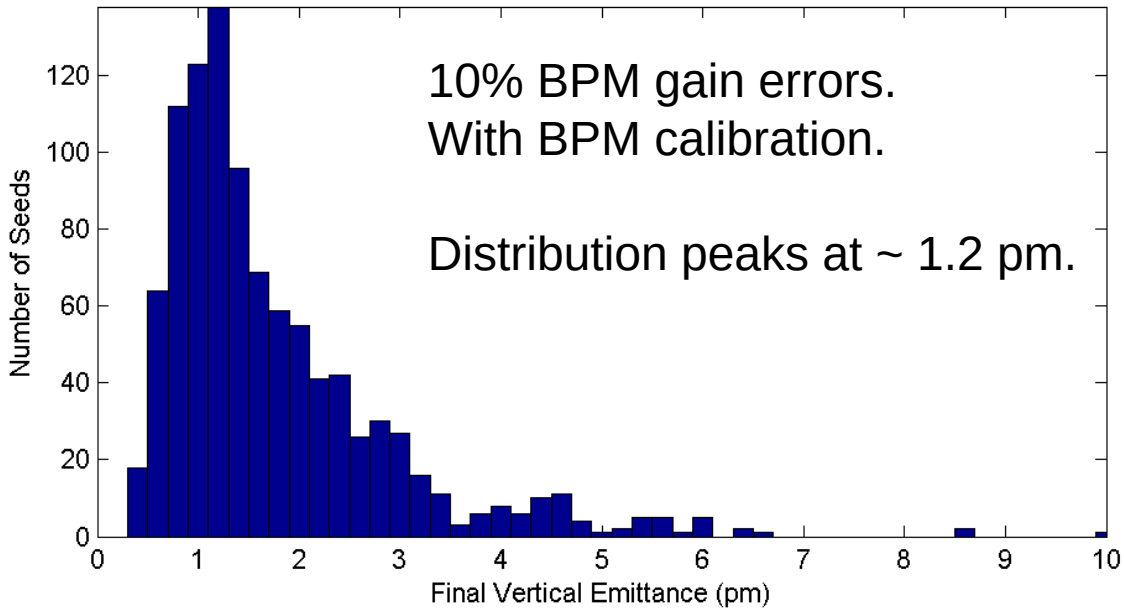
by Andy Wolski

- BPM “Calibration”
  - Kick beam and take turn-by-turn data
  - Determine directions of normal modes for each BPM by analyzing frequency components of the normal modes.
- Correction
  - Minimize dispersion of the vertical like normal mode at each BPM by setting skew quad correctors
- Repeat above（changing skew quad correctors also changes normal mode directions）



Tuning Simulation Results





by Andy Wolski

SUMMARY

What we need for 1~2 pm emittance:

- Good BPM system
  - Need to keep the system always reliable.
  - Beam based various corrections using orbit response.
  - BBA, offset and coupling
- Good alignment.
  - Effect of present misalignment should be checked.
  - More effort for better alignment.
- Good emittance monitor.
  - Work needed for Laser wire in DR.
  - XSR improvement??
- Try “new” method using turn-by-turn orbit data.