ATF Damping Ring emittacne

2008.10.

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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 $\rightarrow$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.
- But emittance has not become smaller.

Recently, Vertical Emittance is Large

20~30 pm (from 2006 ?) !!

- We do not know its reason clearly.
- 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.
  - etc.

Simulation of ATF DR emittance tuning

ERRORS:

(tried to reproduce actual condition)

- Misalignment of magnets: as measured

  + random 30 micron offset

  + random 0.3 mrad. rotation

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

Simulation

Three consecutive corrections:

Simulate actual procedure

Monitor:

BPM (total 96)

Corrector:

Steering magnets (47 horizontal and 51 vertical)

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

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

Simulation

(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

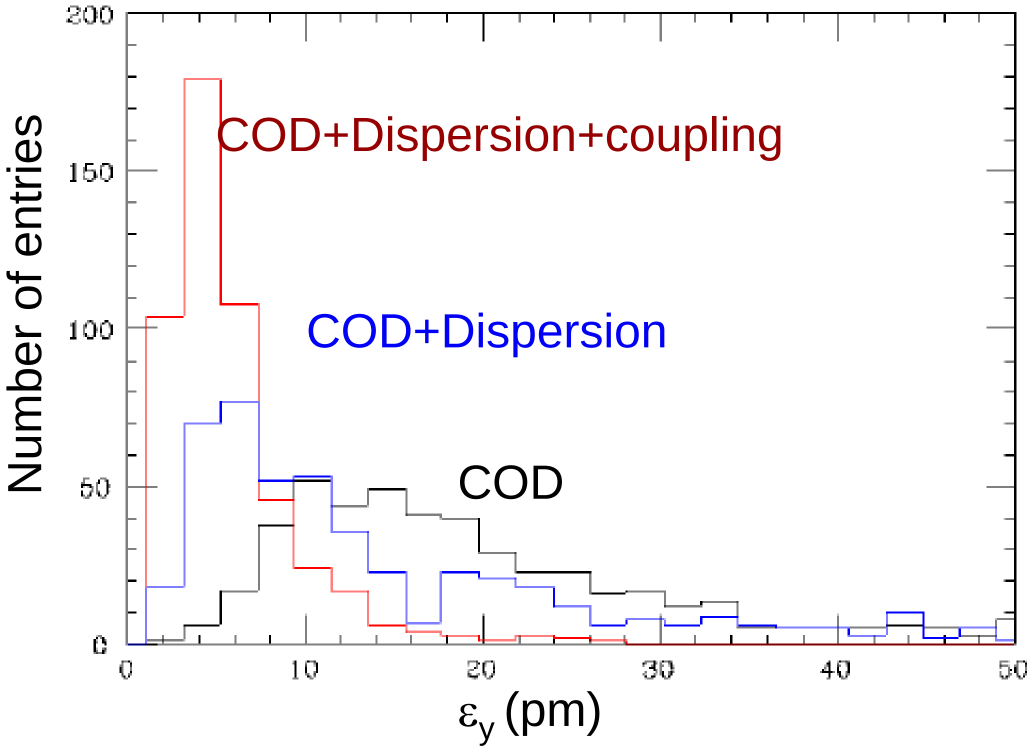
(c) Coupling correction: using skew quads, minimize

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

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

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

Simulated vertical emittance - old result



Distribution from 500 random seeds

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

Vertical emittance became larger

- 5~10 pm had been achieved after emittance tuning described.
- Recently, about 20~30 pm, after the same procedure of the tuning.
- Apparent vertical dispersion and x-y coupling are worse. (? may not be always ?)
- Optics model may be bad. (e.g. tunes and orbit response to steering magnet do not fit with the calculation.)

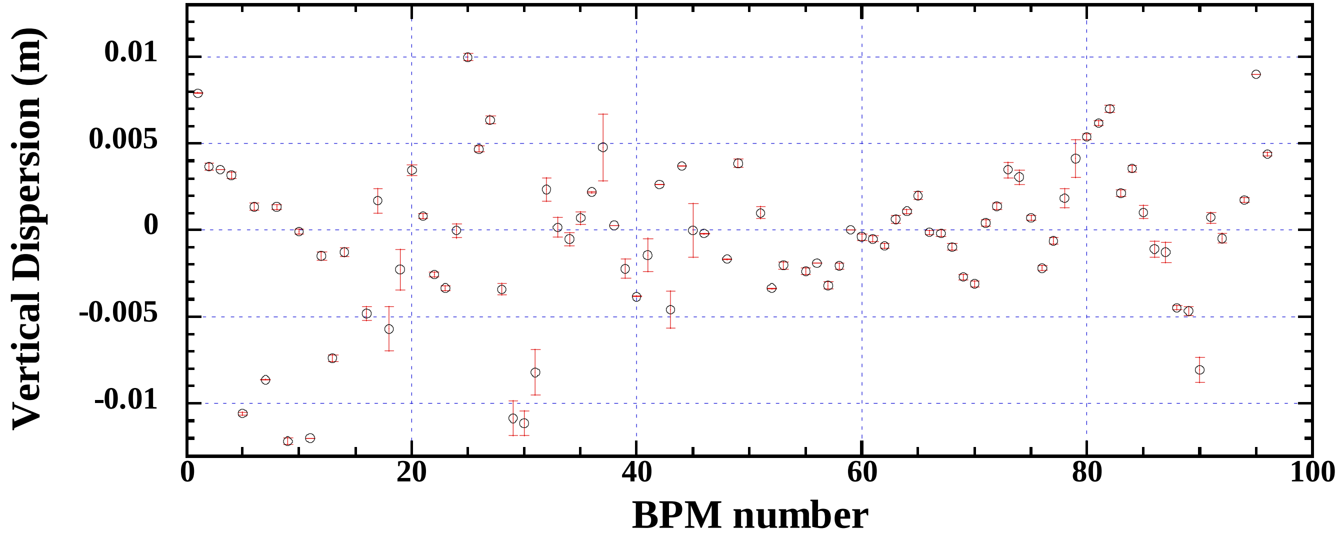
We need to solve the problem.

- – ATF2 assumes ~10 pm.
- – Many instrumentation development need small beam size.
- – ILC damping ring requirement is 2 pm.

Vertical dispersion, recent and old data

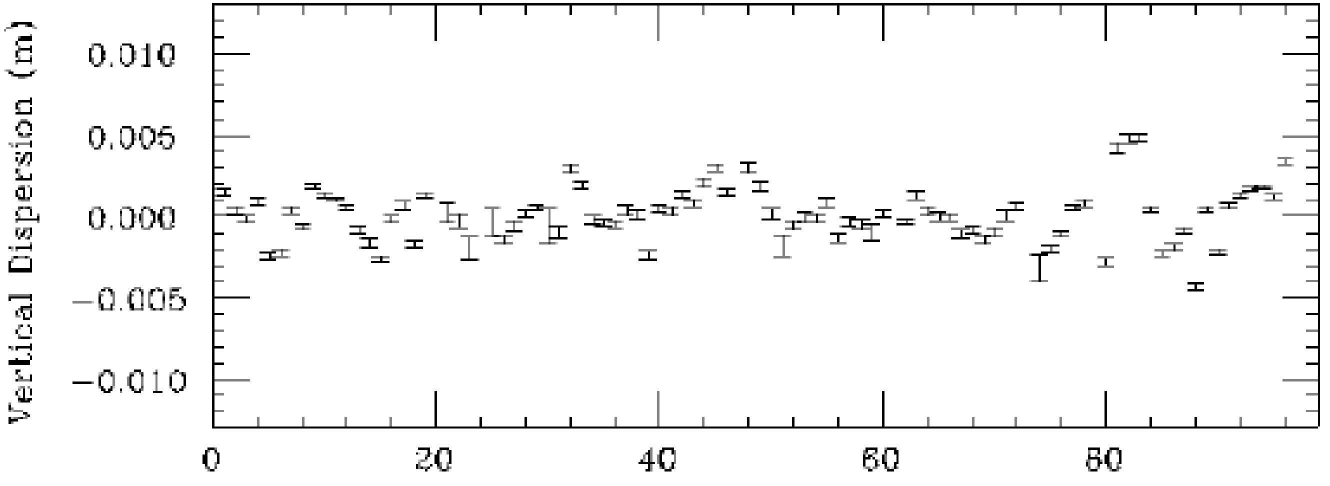
Feb.2008

RMS = 5 mm



May 2003

RMS = 3 mm



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

- Magnets were moved ?
  - Check alignment. Re-align if necessary.
  - Partially done. But not enough?
- BPM offset w.r.t. magnets.
  - BBA. It was done before for main quad magnets in vertical. Should be checked and be done again.
- 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.
  - Other method to adjust optics model. (?)

BPM performance (stability, resolution,,,) is important for reliable data.

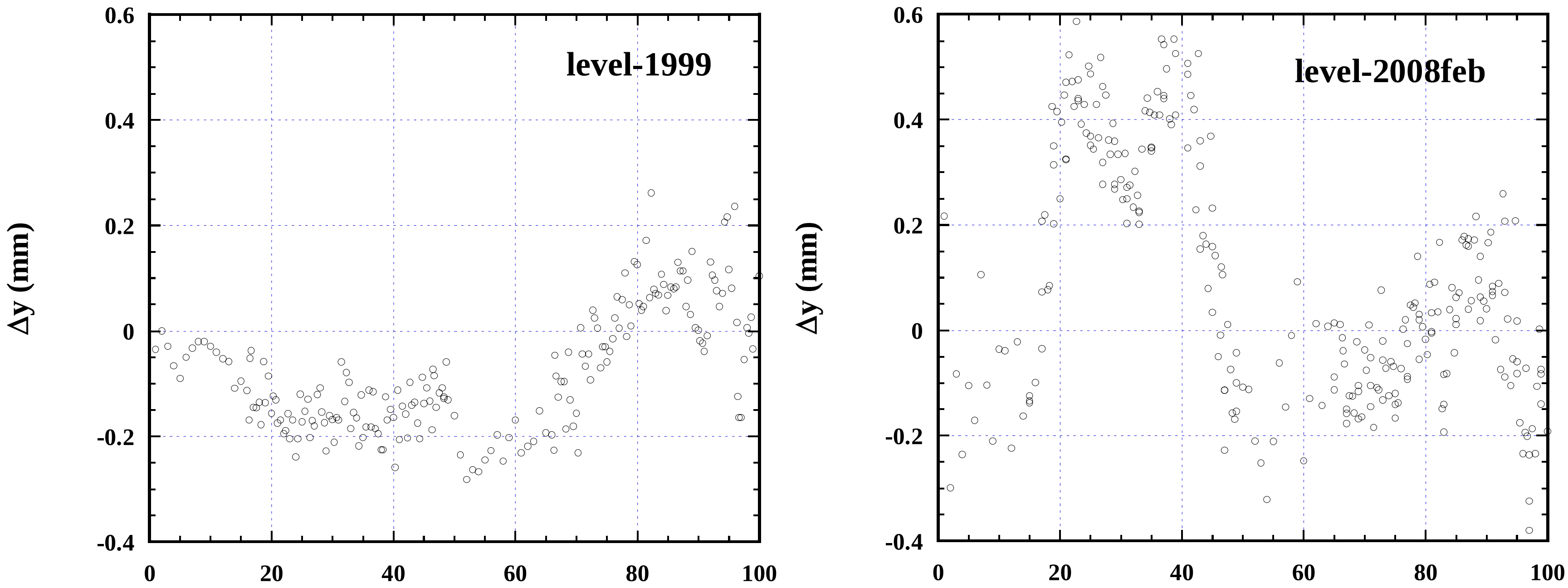
What can be the reason of large emittance? What to do? (2)

- Optics mismatch ?
  - We have not cared much on optics (beta-function beating).
- BPM performance
  - resolution, intensity dependence, etc.
- BPM calibration (calib. factor, rotation)
  - How to calibrate?
- Something else?

We tried to simulate effect of alignment change

- Set magnet alignment as measured
  - Vertical: Bend, Quad and Sext
  - Horizontal: Use “bend-to-bend” for Quad and Sext
- Set BPM offset w.r.t. nearest magnet randomly, 100 random seeds.
- Simulate corrections: Orbit, Dispersion and Coupling
- Look at vertical-like normal mode emittance
- Compare results with measured alignments in 1999 and 2008

Alignment data

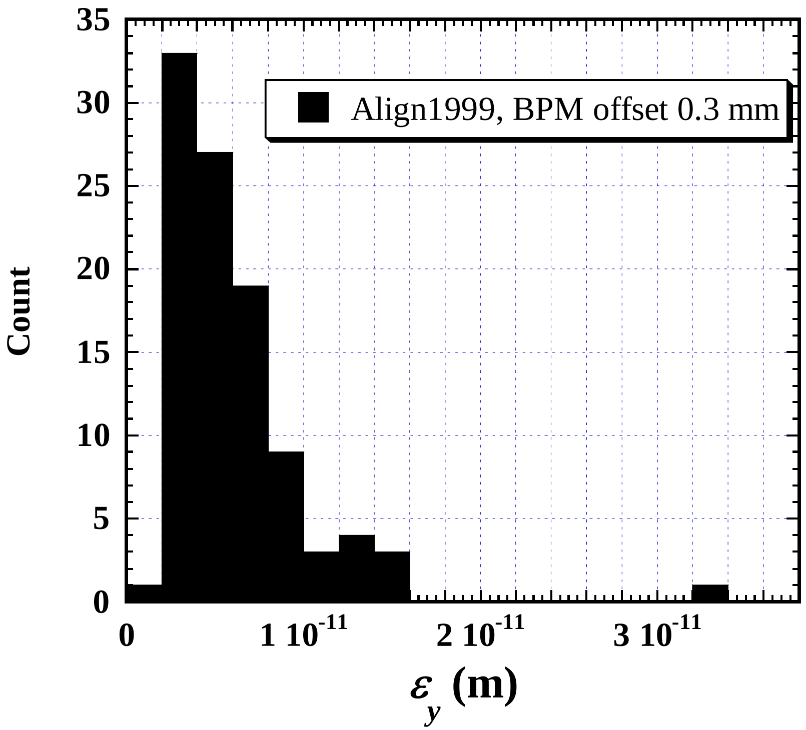


(Data from Takano)

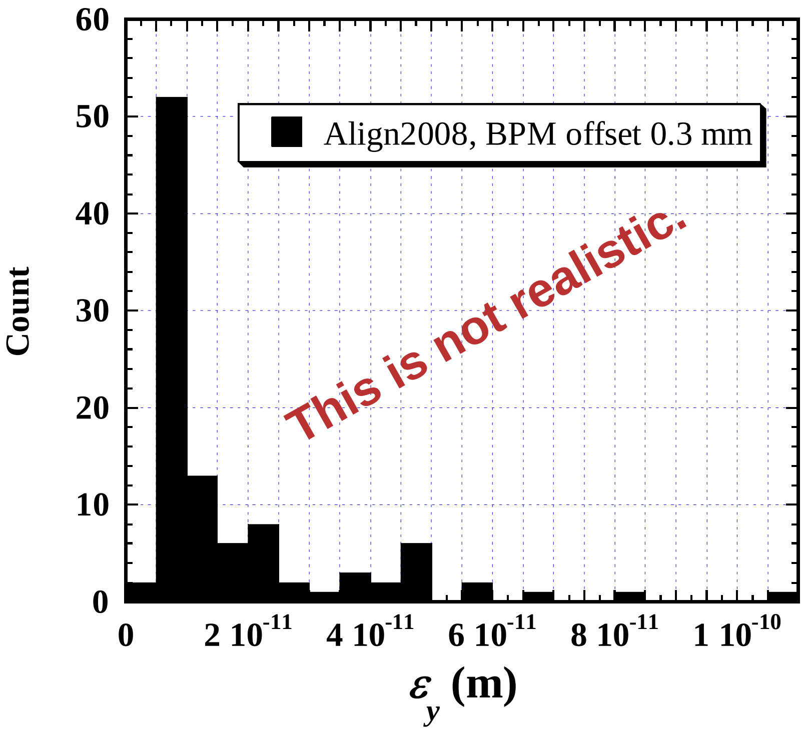
Local (short range) alignment is apparently worse in 2008 than in 1999.
But we have learned that the measurement methods were different and it is not fare to compare these two directory.
→ The result of 2008 may not be reallistic.

Emittance with two sets of misalignment

Alignment 1999



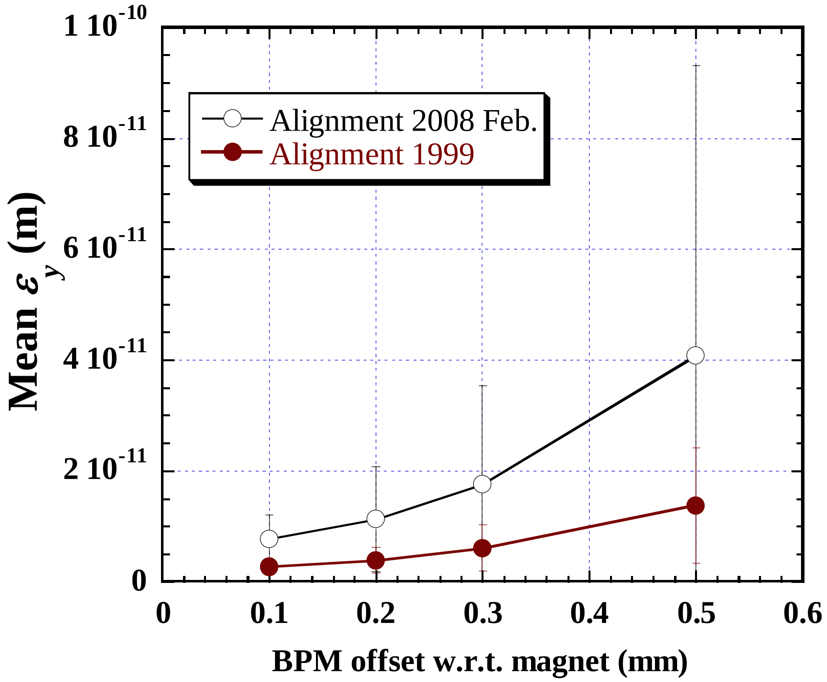
Alignment 2008 Feb
(large measurementerror)



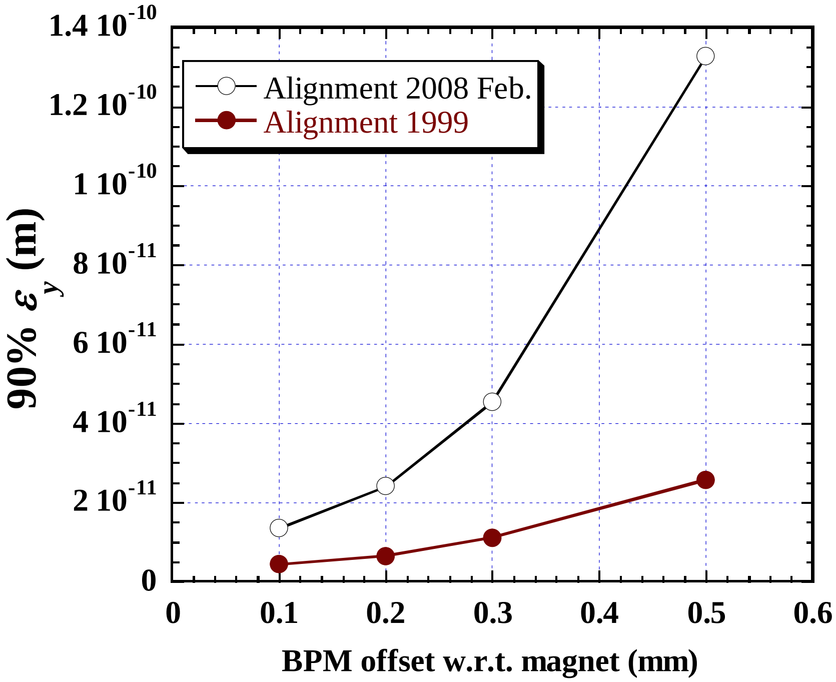
Bad alignment can be obviously the source of the large emittance.
But this new set of alignment data is not accurate enough to compare with the result of 1999.
Alignment should be checked, and re-alignment should be performed.

Emittance vs.
BPM offset w.r.t. nearest magnet

Average of 100 seeds



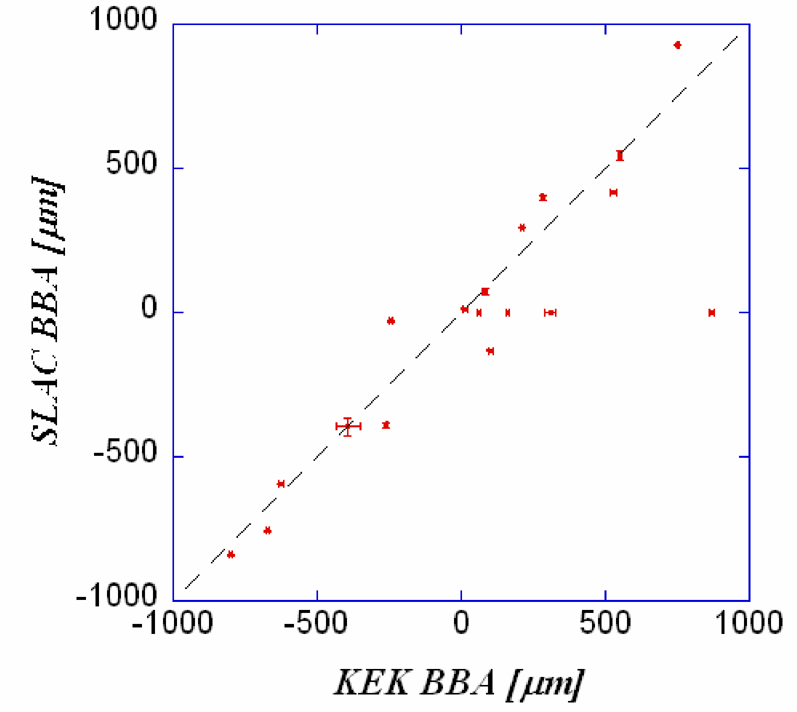
90% CL (90th among 100 seeds)



BPM offset is important. (BBA should be performed.)

BBA result in Dec. 2007 and Apr. 2008, BPM-Quad

Magnet	BPM name	SLAC measurement		KEK measurement	
		mean	error	mean	error
QM20R1	M.32				
QM23R1	M.34			-77.34	15.72
QF2R8	M.36	-1205.40	3.90	-485.08	41.34
QF2R9	M.38	-391.30	6.00	-258.40	4.42
QF2R10	M.40	927.10	0.40	752.27	4.31
QF2R11	M.42	71.80	10.60	80.95	7.07
QF2R12	M.44	-841.10	1.60	-797.40	5.36
QF2R13	M.46	398.90	7.40	280.99	3.74
QF2R14	M.48	543.20	17.90	552.17	5.30
QF2R15	M.50	-212.60	0.20	2222.80	9.74
QF2R16	M.52	-594.40	1.40	-625.47	9.29
QF2R17	M.54				
QF2R18	M.56	417.10	0.20	529.04	9.61
QF2R19	M.58			36.21	4.50
QF2R20	M.60			273.11	9.72
QM1R2	M.62			-374.84	23.65
QM4R2	M.64			65.29	81.84
QM20R2	M.81				
QM23R2	M.83			171.29	11.99
QF2R21	M.85			95.78	11.07
QF2R22	M.87			-36.64	4.89
QF2R23	M.89			61.72	36.63
QF2R24	M.91			-60.36	10.69
QF2R25	M.93	miswired		161.66	5.28
QF2R26	M.95	miswired		310.69	18.91
QF2R1	M.1	miswired		63.53	5.98
QF2R2	M.3	miswired		868.35	7.29
QF2R3	M.5	13.80	0.60	12.80	7.43
QF2R4	M.7	-130.90	2.10	101.10	7.56
QF2R5	M.9	-29.40	1.00	-243.27	4.85
QF2R6	M.11	295.40	0.50	209.35	4.93
QF2R7	M.13	-756.50	2.00	-671.94	8.01
QM1R1	M.15	-396.80	32.50	-392.71	41.14
QM4R1	M.17				



The measured results well agreed with SLAC BBA measurement in 2007 Dec.

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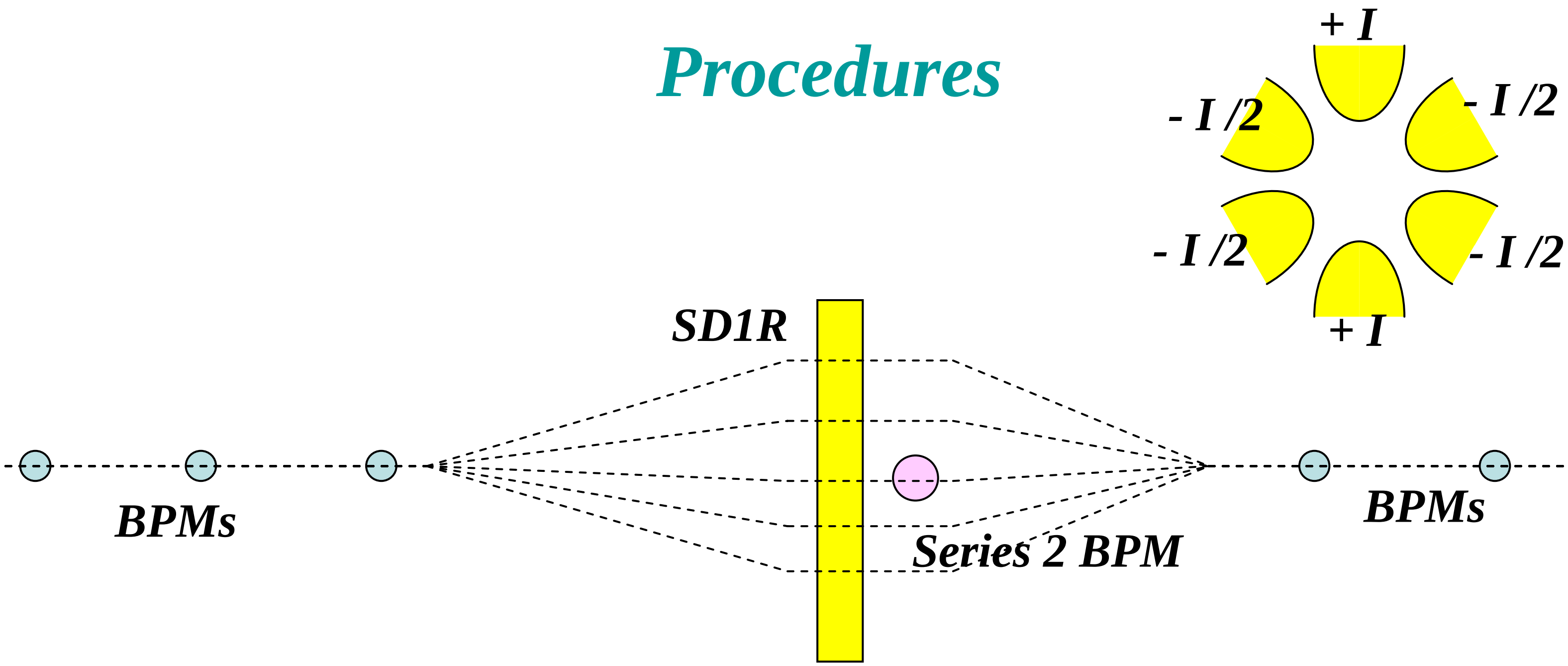
BBA in Apr. 2008, BPM-Sext (skew-Q trim)



1. *Make a vertical local bump at the BPMs.*
2. *Change the SD1R strength by +/- 8A (ΔK_1 = +/- 0.008 /m).*
3. *Measure the horizontal orbit difference for all the BPMs.*
4. *Estimate the minimum orbit difference point by parabolic fitting.*

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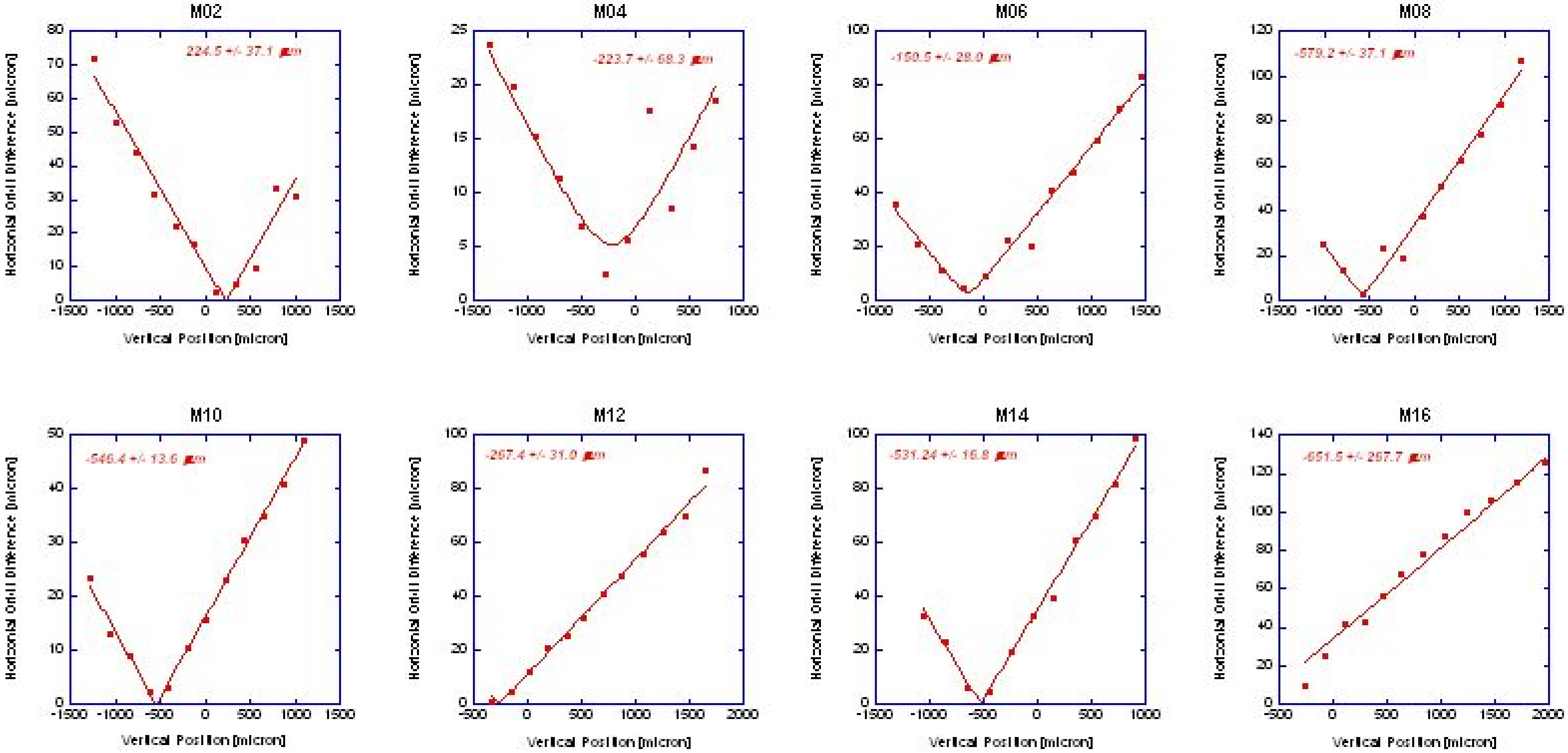
BBA result in Apr. 2008, BPM-Sext (skew-Q trim)



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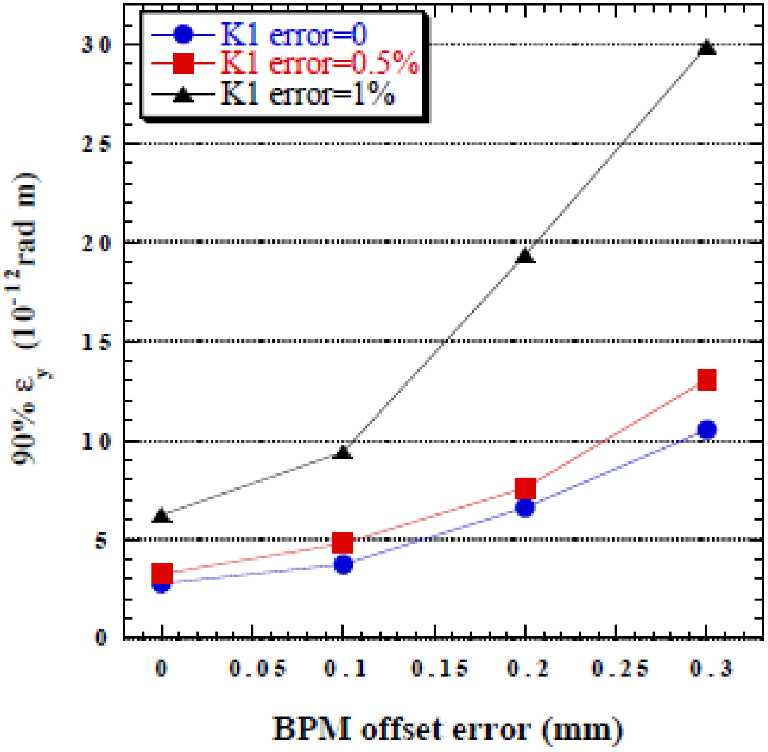
Simulation with optics model error - quad strength error, again

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



0.5% random error looks acceptable. 1% is not.

Recent study of optics model from response matrix (steering to BPM) → LOCO

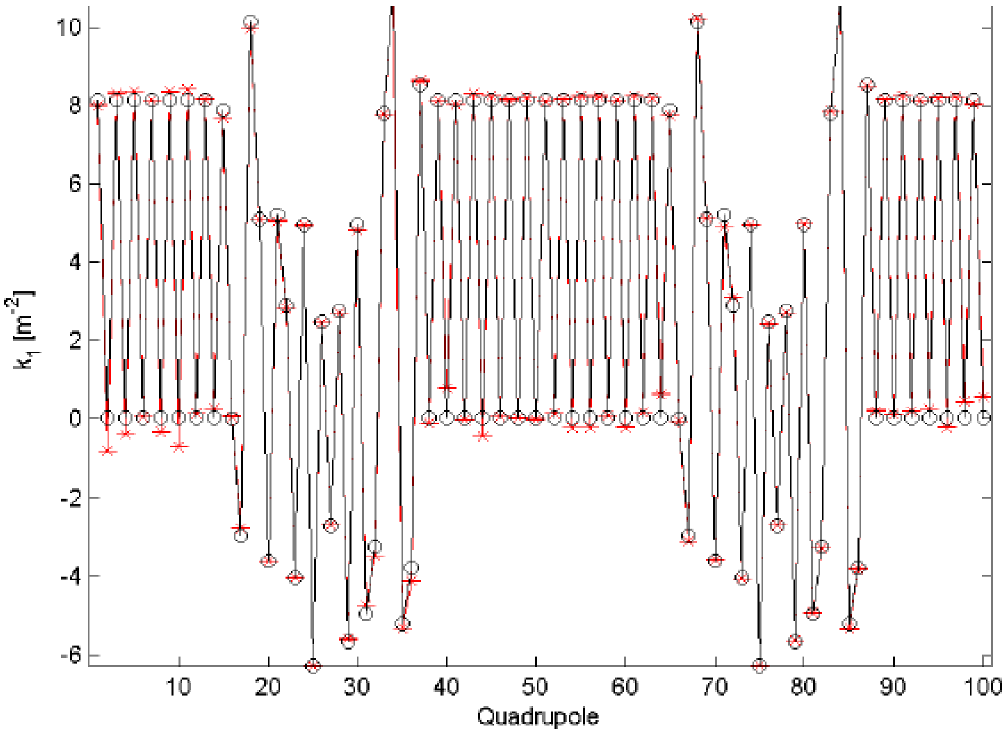
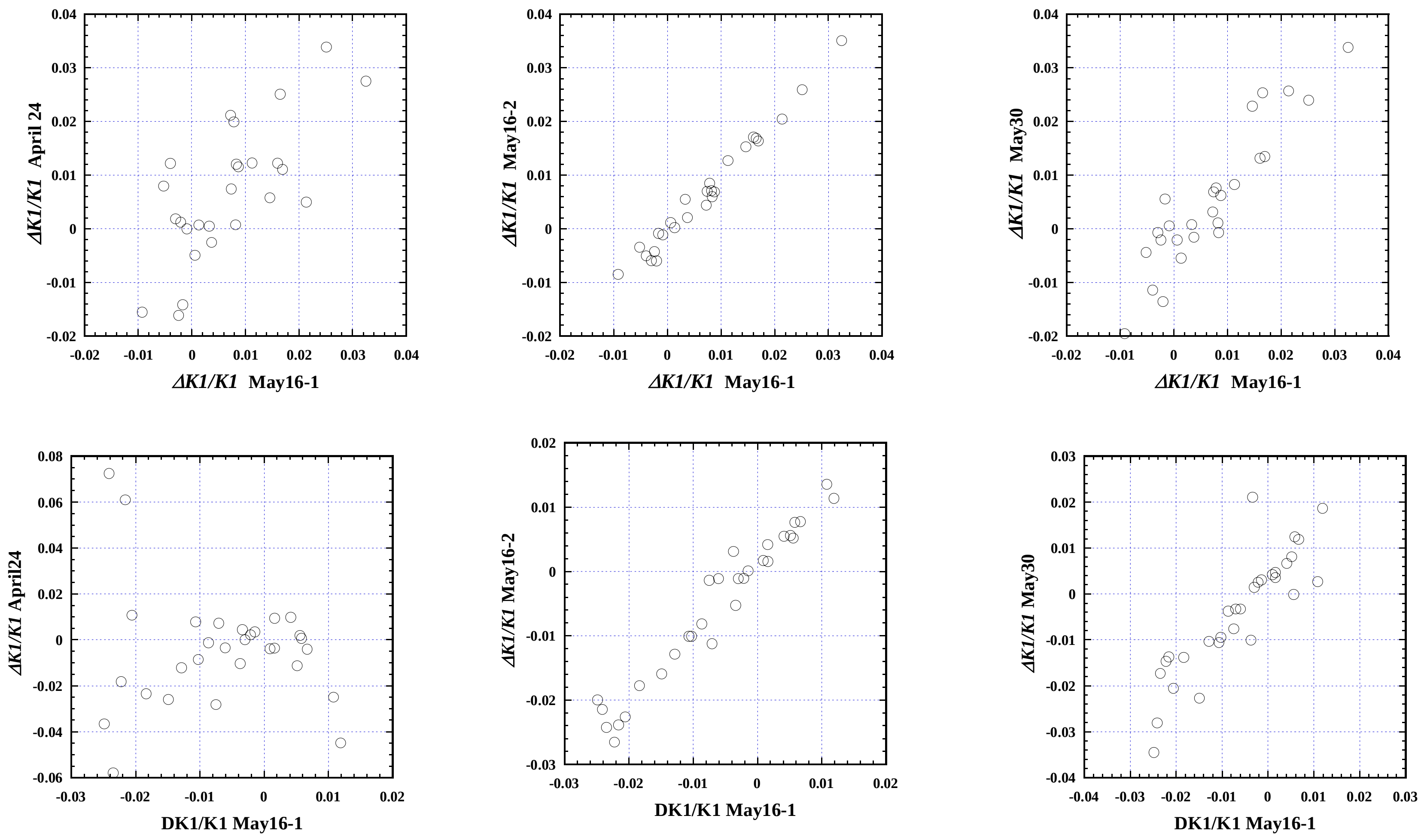


FIG. 7: Quadrupole gradients in the fitted model (red crosses), compared to those in the initial model (black circles).

Typical strength error looks more than 1%, which should be significant.
But result from April 2008 and May 2008 look different.

A. Wolski, et. al. ATF-08-07, 08

(Fitted K1 - Model K1)/(Model K1) of QF2Rs and QMs in straight section 4 measurements are Compared



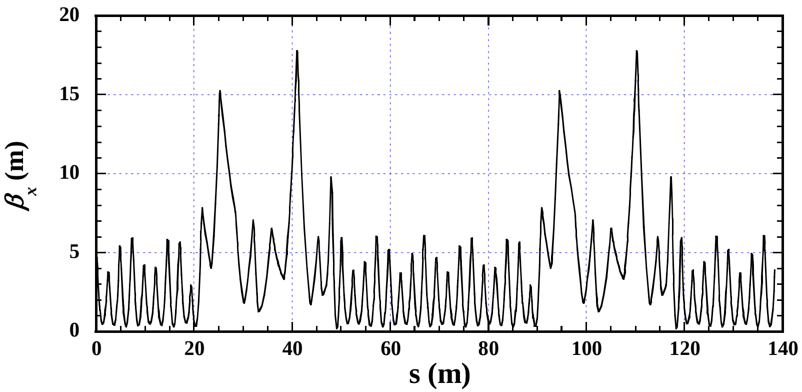
Quad strength fitting results

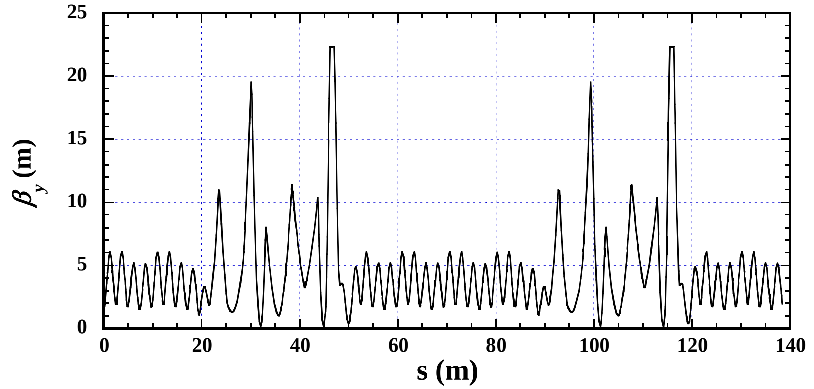
- Measurements May 16-1 and May 16-2 agree well.
- Measurements May 16 and May 30 agree, though a little worse.
- Measurement April 24 is different.
  - Reason is not clear

→ There is no definite conclusion. But it will be worth while to look more and consider setting correction.

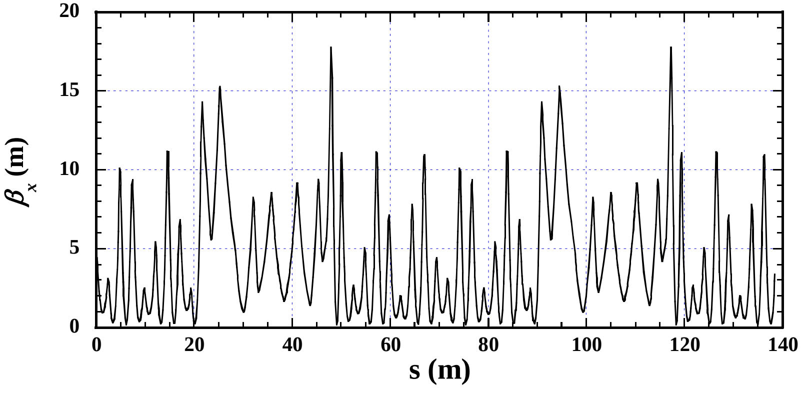
Optics mismatching ?

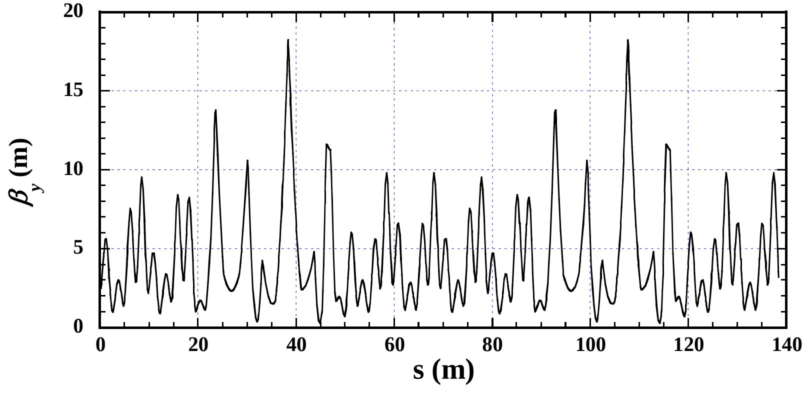
calculated from setting Dec. 10, 1999



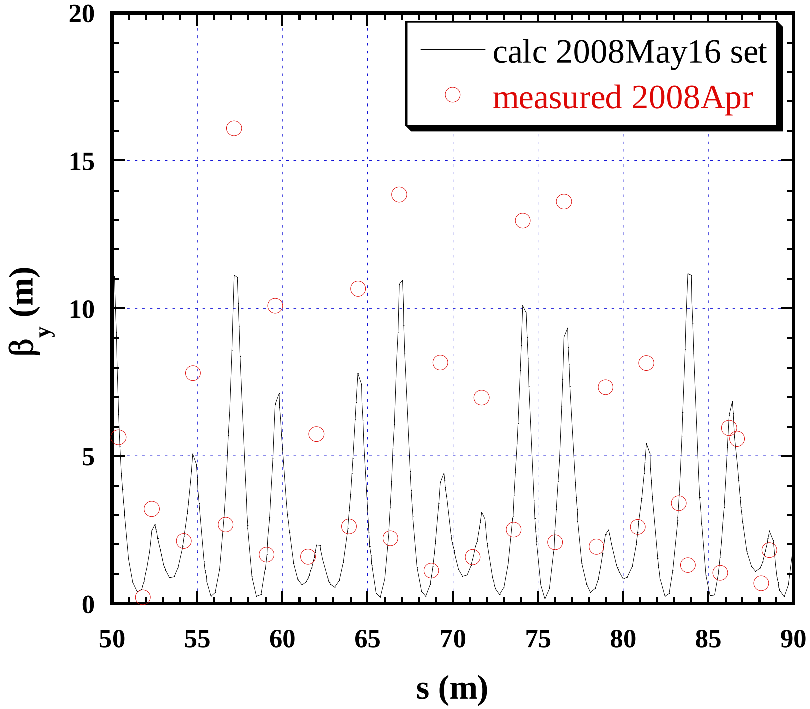


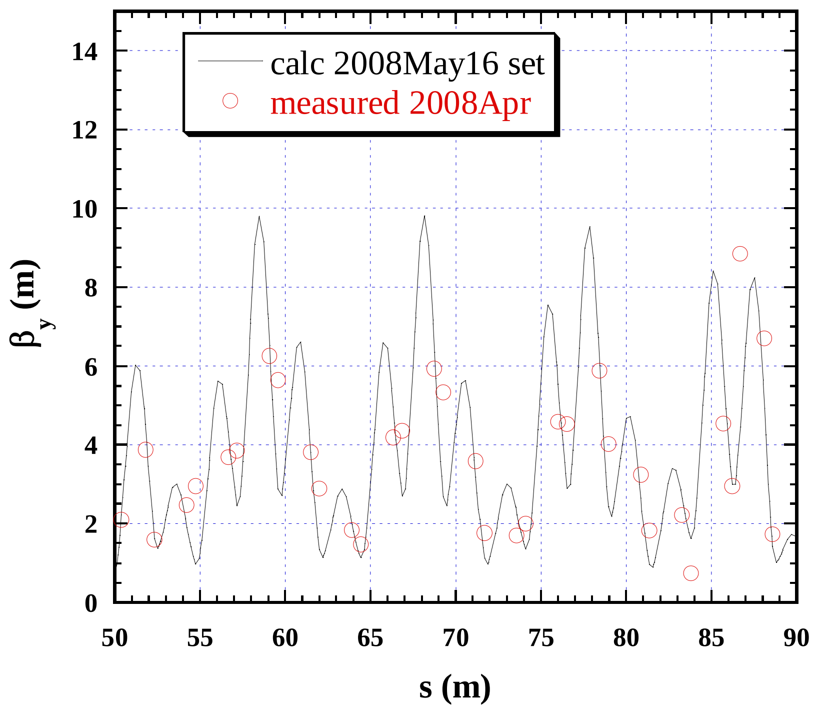
calculated from setting May 16, 2008



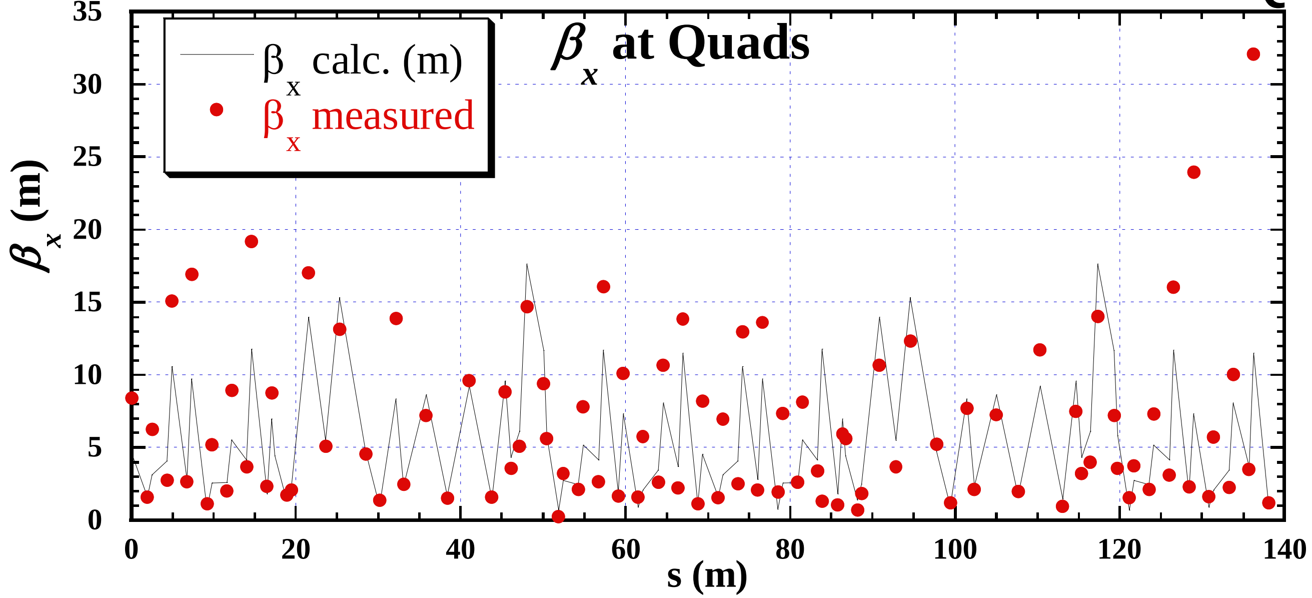


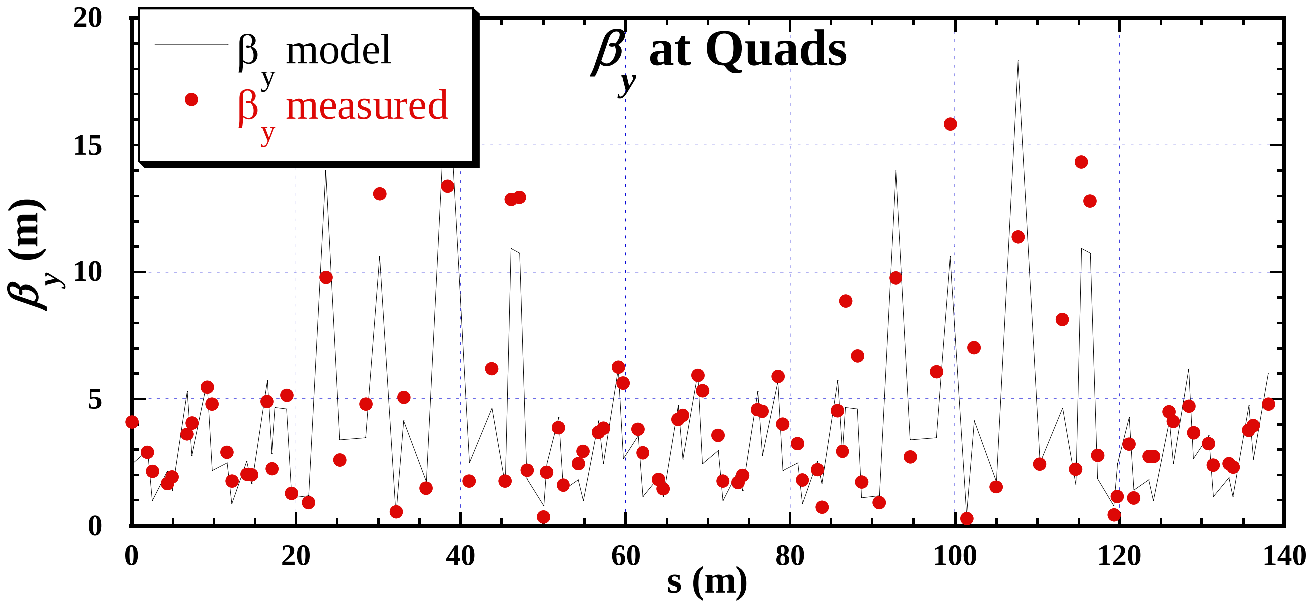
Measured and calculated Betafunction in West arc





Measured and calculated Betafunction at Quads

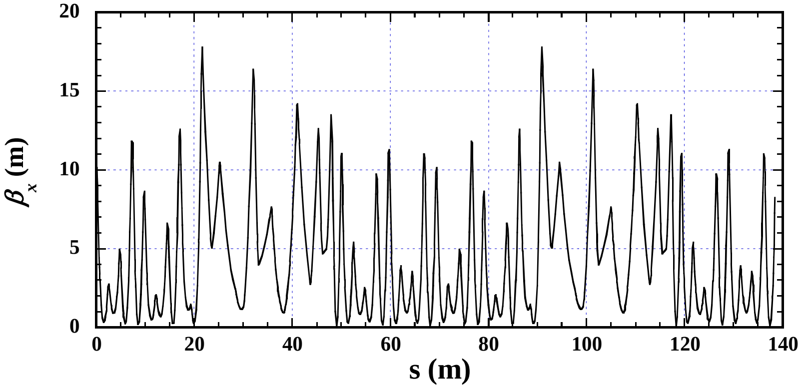


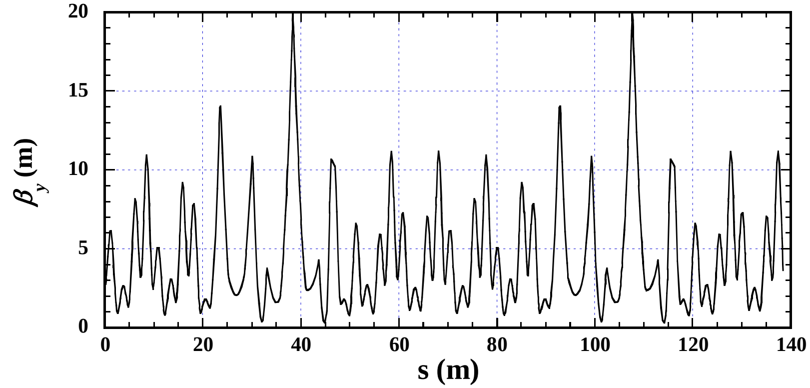


DR tuning simulation for different optics

Optics 1999 Dec, 2008 May and “bad optics” (a little change from 2008 May)

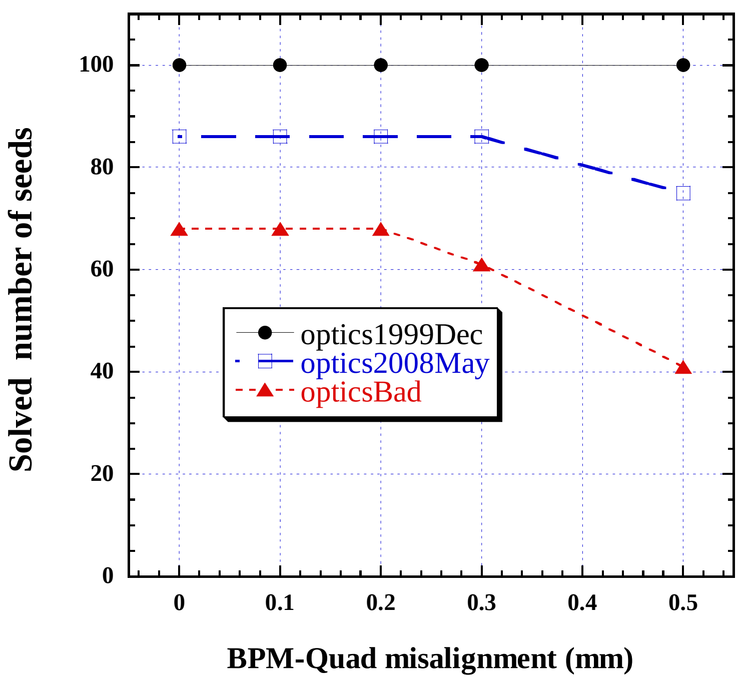
“Bad optics”

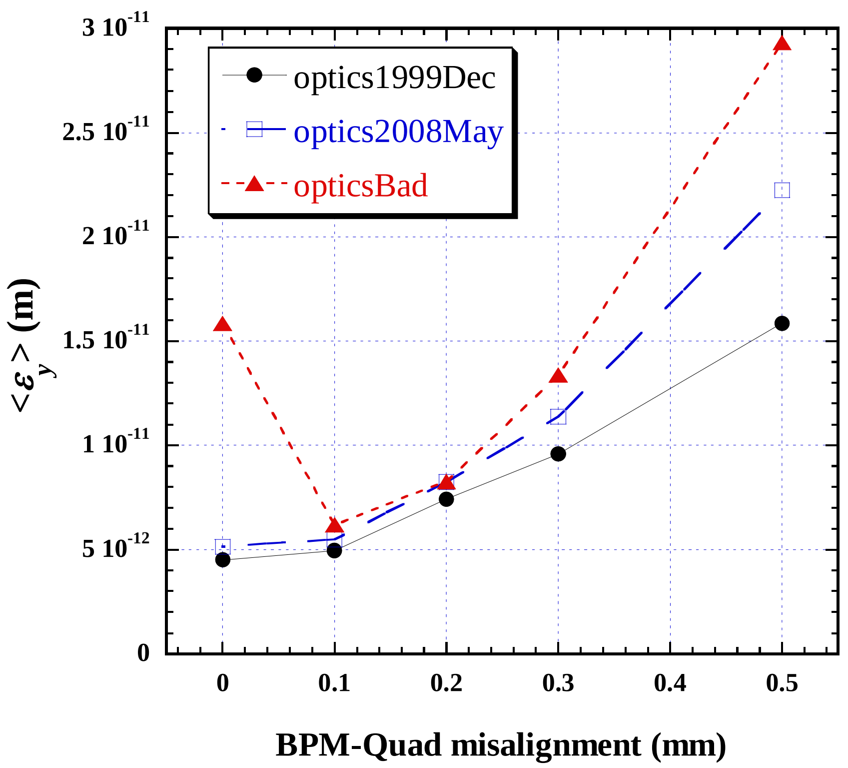




Set magnet misalignment (RMS 20 micron), BPM misalignment
Simulated COD, Dispersion and Coupling corrections

Result of tuning simulation, 3 optics
Number of random seeds giving results
Emittance vs. BPM-Magnet offset error

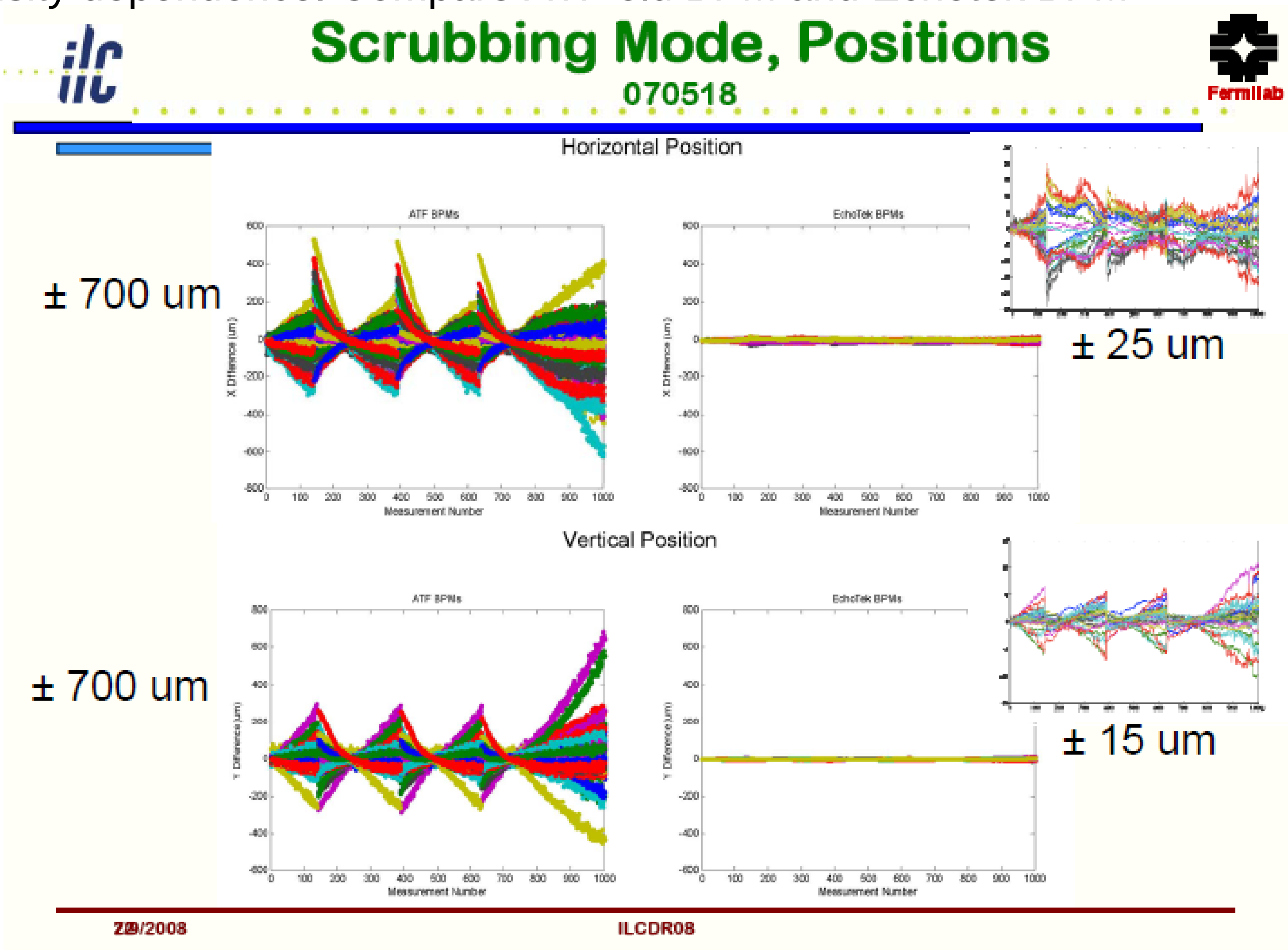




For some random seeds, SAD cannot find closed orbit, betafunctions, etc.
The left figure shows number of seeds out of 100, which give results.
The reason was not well studied and how to treat these results is not clear.

BPM performance ?

Intensity dependence. Compare ATF old BPM and Echotek BPM



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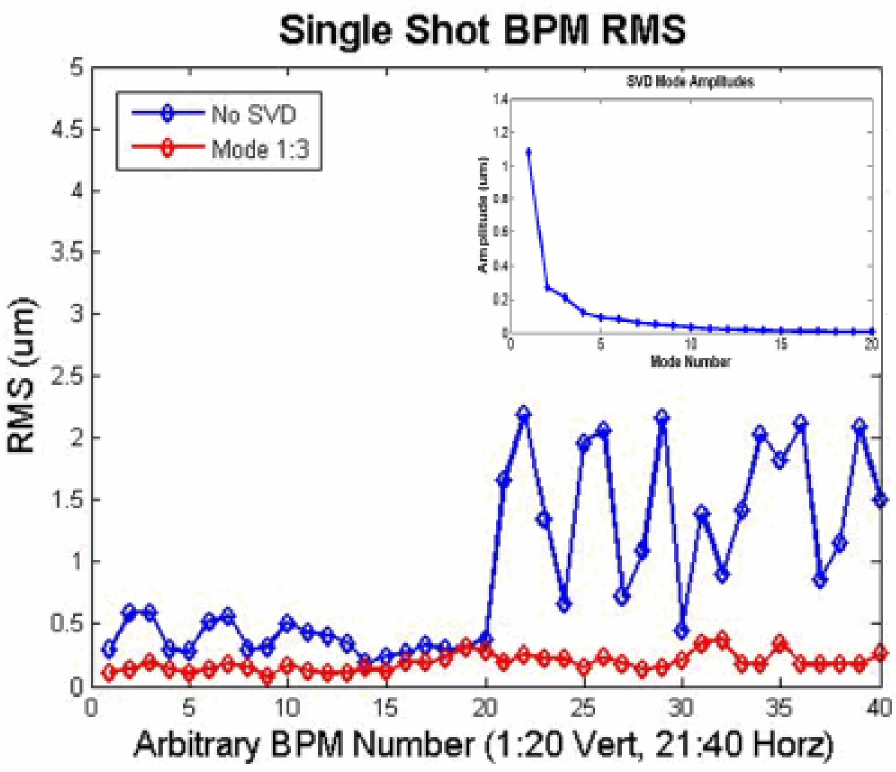
Narrowband Mode Resolution



- Triggered at turn #500,000
- ~200 ms position data per shot (1280 narrowband mode BPM measurements).
- 126 tap box car filter to reject 50 Hz:
  - ~ 800 nm resolution
- SVD analysis, removing modes with hor./ vert. correlation:
  - ~200 nm resolution

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SUMMARY: What can be done?

We should try any possibilities.