PEP-II Beta Beats Fixes with MIA

Yiton T. Yan

SLAC

Acknowledgement:

Y. Cai, J. Irwin, M. Sullivan, F. Decker, S. Ecklund, J. Seeman, J. Turner, U. Wienands, Y. Nosochkov, M. Donald, and other PEP-II members who helped take MIA data.

===

MIA assumes the right locations of Quadrupoles, Sextupoles, and BPMs and then obtain a virtual accelerator that matches the real accelerator linear optics through phase advances and Greens functions fitting that allows BPMs to have gain errors and cross coupling errors. MIA first gets 4 independent high-resolution orbits by two resonance (eigen plane 1 and 2) excitations. ...

Review of MIA process chart

More statements about MIA

Review of MIA's typical plots for understanding optics

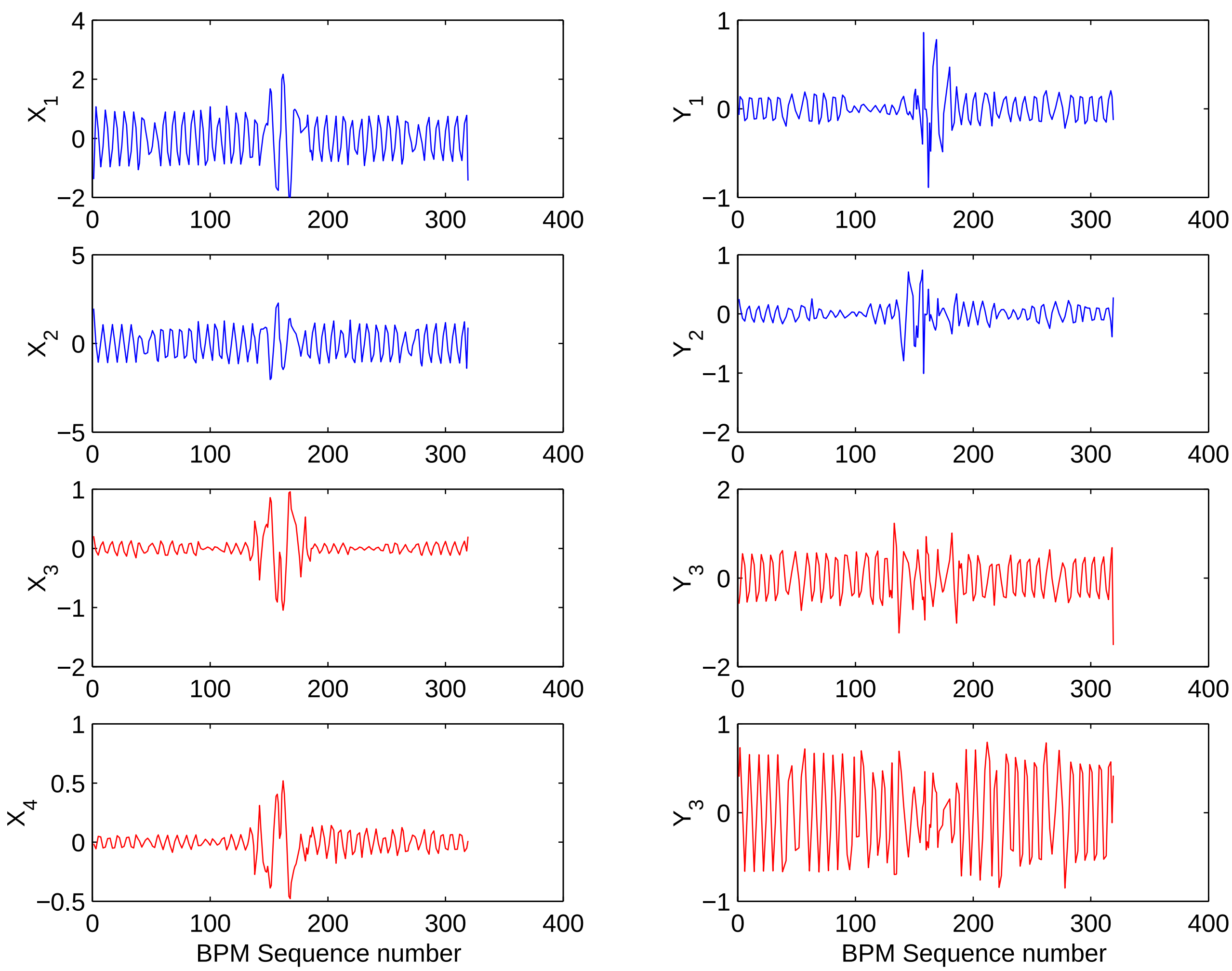
Review of completed MIA's applications to LER

Jan. 9, 2003; Jan. 30, 2003; Apr. 29, 2003; -- successful rate 2/3 = 67%.
(Uncompleted: Jan. 22, 2003 -- NOT MIA's fault)

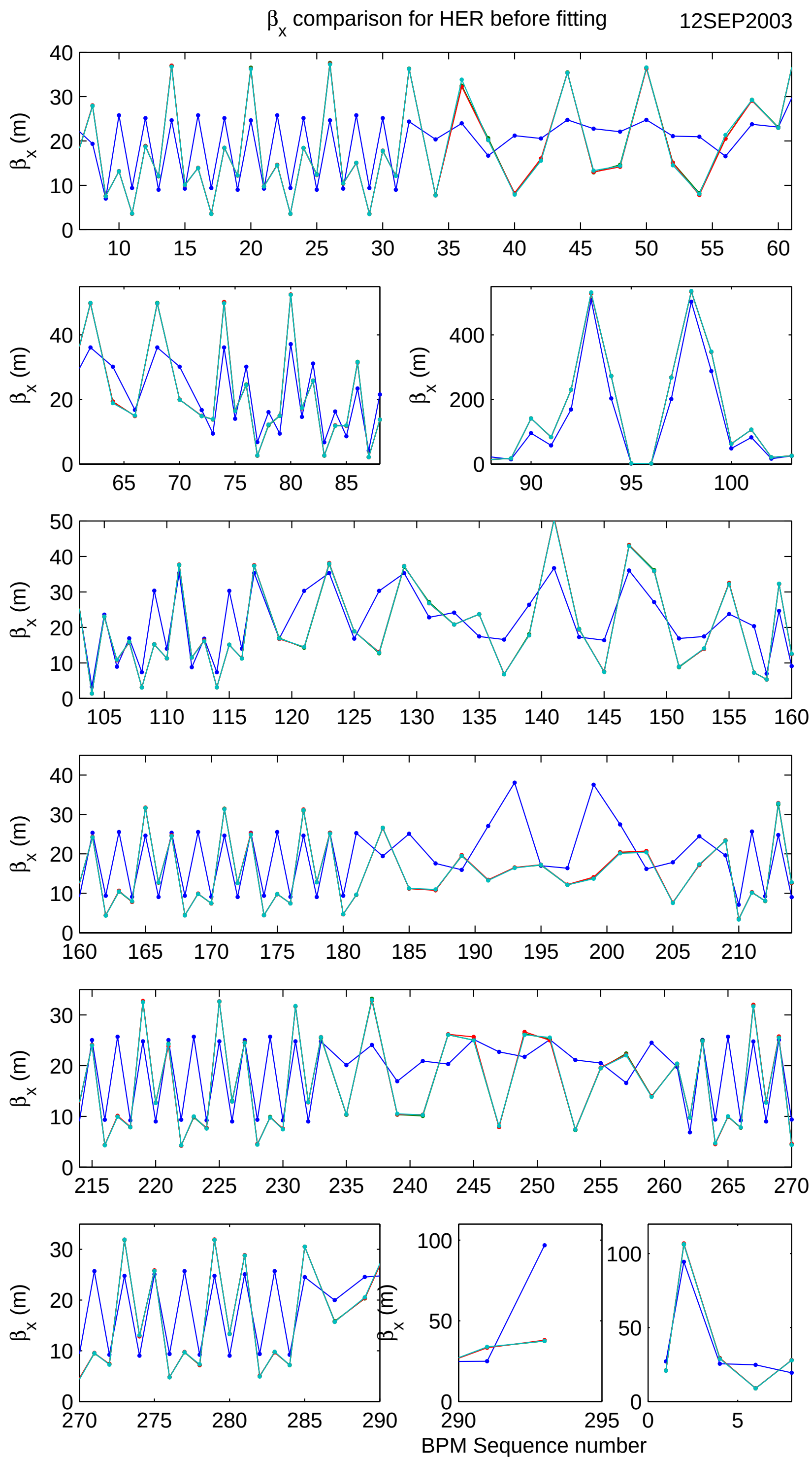
Status of MIA Application to HER for beta beats fixes

Summary

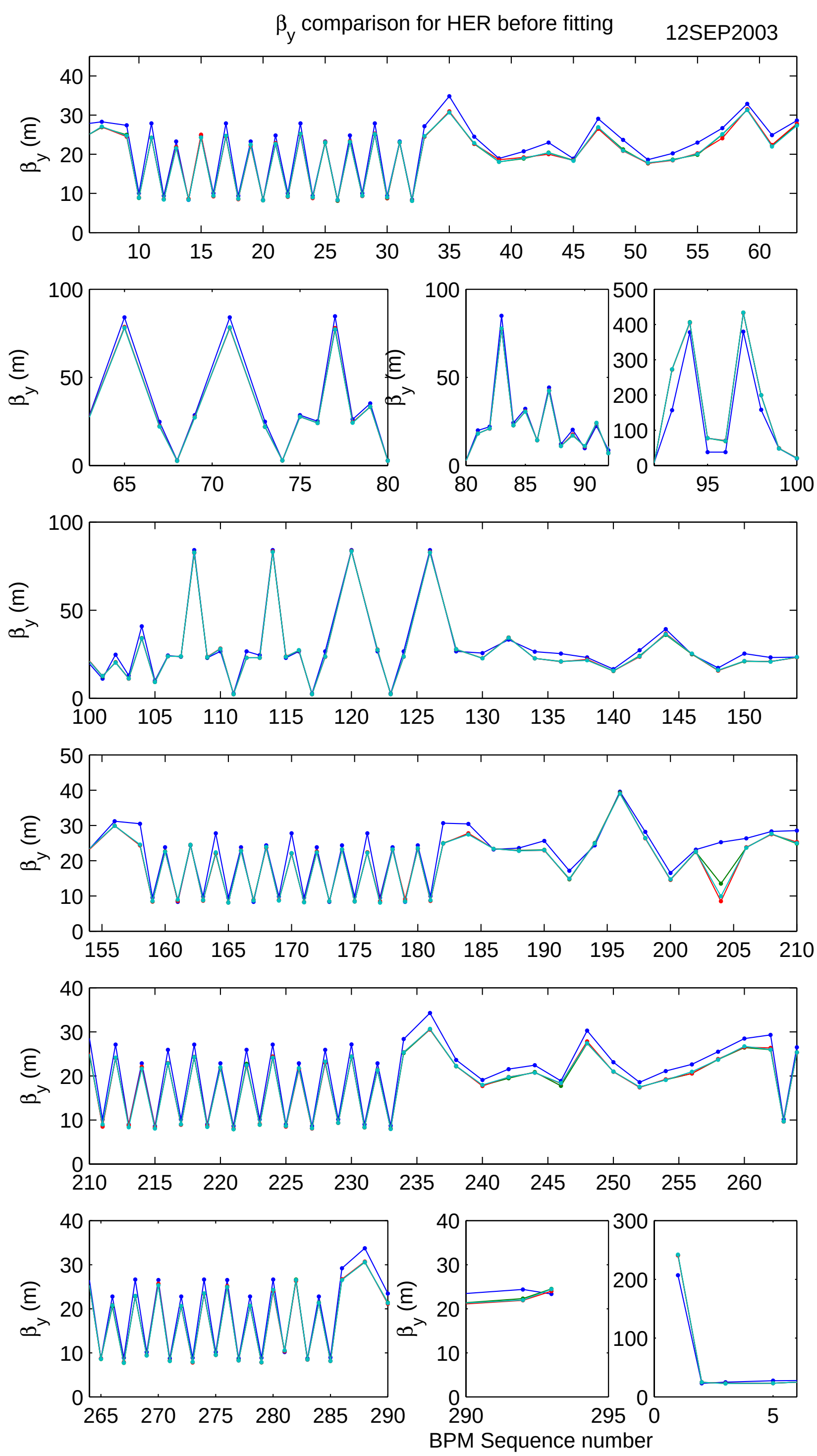
A typical high-resolution 4 orbits for LER, showing strong couplings. The top two orbits, the cosine-like orbit, (x_1, y_1), and the sine-like orbit, (x_2, y_2), are from eigen-plane-1 resonance excitation while the bottom two orbits, the cosine-like orbit, (x_3, y_3), and the sine-like orbit, (x_4, y_4), are from eigen-plane-2 resonance excitation. Assuming no BPM coulings, phase advances can readily obtained from these orbits.



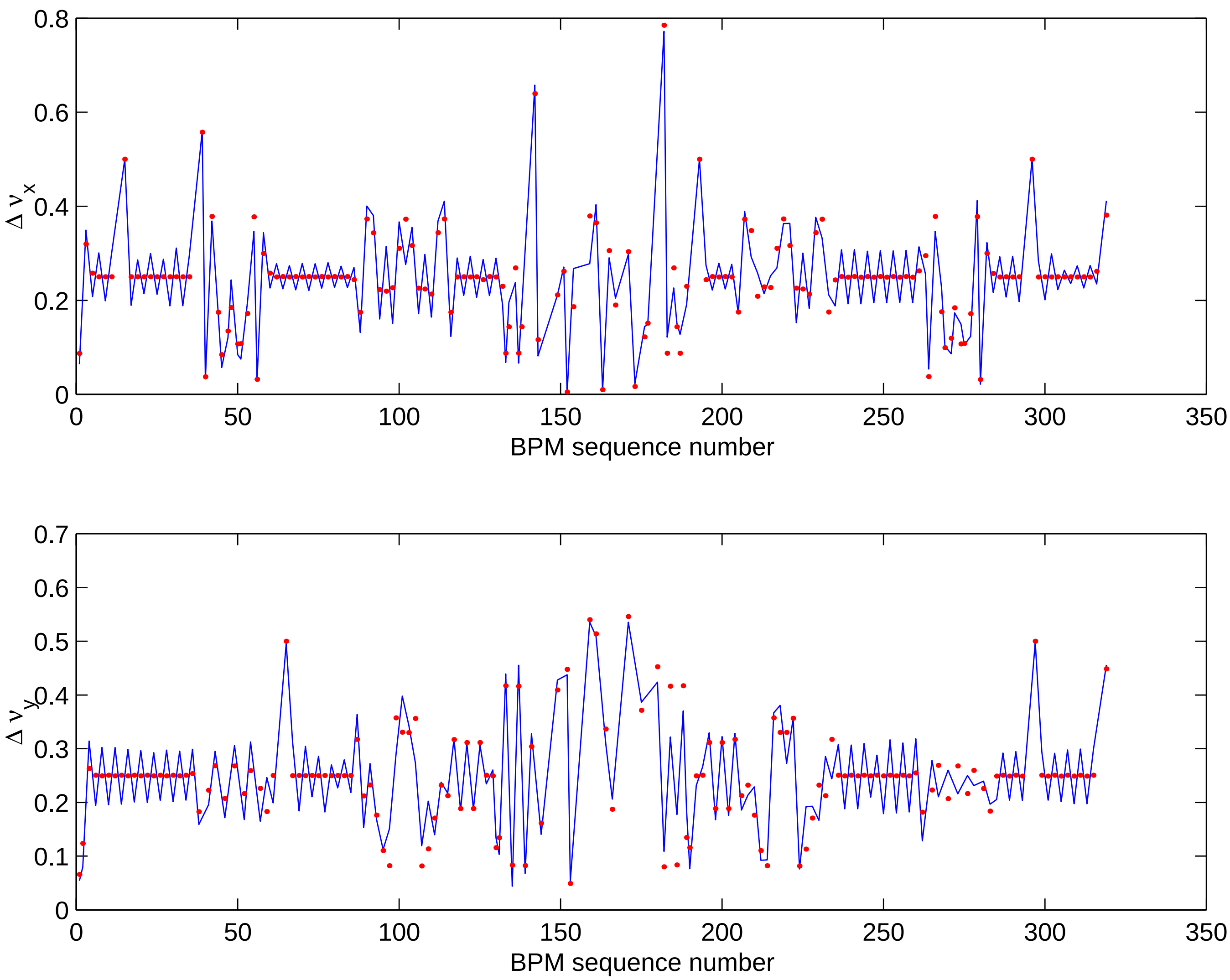
HER-12SEP2003 β_x function comparison between the ideal lattice (blue) and the BPM-error-included measurement (green). This plot can be obtained within a couple of minutes after the MIA BPM buffer data are obtained.



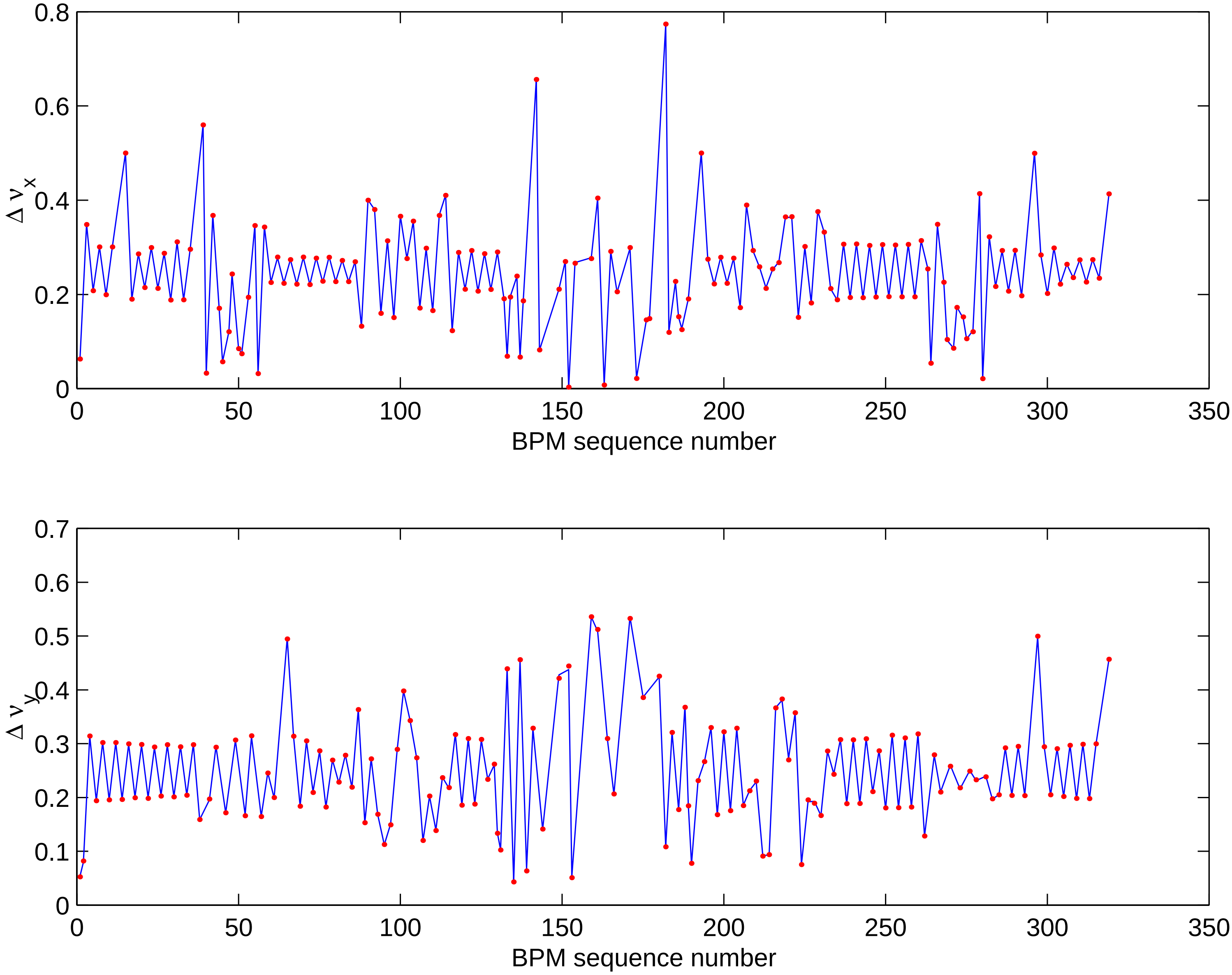
HER-12SEP2003 β_y function comparison between the ideal lattice (blue) and the BPM-error-included measurement (green). This plot can be obtained within a couple of minutes after the MIA BPM buffer data are obtained.

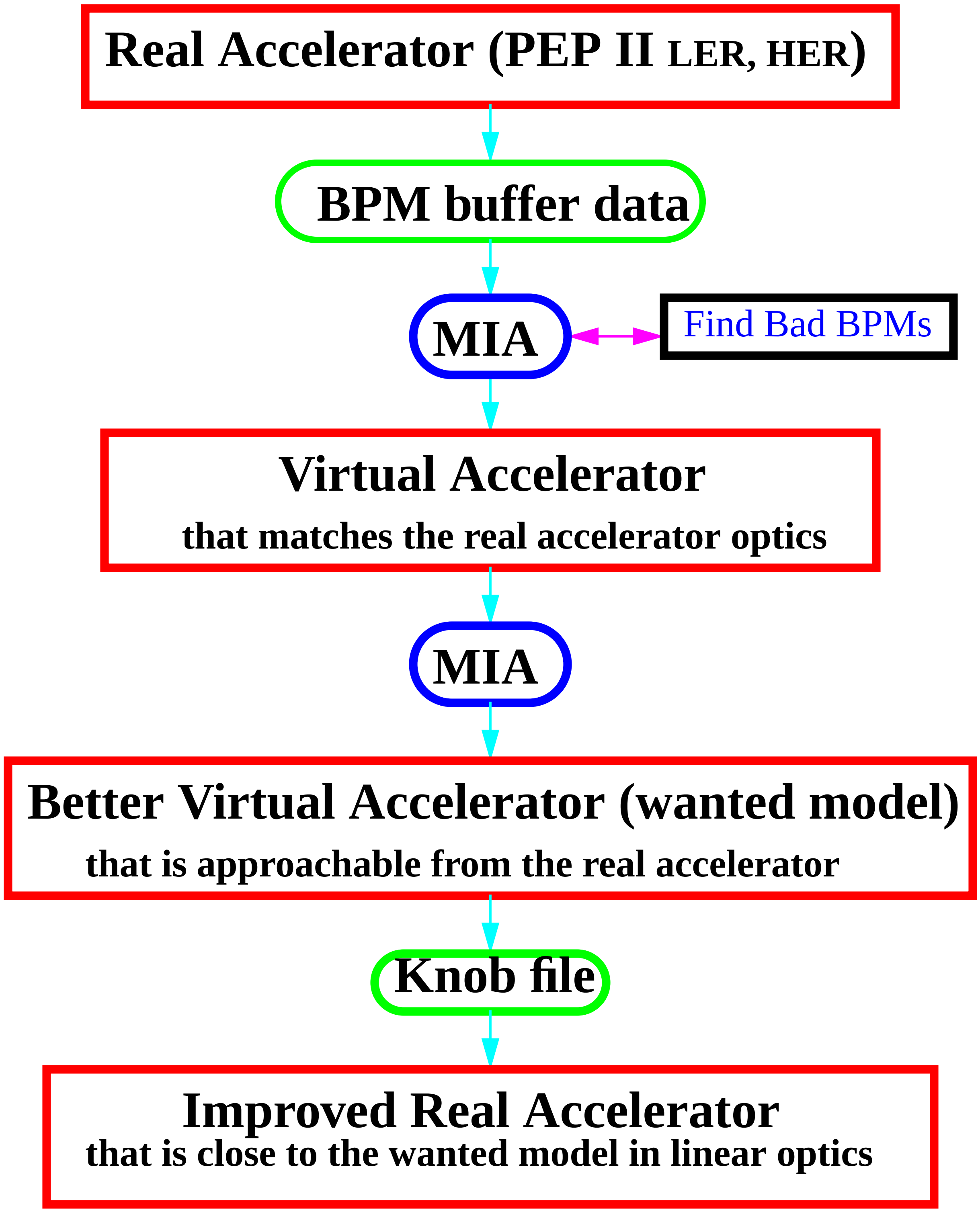


A typical Comparsion of phase advance between measurement (blue) and the ideal lattice (red) for LER without (before) fitting. Note that the phase measurement is immune from BPM gains but is not accurate if there are both linear couplings and BPM cross coulings



A typical Comparsion of phase advance between measurement (blue) and the virtual machine (red) for LER. Note that the phase measurement is accurate regardless of BPM gains, BPM cross couplings, and liear couplings.




Real Accelerator (PEP II LER, HER)
BPM buffer data
MIA
Find Bad BPMs
Virtual Accelerator
that matches the real accelerator optics
MIA
Better Virtual Accelerator (wanted model)
that is approachable from the real accelerator
Knob file
Improved Real Accelerator
that is close to the wanted model in linear optics

More statements about MIA

I. **MIA takes LEGO (MAD) generated linear maps as initial state for fitting to find the difference of the real machine from the initial state --- virtual machine.**

II. **Those magnet variables (difference from the initial state) are all treated as 2nd-order symplectic integrators. Doublets are with slices.**

III. **MIA treat linear coupling completely without any discount.**

IV. **MIA can also include tilt angles and coupling ellipses as part of the fitting. But had chosen not to do so to reserve a process for checking fitting accuracy.**

V. **MIA has a sufficient “mathematical” conditions for fitting and checks the necessary conditions for making a judgement of accurate fitting -- the tile angles and ellipse axis ratios are matched without fitting them.**

VI. **If there is solenoid errors, they are fitted with normal and skew quad variables.**

The best would be that the initial state has already got the solenoid very close to the real machine.

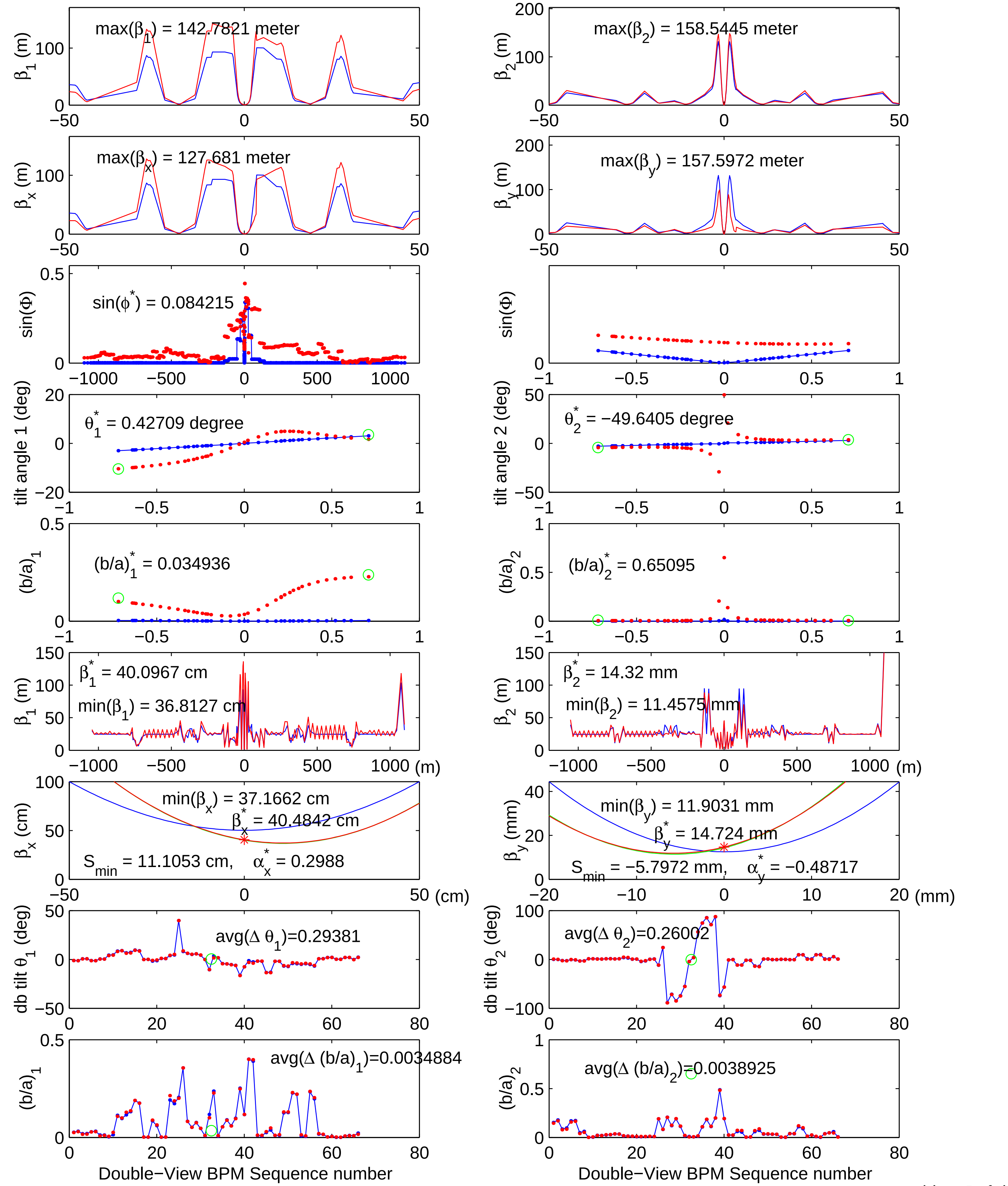
VII. **With the virtual machine as the initial state, MIA picks limited number of key magnets as variables for fitting to certain chosen constraints (description of wanted optics) to obtain an approachable wanted model. A knob file is then generated for dialing in the real machine. Generally, the real machines have responded quite well to MIA's wanted models regardless the luminosity is improved or not.**

VIII. **So far MIA has been applied to LER quite well. We are in a process of correcting HER beta beats. MIA has helped bring LER to half-integer working tune and correct the beta beats to achieve the record peak luminosity during last MAY - JUNE.**

IX. **MIA indeed has a slightly larger residual in the IR than in the arc. Is this**

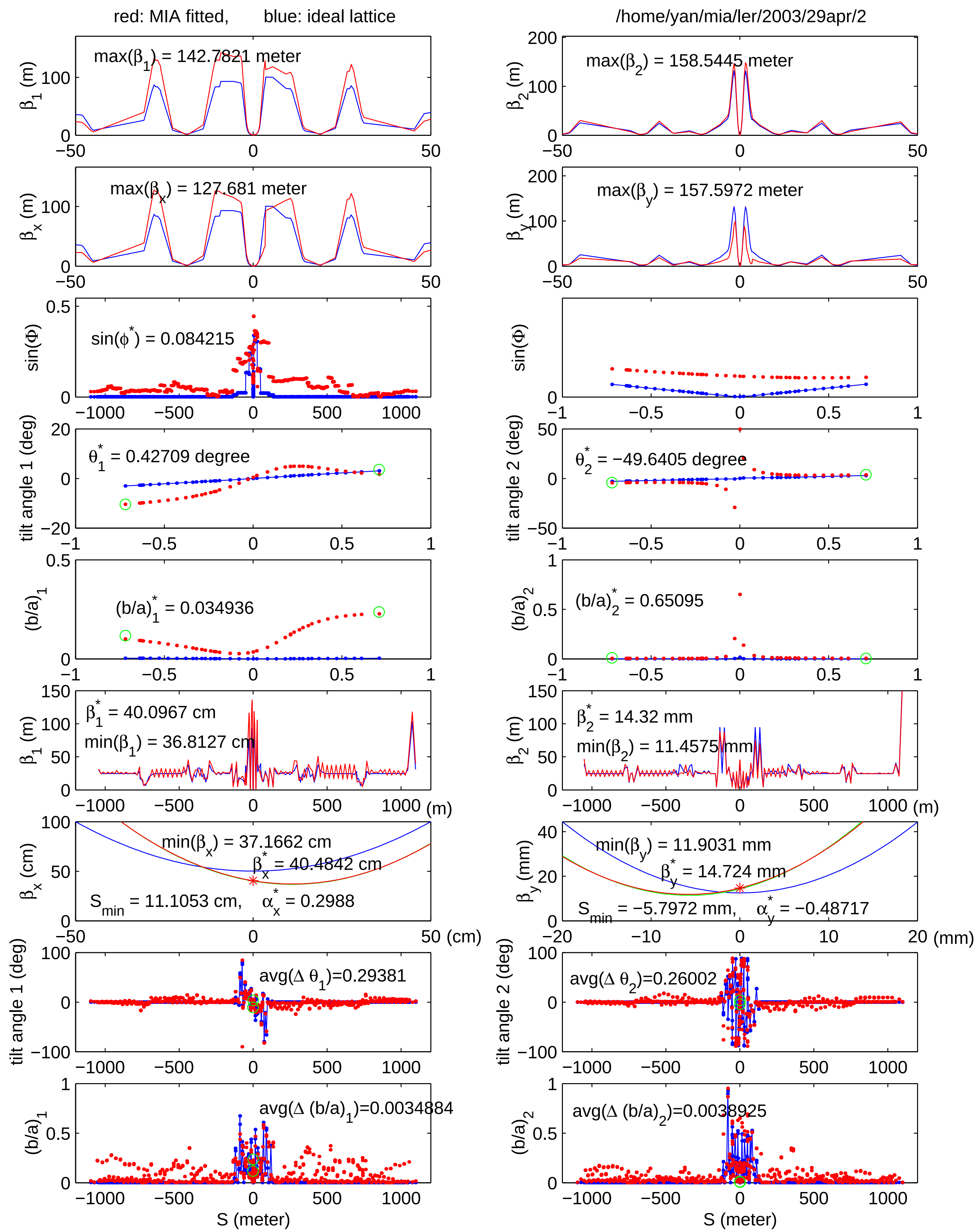
due to inaccurate solenoid modeling or due to inaccurate measurement (BPMs) or both?

red: MIA fitted, blue: ideal lattice /home/yan/mia/ler/2003/29apr/2



red: MIA fitted R(phx,phy,tunes,Rab) = 0.00053026 0.00066776 8.1141e−05 0.044606 blue: Buf da

delBx = 1 53 56 140 delBy = 1 54 115



R(phx,phy,tunes,Rab) = 0.00053026 0.00066776 8.1141e−05 0.044606

delBx = 1 53 56 140 delBy = 1 54 115

Review of completed MIA applications to LER - Jan. 9, 2003

The first time we try to dial in MIA wanted model to LER.

Data Taken by Mike Sullivan and Stan Ecklund for LER, etc. was excellent.

MIA raw data analysis package, “buf/” was proven to be practical, fast and friendly to use. Four independent orbits can be obtained and dead, bad, noisy (unstable) BPMs can be identified within a few minutes as soon data as acquisition is completed.

MIA fitting to find the virtual machine representing the LER was successful though a few surprises that delay the fitting for about 10 minutes. MIA fitting programs was proven to be practical and fast(?) given so much to be fitted simultaneously.

MIA process of finding the “wanted model” was **good** but not perfect due to we were hurry to get what we wanted - beta beating (along with linear coupling) much reduced, Beta_y* reduced and so stopped the fitting process without checking if the tunes had been fitted to the working LER.

Knob includes tune trombones, global and local skews.

Implementation of the Wanted model to LER by Jim Turner and Yunhai was excellent. They found vertical tune was down shifted significantly by 0.013 which was later found to be almost consistent with the “incomplete” wanted model.

Table 1: Comparison of tune shifts from the operation tunes

	The incomplete wanted model	Actual implementation
Horizontal tune shift	+0.002	+0.0013
Vertical tune shift	-0.015	-0.013

Mike Sullivan said: **LER beam immediately became the strong beam, the luminosity was increased by 15%.**

Review of completed MIA applications to LER - Jan. 30, 2003

On Jan. 22 we tried to fix LER for fringe field (of QD and QF) compensation, which should have been an easy and successful one. But due to surprising miscommunication of mixing two different machine BPM buffer data, we did not accomplish it. However it is absolutely

NOT MIA’s fault.

We were still optimistic with MIA

On Jan. 30, 2003, we were still with full confidence. We tried to use a whole bunch of magnets to get a very nice wanted model -- beta beating, linear coupling were fixed beautifully, beta*s were adjusted to what we wanted. After dialed in and get the BPM buffer data, we were so excited that the beta beating was indeed fixed perfectly and the machine indeed responded to the difference of the wanted model and the virtual model. But after one-day struggling, we were unable to improve the luminosity. What’s wrong? still a puzzle.

Then,

MIA was idle for a few months till late April.

Review of completed MIA applications to LER - APR. 29, 2003

On April 29, after 3 month idle, we tried MIA again, hoping to bring the LER working point to near half integer while fix the beat beating. It was found that use of only the trombones (including the tune trombone and global skews) can easily achieve this task. I gave a few optimistic e-mails out before we tried to dial in the knob. We got what we wanted -- the LER X working tune was brought to near half integer and the beat beating was fixed.

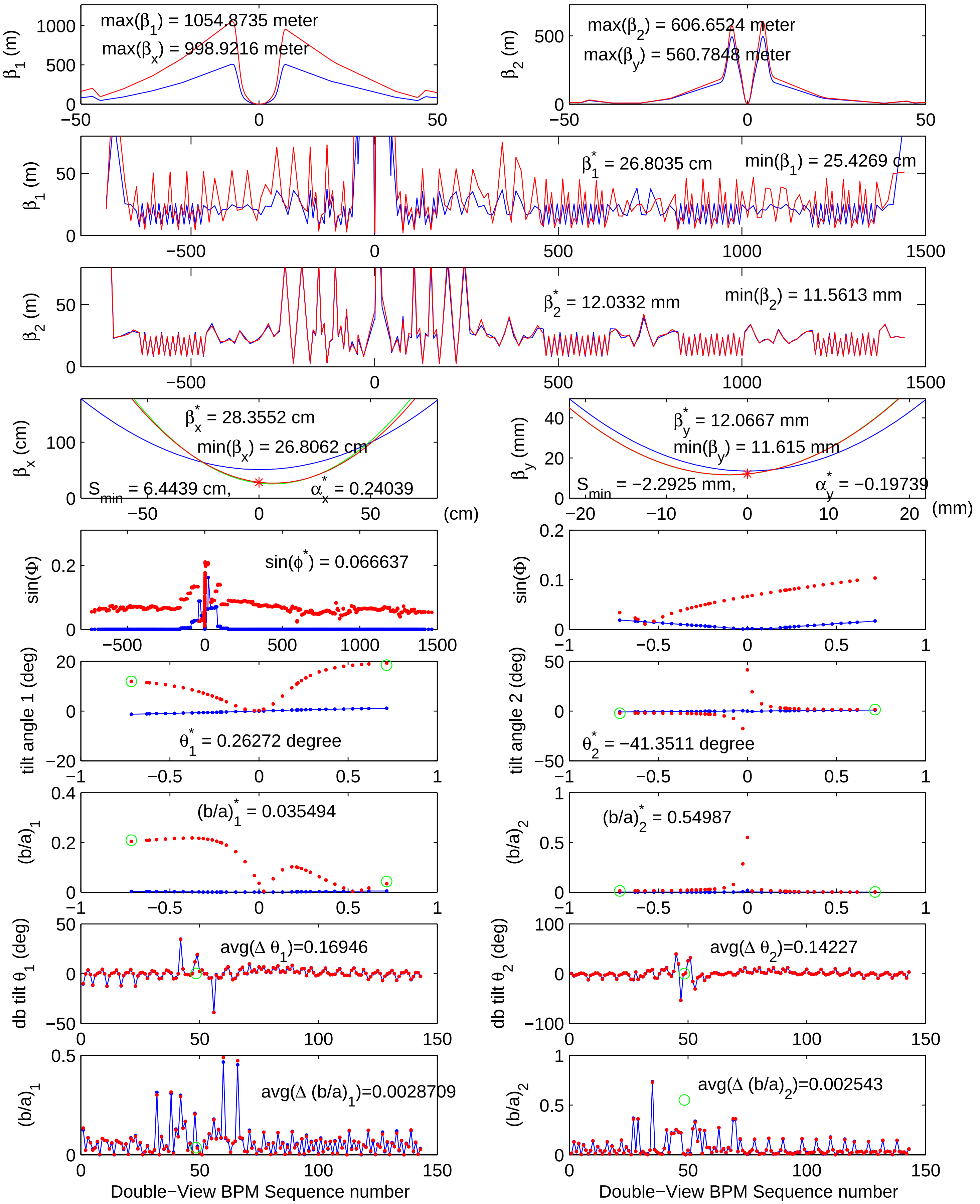
The LER then became too strong for the HER. Breaking luminosity above 6.0e33/cm**2/s was achieved after LER Beta_X* is increased while HER beta_x* was dramatically reduced to balance and match LER and HER beams (verified by MIA at a later time).

Then **we have a very strong HER beta beating to fix**.

MIA has a “net” successful rate (dial in MIA knobs) of 2 out 3 which is 66.6666...%

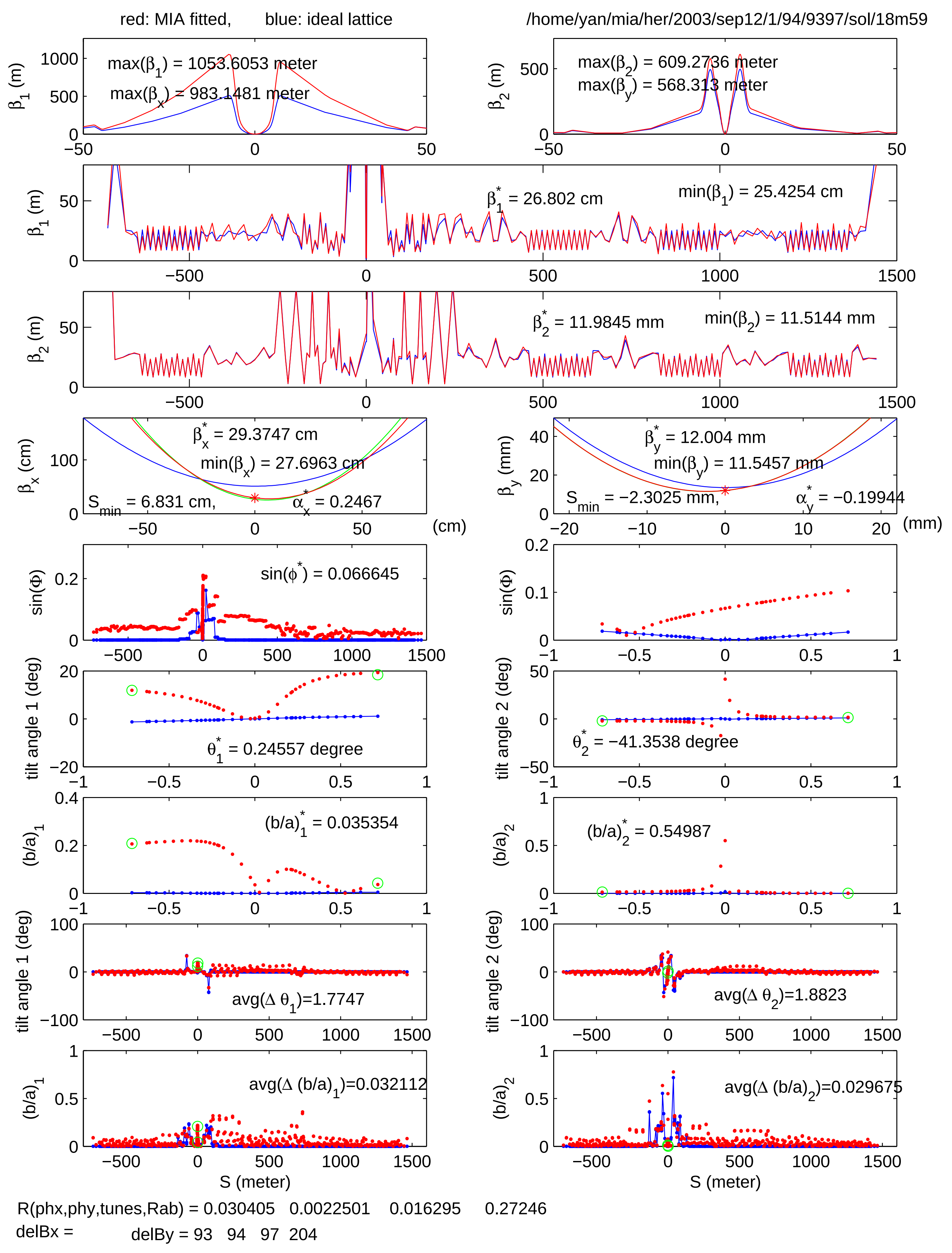
The next page shows the current HER optics. One can see a strong beta_x beat over 100%. One can also see a very small Beta_x* at about 27 cm. The beta-beats can be easily fixed by the tune trombones and global skews but the beta_x* will be retored to about 50 cm. This is not what we want. We want the beta_x* be kept small while the large beta-beats are corrected.

red: MIA fitted, blue: ideal lattice /home/yan/mia/her/2003/sep12/1/94/9397



R(phx,phy,tunes,Rab) = 0.00028956 0.00060294 1.2611e−05 0.047256

delBx = delBy = 93 94 97 204



red: MIA fitted, blue: ideal lattice
/home/yan/mia/her/2003/sep12/1/94/9397/sol/18m59
max(β1) = 1053.6053 meter
max(βx) = 983.1481 meter
max(β2) = 609.2736 meter
max(βy) = 568.313 meter
β1* = 26.802 cm
min(β1) = 25.4254 cm
β2* = 11.9845 mm
min(β2) = 11.5144 mm
βx* = 29.3747 cm
min(βx) = 27.6963 cm
Smin = 6.831 cm,
αx* = 0.2467
βy* = 12.004 mm
min(βy) = 11.5457 mm
Smin = −2.3025 mm,
αy* = −0.19944
sin(φ*) = 0.066645
θ1* = 0.24557 degree
θ2* = −41.3538 degree
(b/a)1* = 0.035354
(b/a)2* = 0.54987
avg(Δ θ1)=1.7747
avg(Δ θ2)=1.8823
avg(Δ (b/a)1)=0.032112
avg(Δ (b/a)2)=0.029675
S (meter)
R(phx,phy,tunes,Rab) = 0.030405 0.0022501 0.016295 0.27246
delBx =
delBy = 93 94 97 204

Table 1: Wanted model knob for HER 12SEP2003 config.

Mag names	Low range	High range	Current	Step1 knob	Step2 knob
QF7L	3.5920	67.3800	60.2800	-5.2971	0.6405
QD6L	-89.3300	-5.1800	-81.8300	2.8461	-1.3779
QF5L	7.5470	129.8000	94.2700	0.6256	-0.0054
QD4L	-143.5000	-8.6370	-119.1000	-0.2867	0.0395
QD4R	-149.9000	-8.6480	-119.1000	-0.2357	-0.0531
QF5R	7.5520	129.8000	94.4500	0.5233	0.1884
QD6R	-89.3300	-5.1820	-79.9700	2.0069	-1.4254
QF7R	3.5890	67.3300	57.1600	-3.0237	-0.1482
QFP9R04	7.9970	129.7000	50.5200	-0.0785	0.1323
QDP8R04	-89.3400	-5.1840	-39.4800	-0.1230	0.3026
QFP7R04	7.9720	129.2000	45.6700	-0.0671	-0.0148
QDP6R04	-129.6000	-4.0000	-46.9700	-0.1061	0.3192
QFP	6.3890	101.1000	41.3100	0.1174	-0.7294
QDP	-101.3000	-5.1920	-40.0100	-0.3731	0.6533
QFP9R06	7.9970	129.2000	50.6000	-0.1466	-0.0781
QDP8R06	-89.4200	-5.1810	-39.1300	-0.0699	0.1420
QFP7R06	7.9710	128.4000	45.5800	-0.0476	0.1484
QDP6R06	-129.7000	-3.9990	-46.4200	0.0204	0.1586
SQ4L	-0.6360	0.6360	-0.3600	0.0620	0.1493
SQ3L	-0.6360	0.6360	0.1600	0.0584	-0.0446
SQ2L	-4.0000	4.0000	-0.2300	-0.3117	0.0104
SQ1L	-4.0000	4.0000	0.3800	-0.0920	0.0676
SQ1R	-4.0000	4.0000	0.9200	0.2770	-0.0196
SQ2R	-4.0000	4.0000	-1.2340	0.1665	-0.1307
SQ3R	-0.6400	0.6400	-0.4900	0.4706	0.0939
SQ4R	-1.0600	1.0600	0.3716	0.0922	0.2090
SQG2	-7.0000	7.0000	0.6568	+0.2631	+0.1726
SQG1	-7.0000	7.0000	-0.2151	-0.0542	-0.4832
SQG4	-7.0000	7.0000	-5.3950	+0.9587	+0.1090
SQG3	-7.0000	7.0000	1.2390	+0.5508	+0.1642

As an example to see how accurate of MIA's virtual machine is:

the following table confirms that PEP-II HER global skews have a wrong parity as Yunhai has kept warning.

Table 2: Comparing MIA fitted global skews with the config for HER

Global Skew	MIA (KG)	Config (KG) *
SQG1	+1.0752	-1.0795
SQG2	-0.2898	+0.46833
SQG3	-1.8872	+1.7705
SQG4	+5.3773	-5.3847

*** global skew config value from Uli.**

Summary

MIA has been used frequently to learn PEP-II real machines' (LER and HER)'s optics ---
IP betas, linear couplings, beta beats, etc.

MIA has helped PEP-II improve its LER optics, bringing LER working tune to near half integer while fixing its beta beat and reducing its couplings.

MIA is on its way of trying the possibility of improving HER optics. The last try had shown that the HER responded positively to MIA wanted-model knob.