Optics Tuning in 2024a

Hiroshi Sugimoto
Beam optics group

The 27th KEKB Accelerator Review Committee 25th~27th March 2024

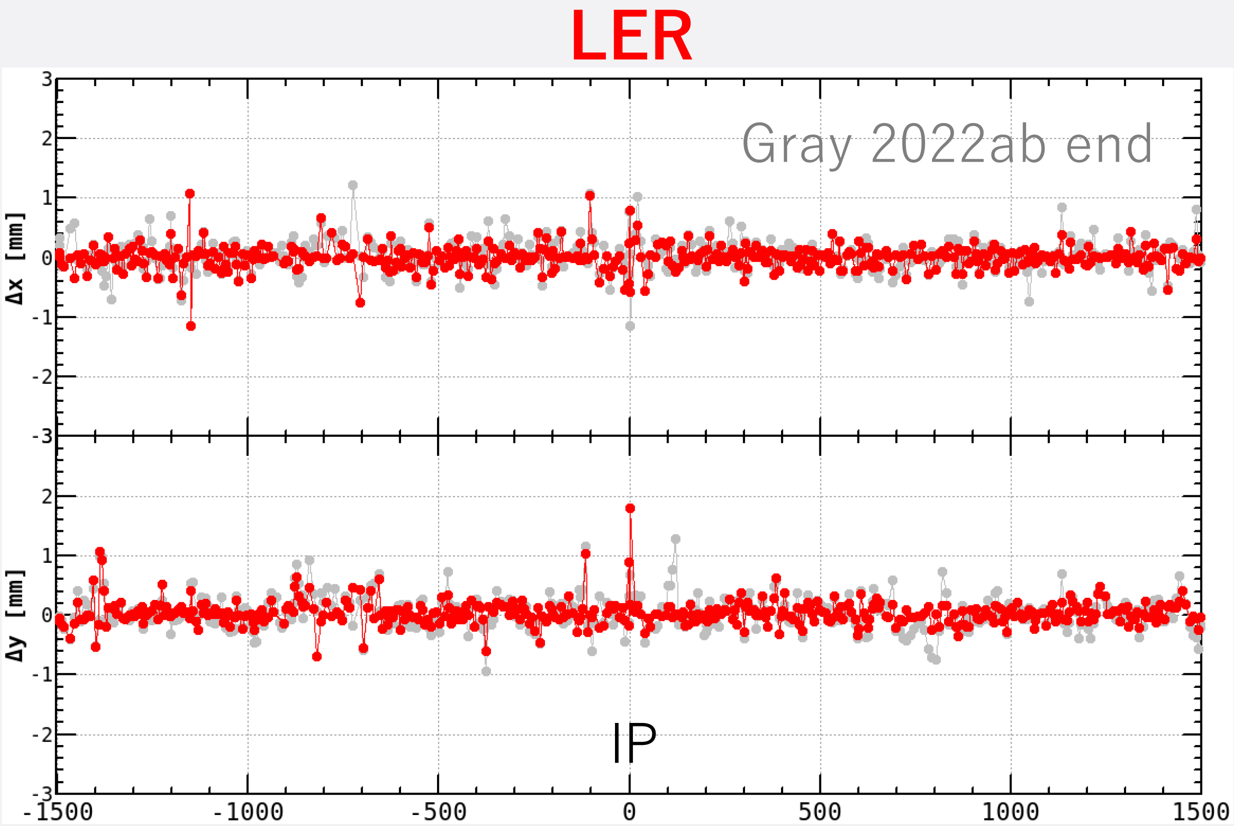
Contents

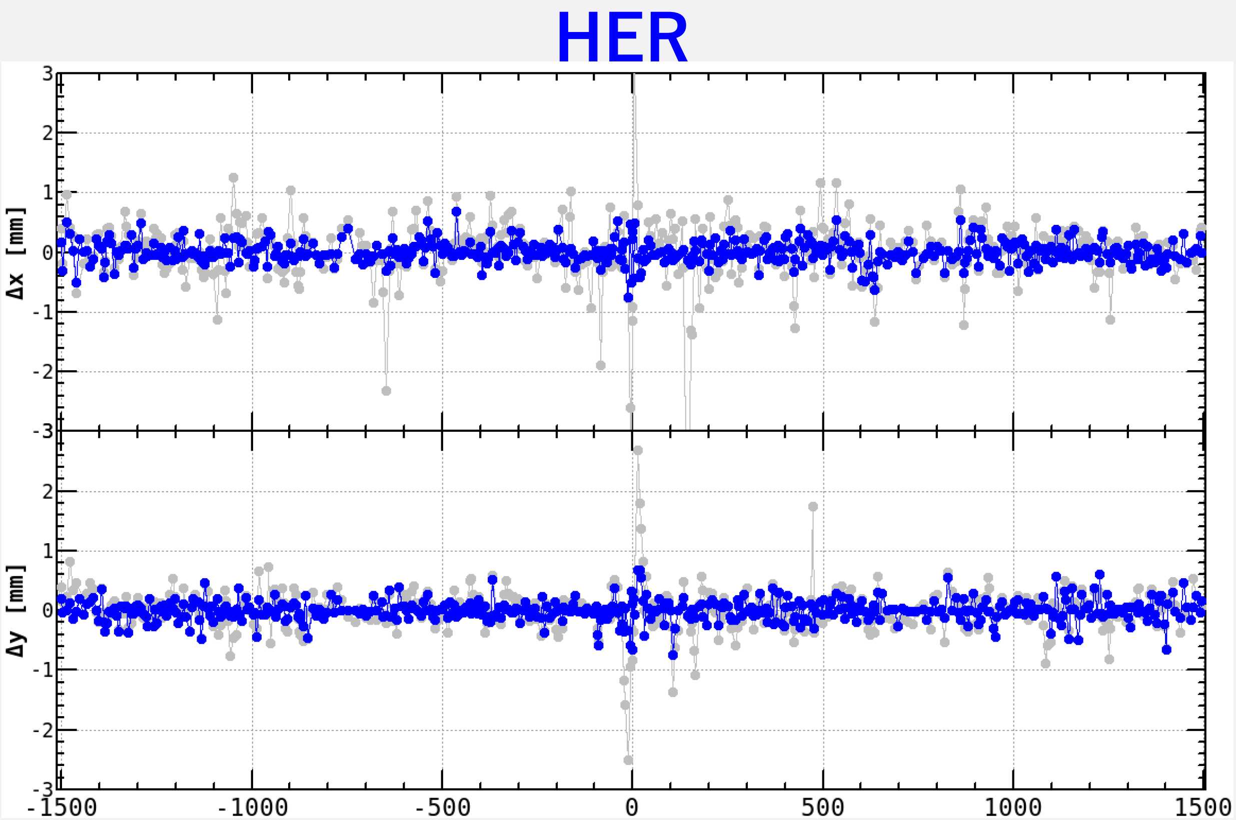
- Several Topics in 2024a Run
- Optics Tuning for Nonlinear Collimator (D05V1) in LER
- Estimation of Betaron-Detuning in HER - Very Preliminary -

Several Topics in 2024a Run

Closed Orbit Cleaning

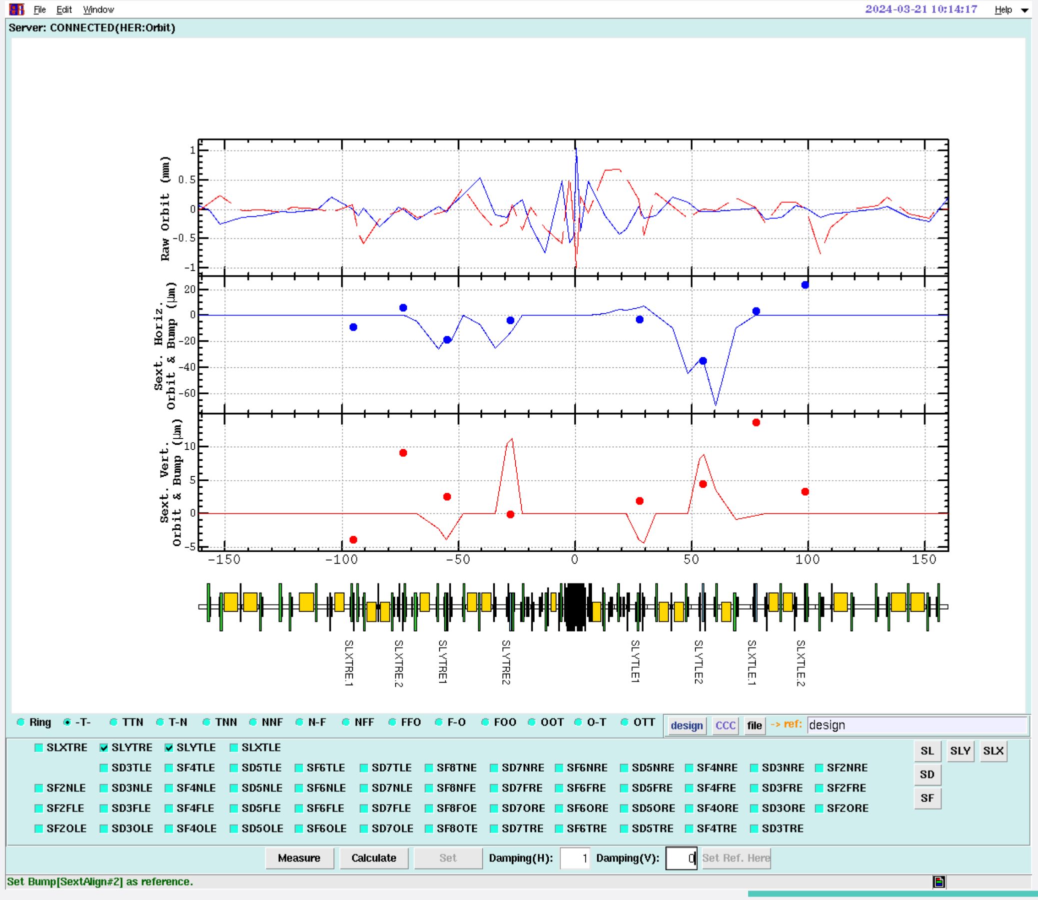
- We spend more time in orbit tuning to establish smooth gold orbit.
- Beam orbit is smoother than that of before LS1, especially in HER.
- Proper management of the orbit reduces the # of iterations in the optics correction.



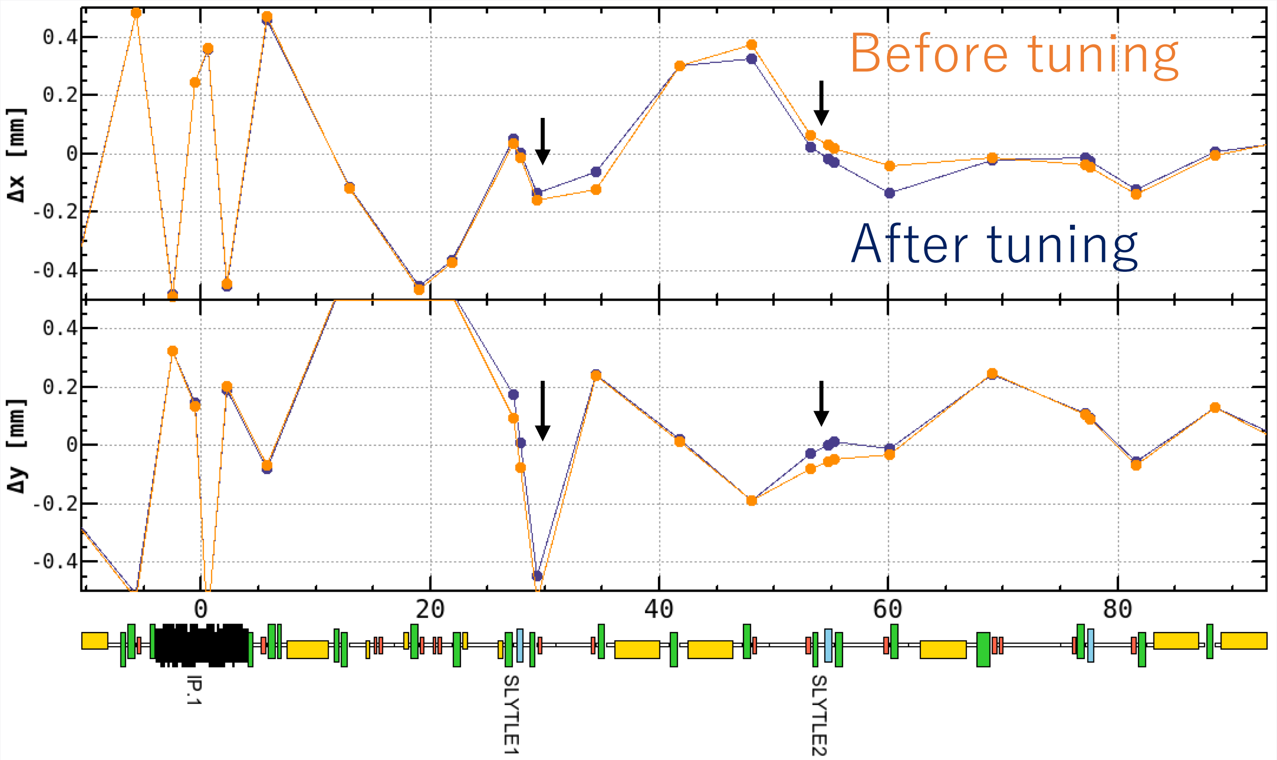


Orbit Tuning Tool for Sextupole

- An orbit tuning tool dedicated to sextupoles was developed by Morita-san.
- It corrects the orbit locally by using localized bump orbit.
- It is very simple to use and very efficient for orbit tuning.



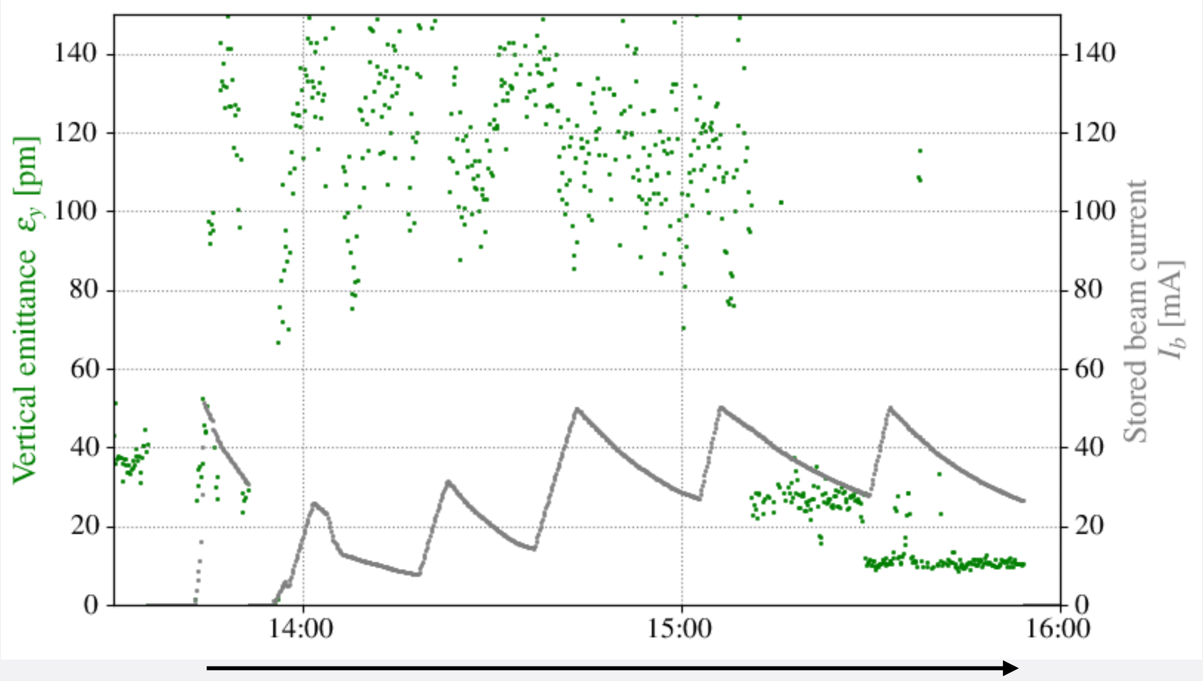
Example: Orbit tuning for SLY magnets



Vertical Emittance Just After Optics Tuning

	2022ab	2024a
HER	20 ~ 40 pm	10 ~ 20 pm
LER	20 ~ 40 pm	10 ~ 20 pm

Vertical emittance during optics tuning

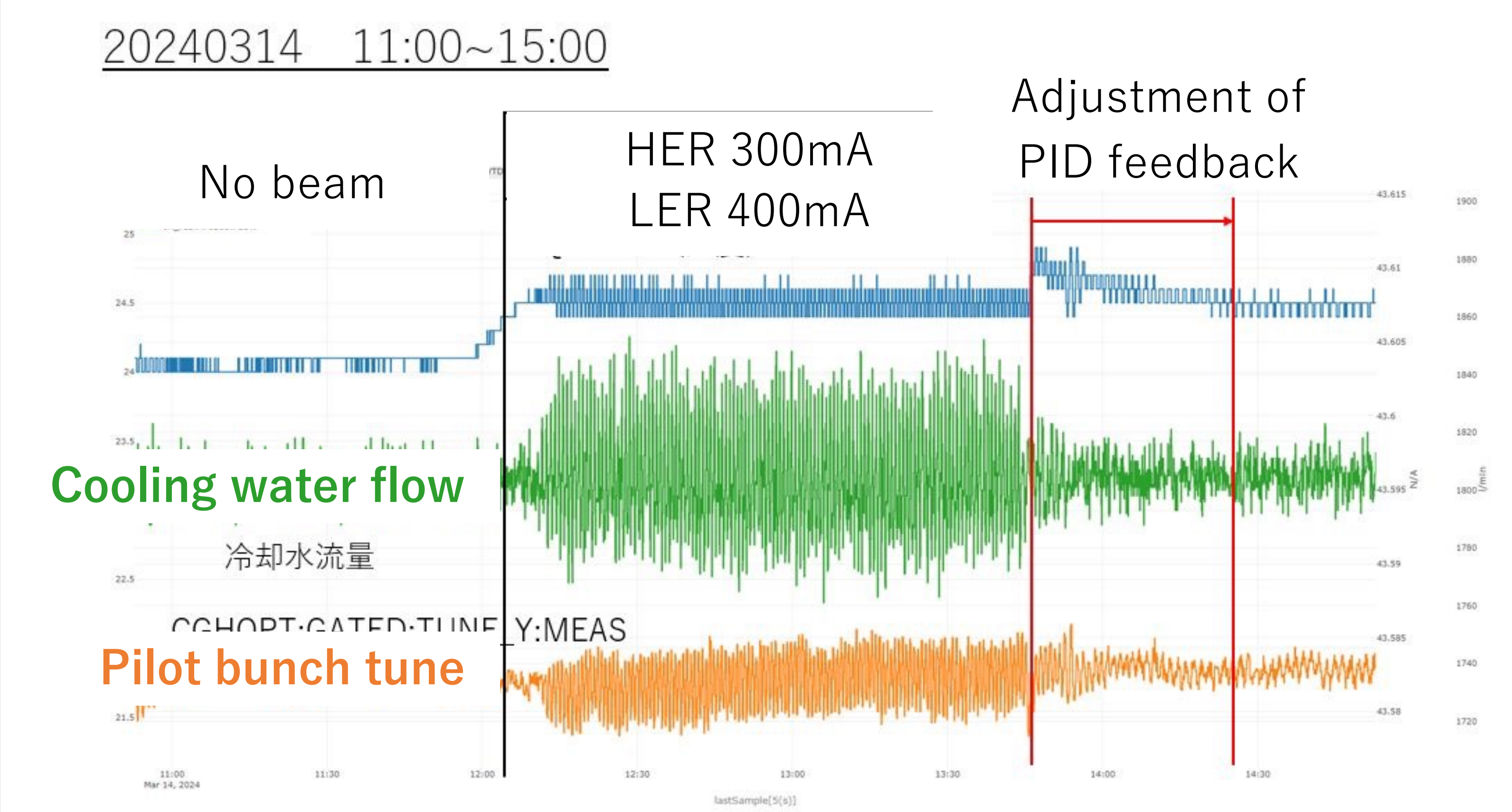


Optics Tuning

- The vertical emittance is lower than that of 2022ab.
- The reason of the improvement is still not clear. Thanks to the smoother COD?
  -> Under consideration.
- It is better to perform beam-beam scan with very low bunch current to make sure that we really achieved lower vertical emittance?
- The vertical emittance does not show clear dependence on by* so far.
- Maintaining the vertical emittance is more difficult in lower by* operation.

Cooling Water and Vertical Tune Fluctuation

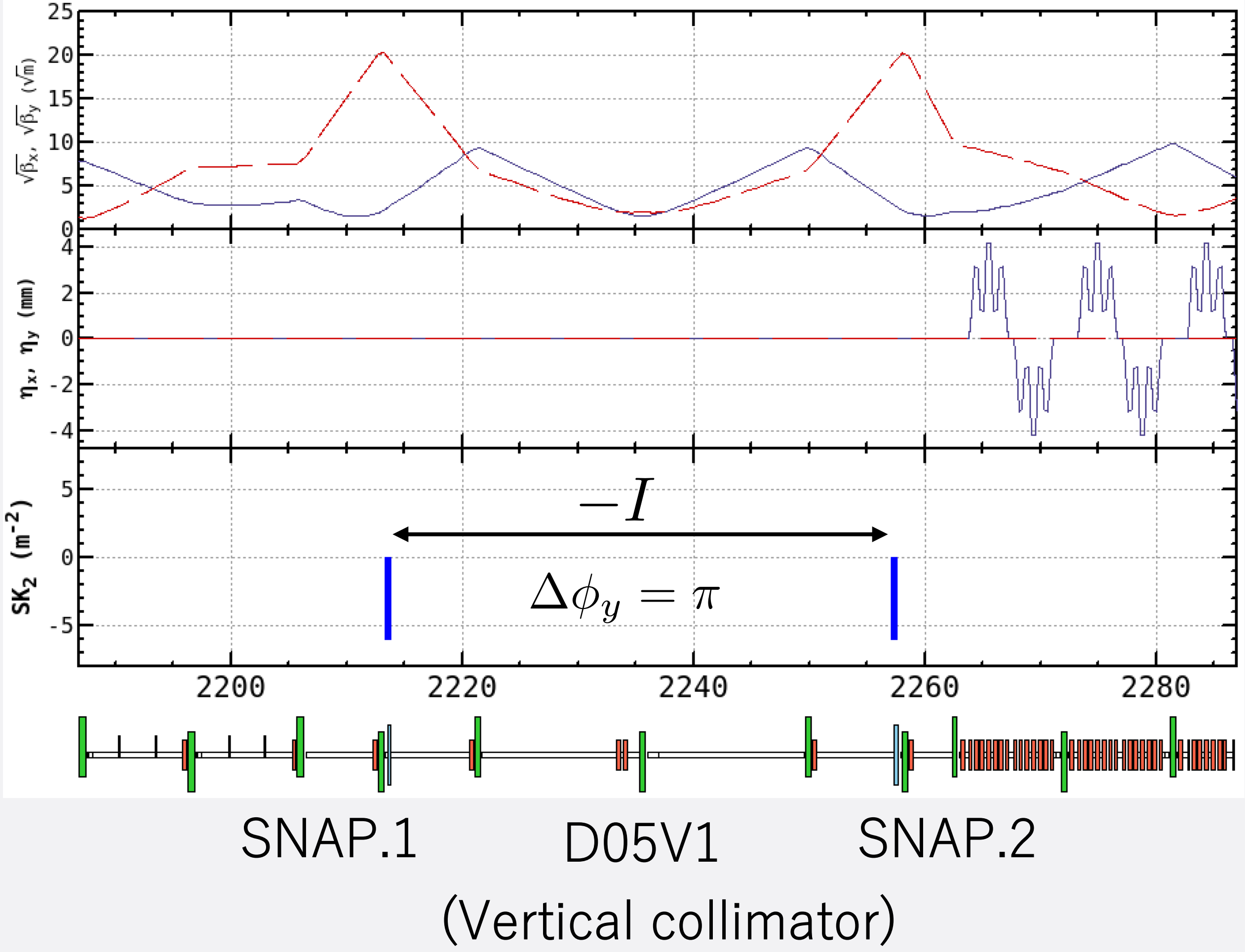
- We observed large tune fluctuation compared to that of 2022ab
- Correlation with the cooling water flow for beam-pipe was pointed out. (by M. Kikuchi)
- Tuning of PID parameters for the cooing water system recovers the situation.



Optics tuning
for Nonlinear Collimator (D05V1) in LER

Beam Optics for D05V1

- A new skew sextupole (SNAP) pair with high vertical betatron function.
- Utilization of nonlinear vertical kick and a – I cell.

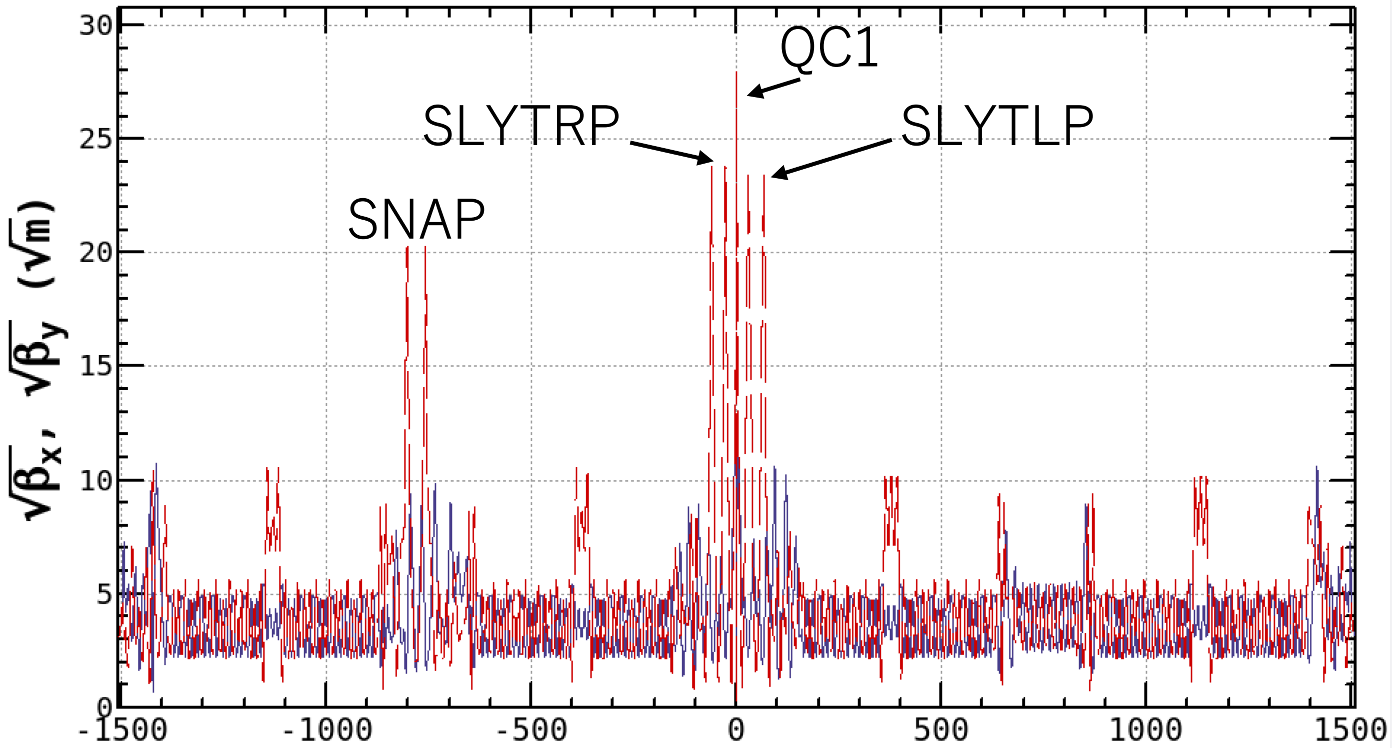


$$\Delta p_y \propto SK_2(y^2 - x^2)$$

- Better collimation effect with larger collimator gap.
- Lower transverse impedance.
- The nonlinear kick is localized in the SNAP pair thanks to the – I cell condition.

Beam Optics Parameters

- $\beta_y \times (K2 \text{ or } SK2)$ is larger than that of SLY magnet.
- Careful attention to the orbit at SNAP is essential for the stable operation.



$\beta_y^* = 1 \text{ mm}$

	SNAP	SLYTLP1 SLYTLP2	SLYTRP1 SLYTLP2
β_y [m]	387	525	521
$K2$ or $SK2$ [m^{-2}]	-6	1.3 3.5	1.2 3.5
$\beta_y \times (K2 \text{ or } SK2)$ [m^{-1}]	-2322	682.5 1838	625 1823

Optics Distortion caused by Orbit Deviation at SNAP

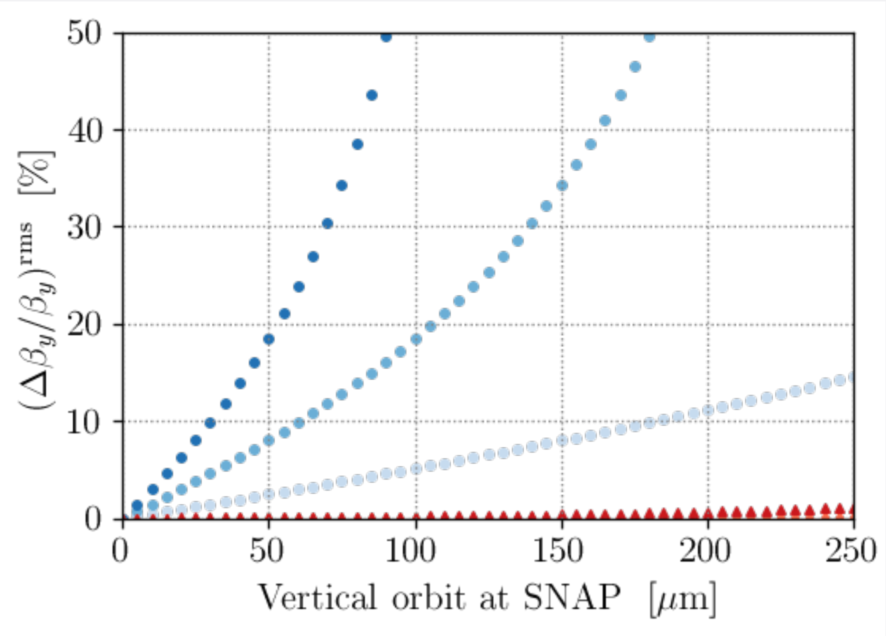
- Horizontal orbit deviation

  Mainly causes Betatron-coupling (XY-coupling) -> Vertical emittance degradation

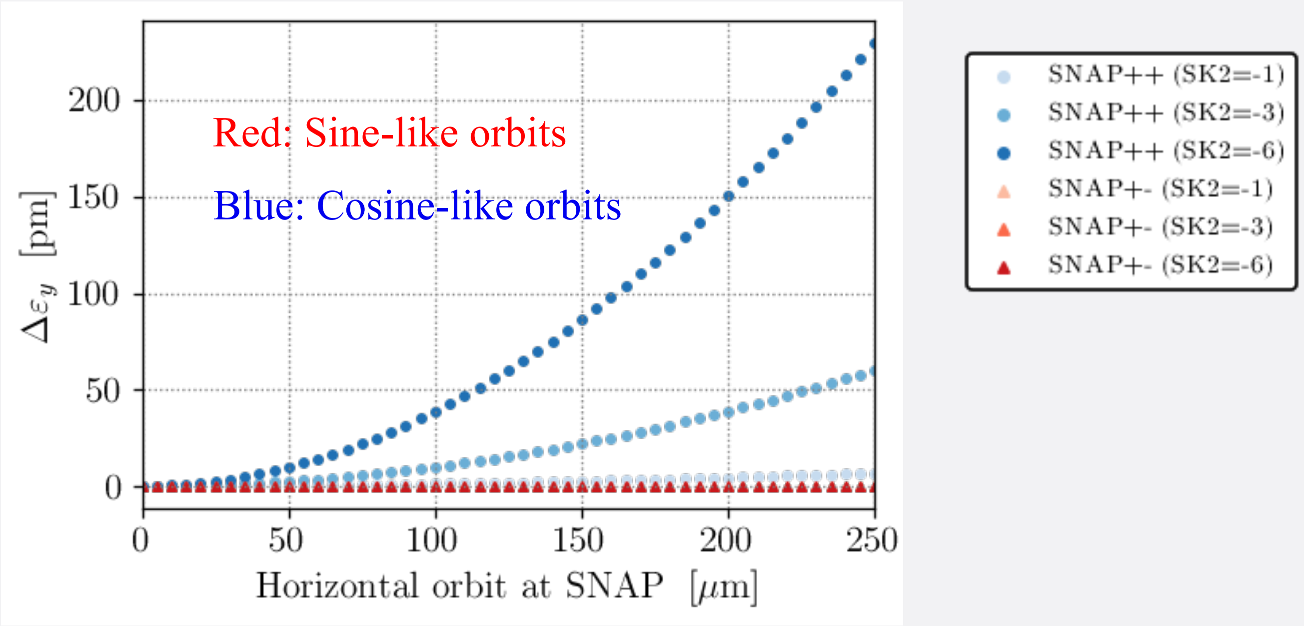
- Vertical orbit deviation

  Mainly causes Beta-beating including tune shift

Beta-beating



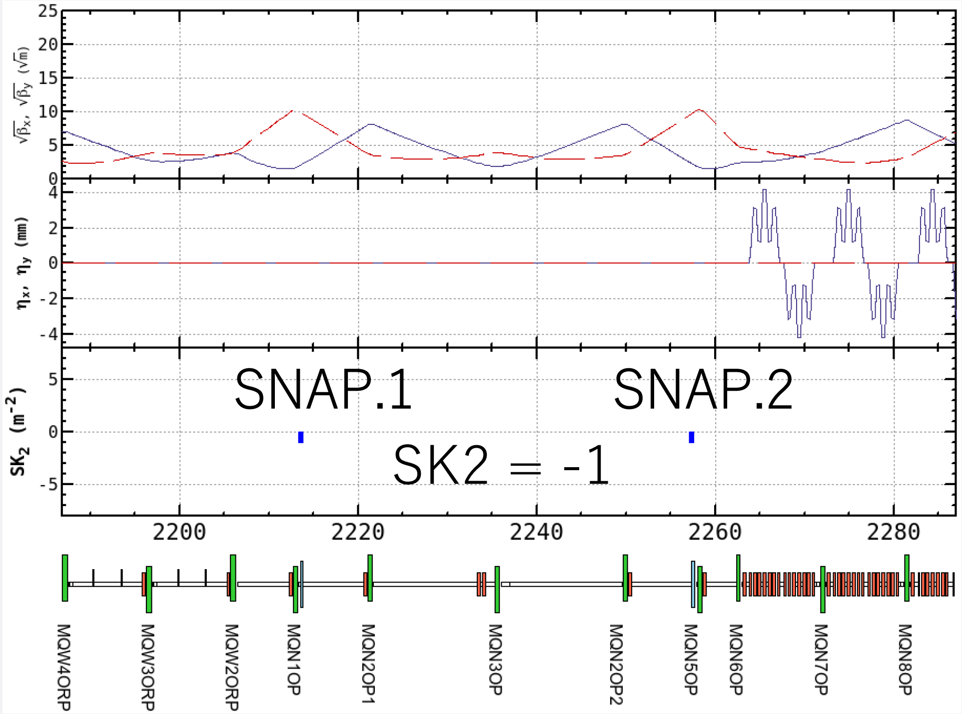
Vertical emittance



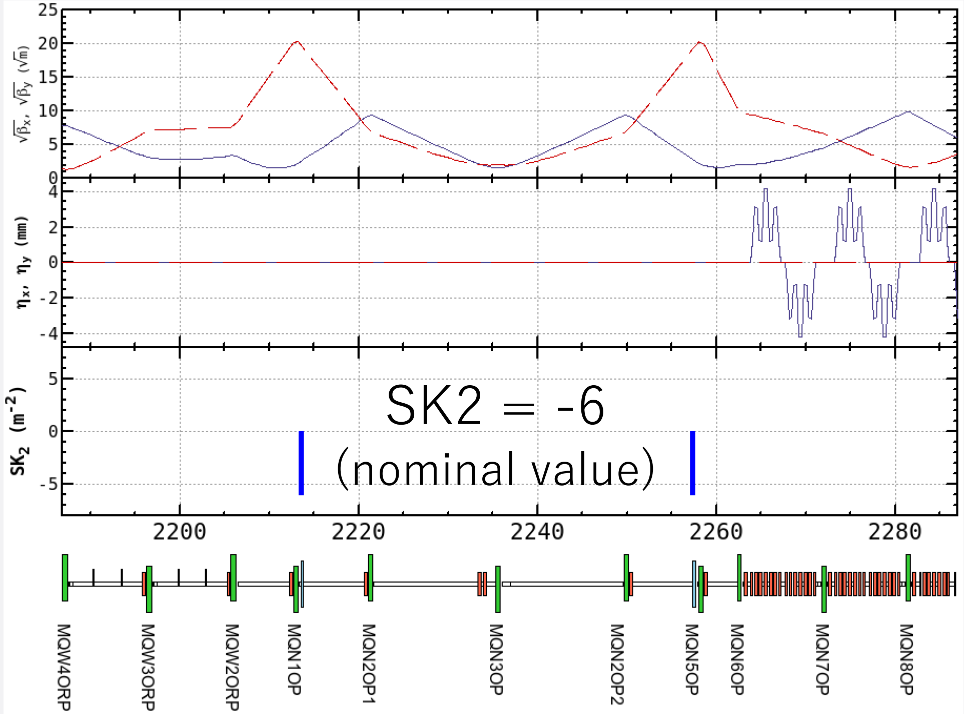
Startup of the D05V1 Section

- Started with smaller beta function and weaker field strength of SNAP. (SK2=-1 for the startup. The nominal value is SK2=-6)
- Move on to the nominal optics and change SK2 from -1 to -6.

~ 02/05/2024



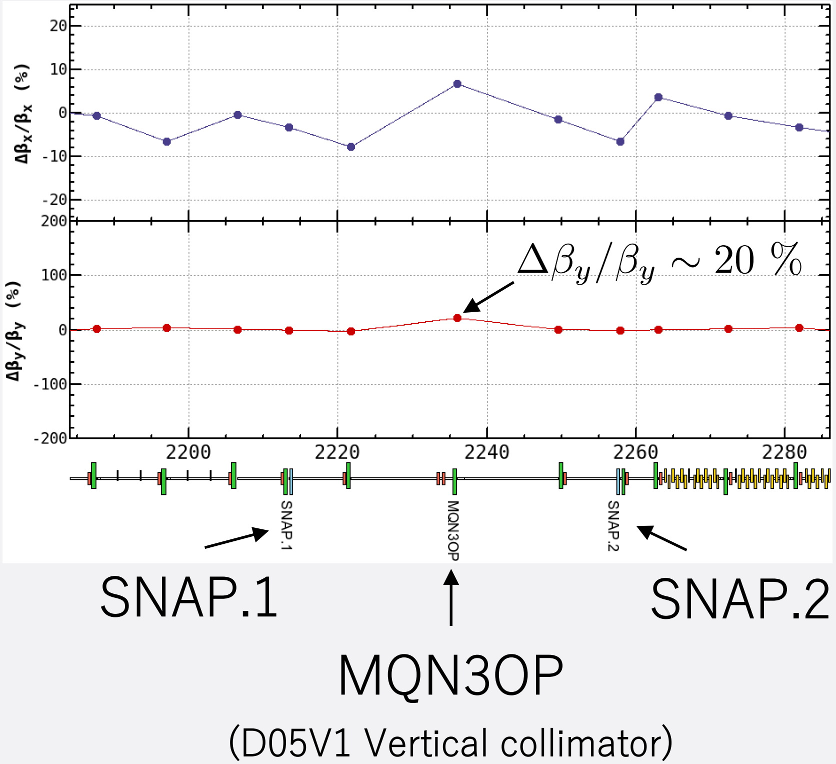
02/06/2024 ~



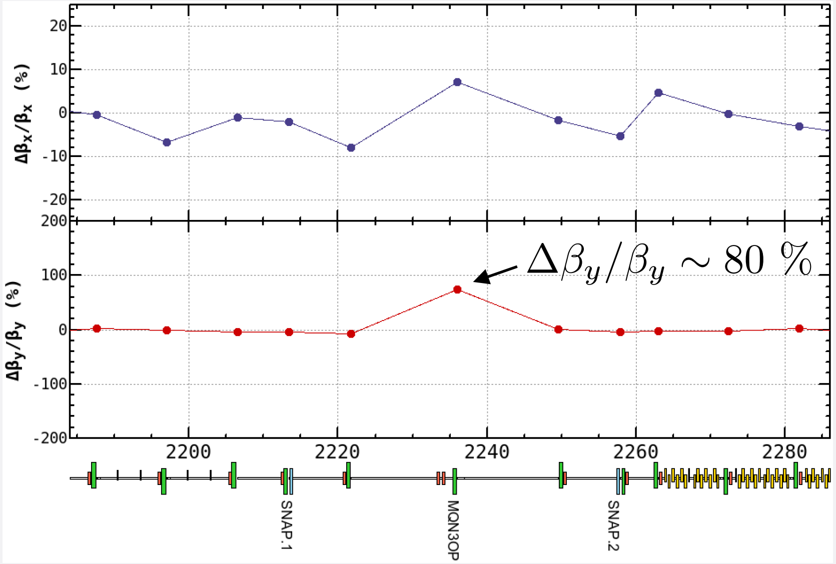
Large Beta-beating at D05V1 ?

- The measured vertical beta-beating at D05V1 becomes larger as we increases SK2.
- The beta-beating at D05V1 could not be corrected using existing knobs.

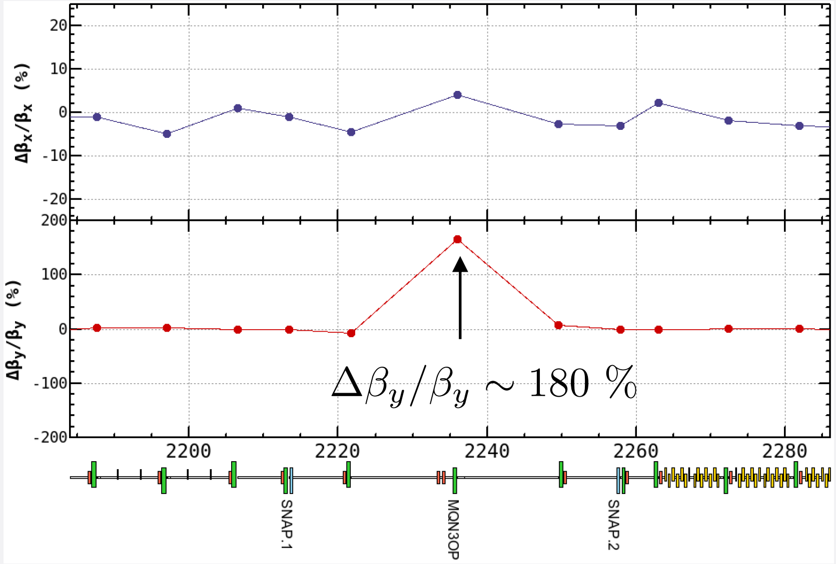
SNAP SK2 = -1



SNAP SK2 = - 3



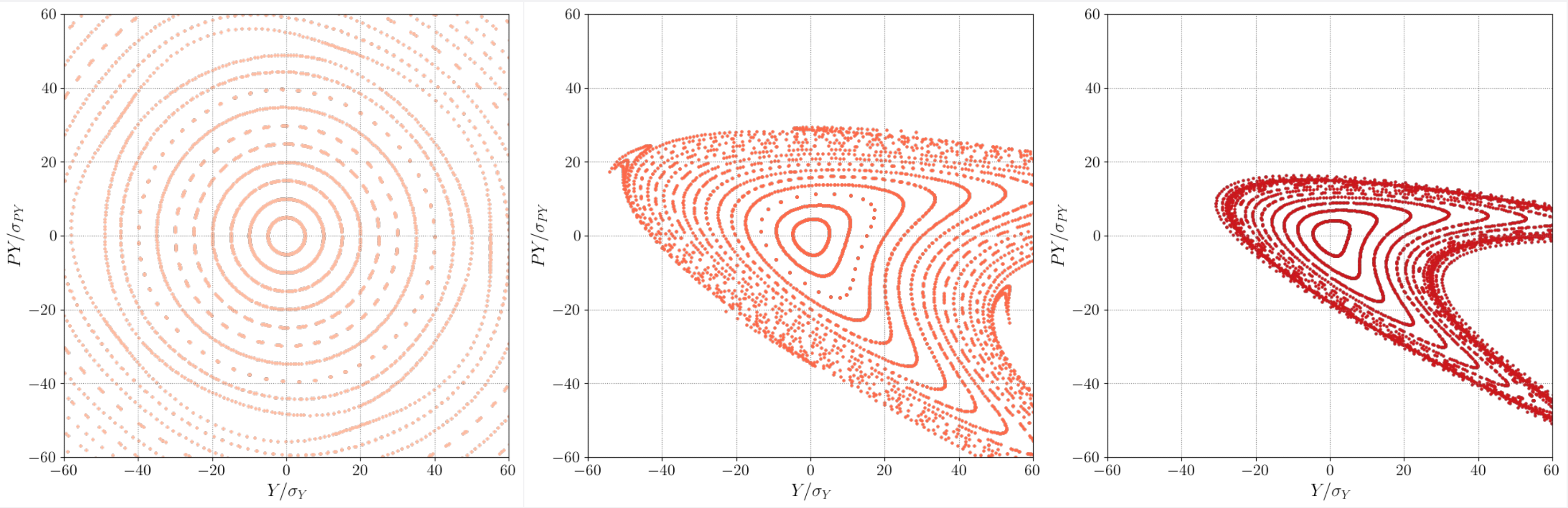
SNAP SK2 = -6



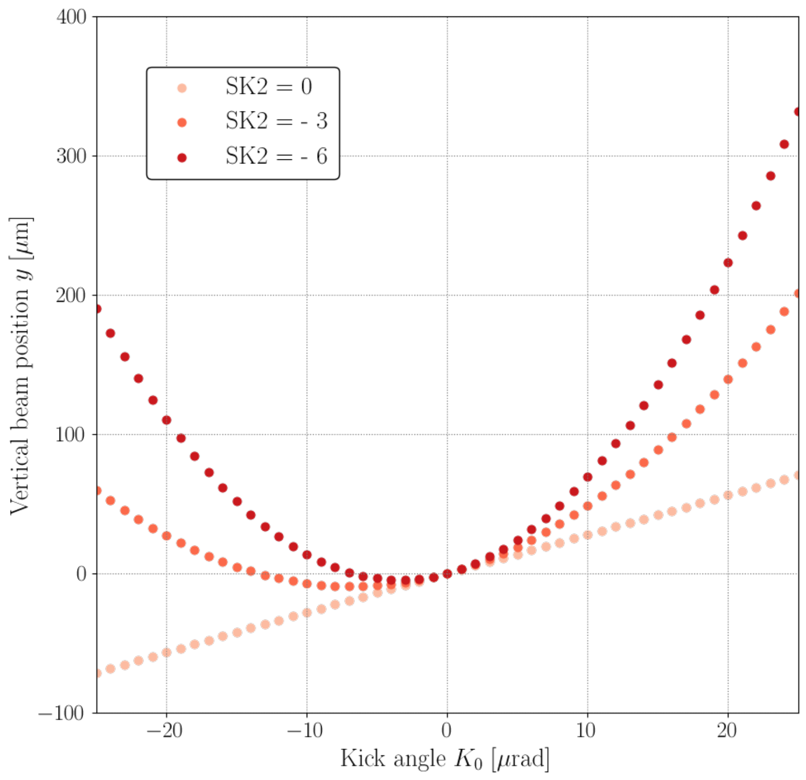
Vertical Phase Space and Orbit Response at D05V1

- The essence of nonlinear collimator is lattice nonlinearity.
- The strong nonlinearity disturbs the orbit response inside of SNAP pair

SNAP SK2 = 0　　SK2 = - 3　　SK2 = - 6



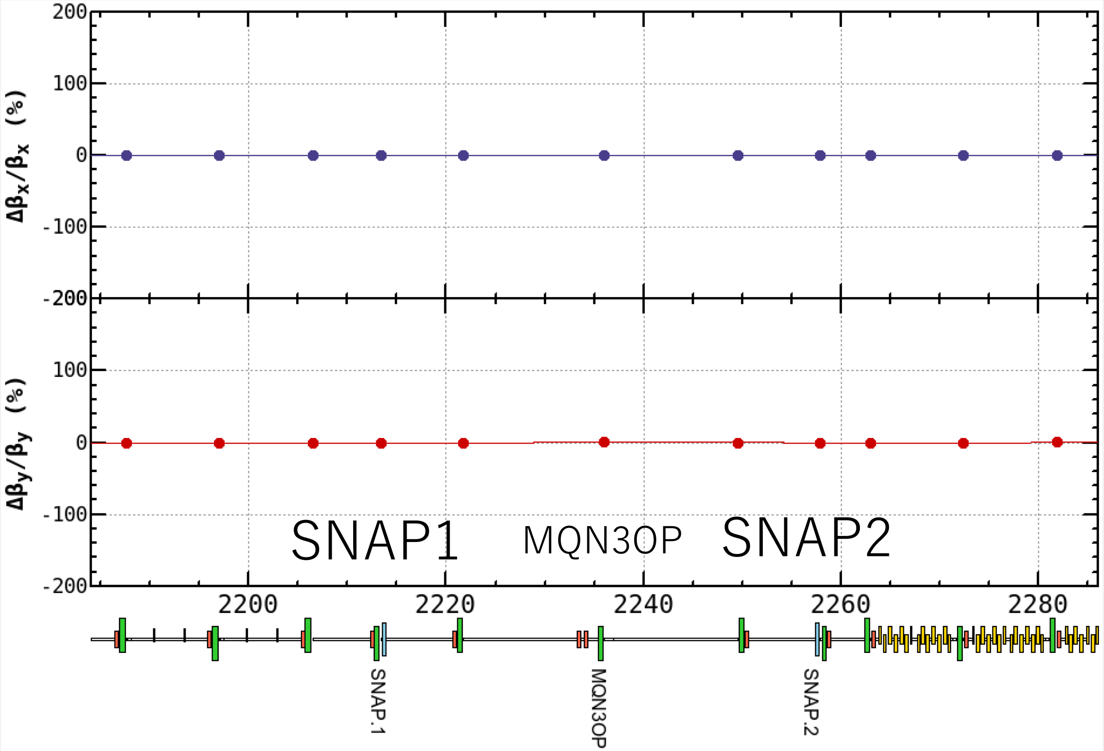
Orbit Response - simulation -



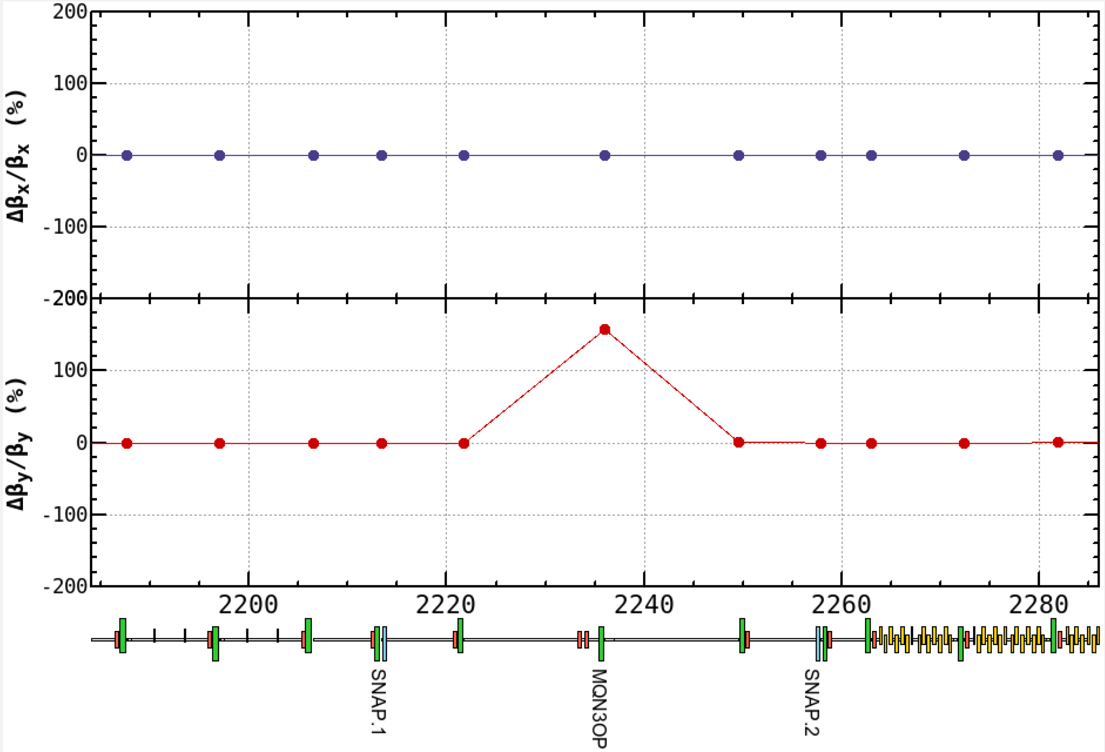
Simulation of Optics Measurement at D05V1

- Emulation of the real measurement procedure on the model lattice
  - No lattice error and no BPM reading error.
  - Extract betatron function from 6 kinds of orbit responses.
- Apparent large beta-beating is indeed appeared.

SNAP SK2 = 0



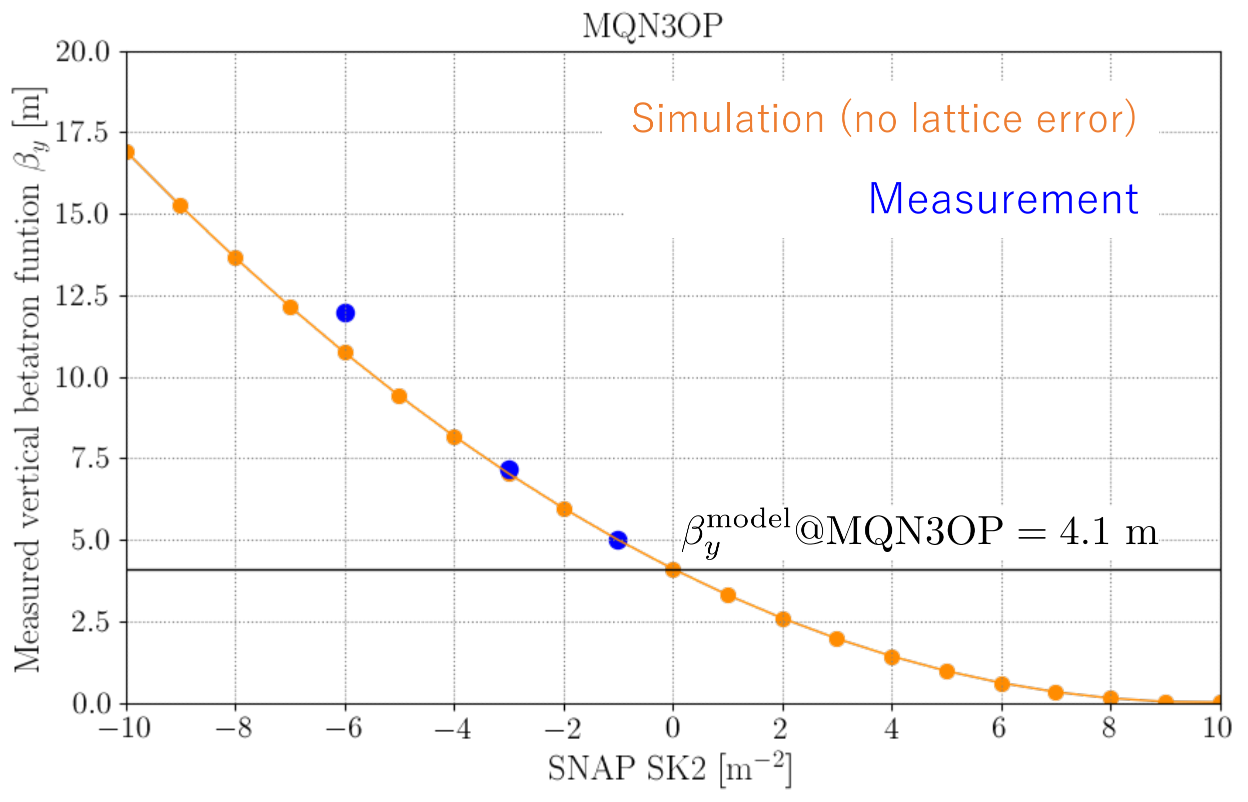
SK2 = - 6



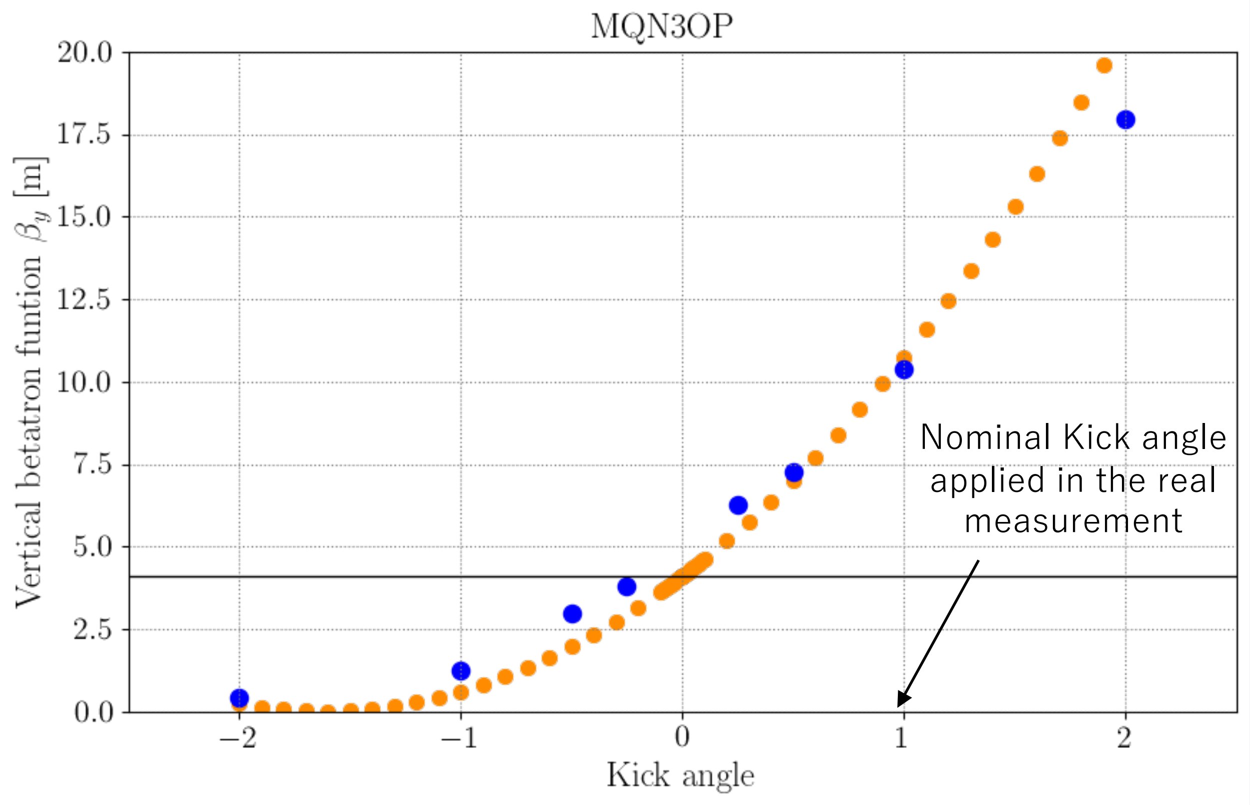
Comparison between Simulation and Measurement

- Apparent beta-beating depends on SK2 and the amount of kick angle used in optics measurement.
- Measurement results are qualitatively consistent with simulation results.
- A quantitative difference between them may be coming from lattice error and measurement uncertainty.

SK2 Dependence

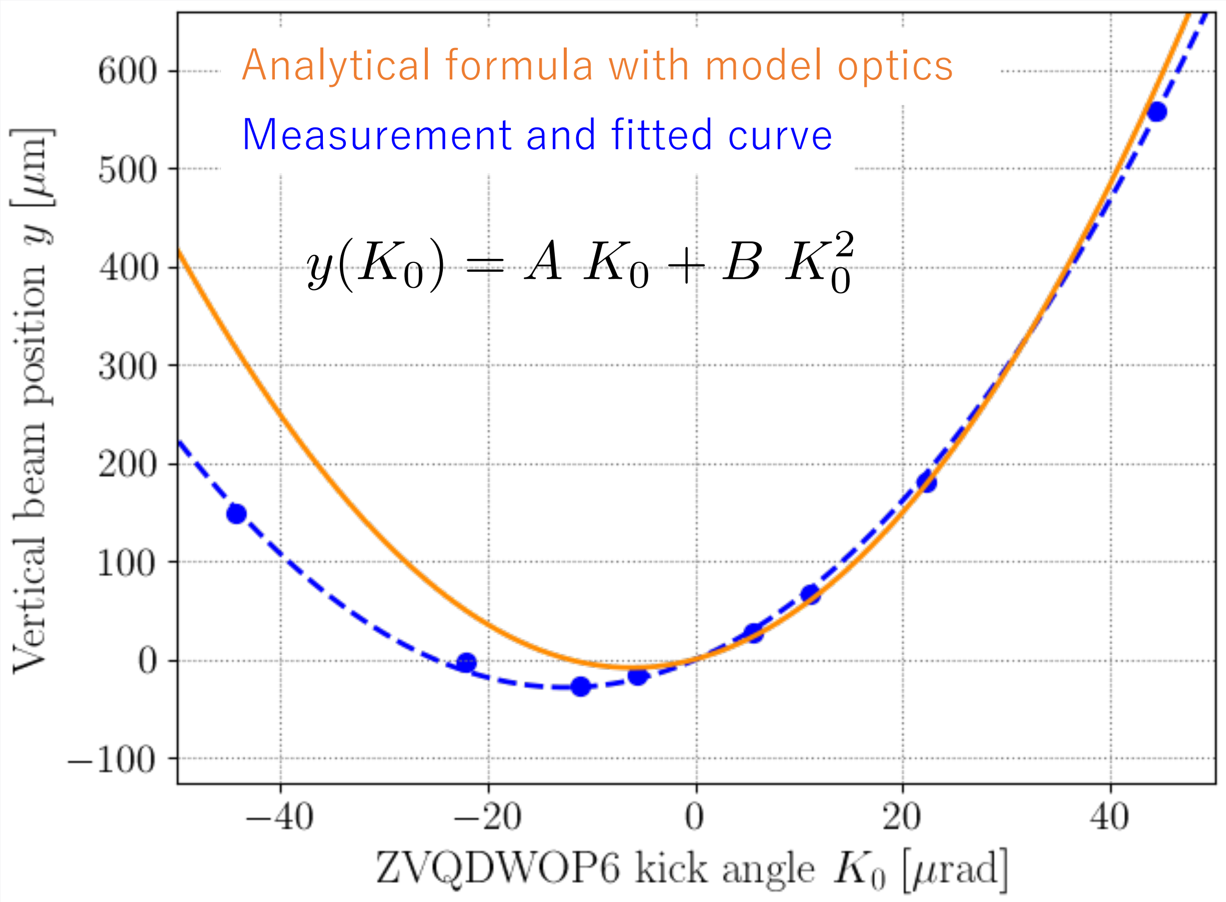


Kick-Angle Dependence



Extraction of Linear Component

Orbit Response at MQN3OP



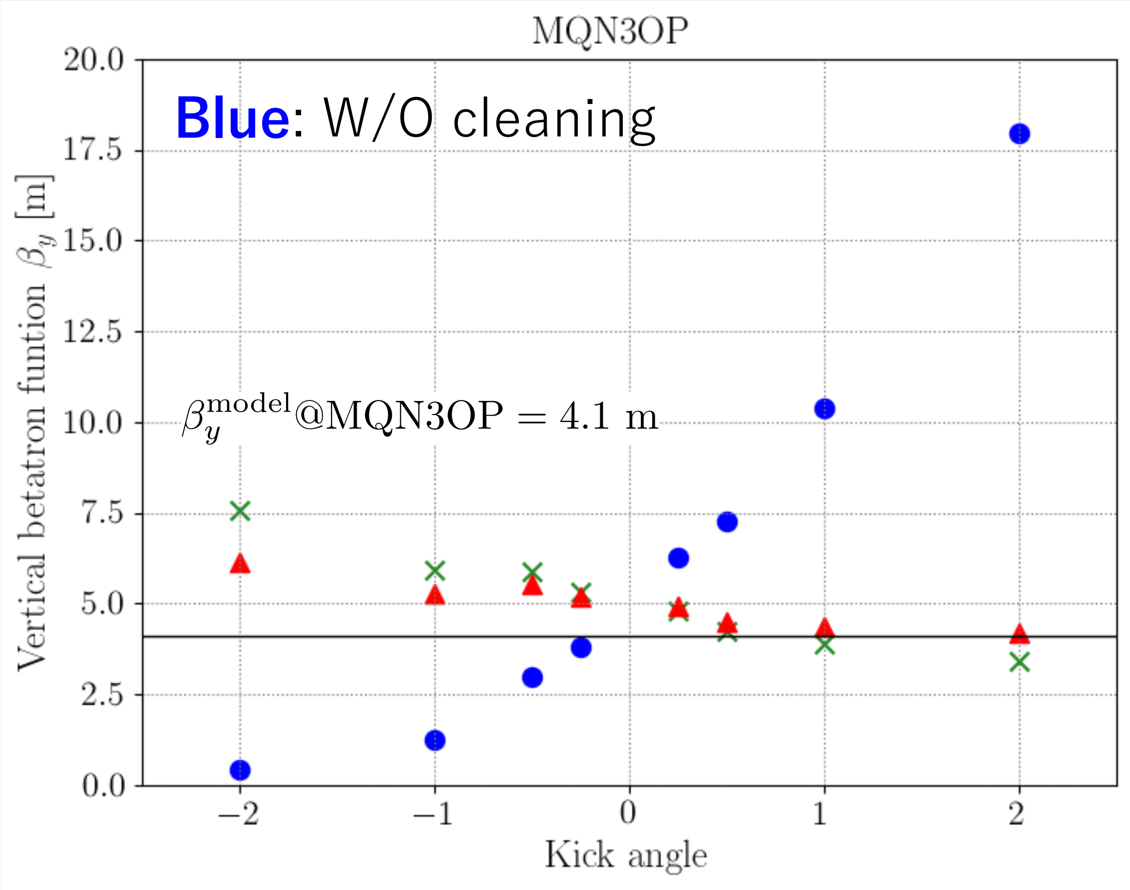
- The 2nd polynomial fitting to measured response.
- Measured response is well described by the fitting.
- In principle, we can reduce nonlinear component by using the fitting results.
- However, it's hard to perform measurement with various kick angles in practice because it is too time consuming.

Cleaning of Nonlinear Component

- Try to extract linear component only by using,

Green: an analytical formula.

Red: the fitting to the measured orbit response



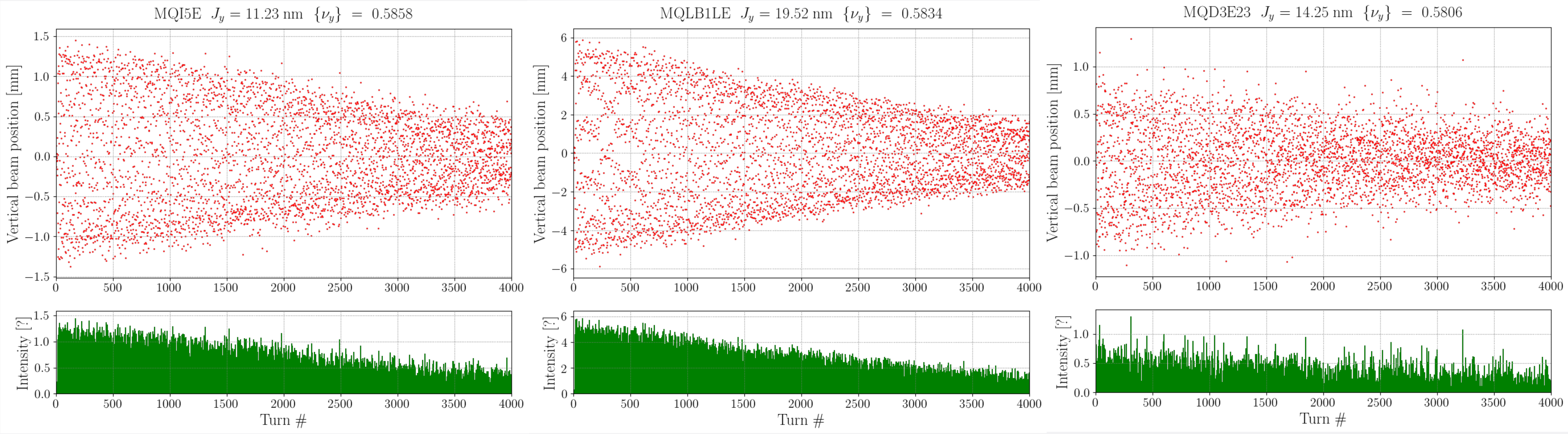
- Even after the cleaning, estimated beta function has kick-angle dependence.
- It seems that uncertainty of beta-function measurement is an order of 10 %.
- We have a chance to perform optics measurement in the case of SK2=0 soon.

Estimation of Betatron Detuning in HER

- Very Preliminary -

Estimation of Amplitude Detuning

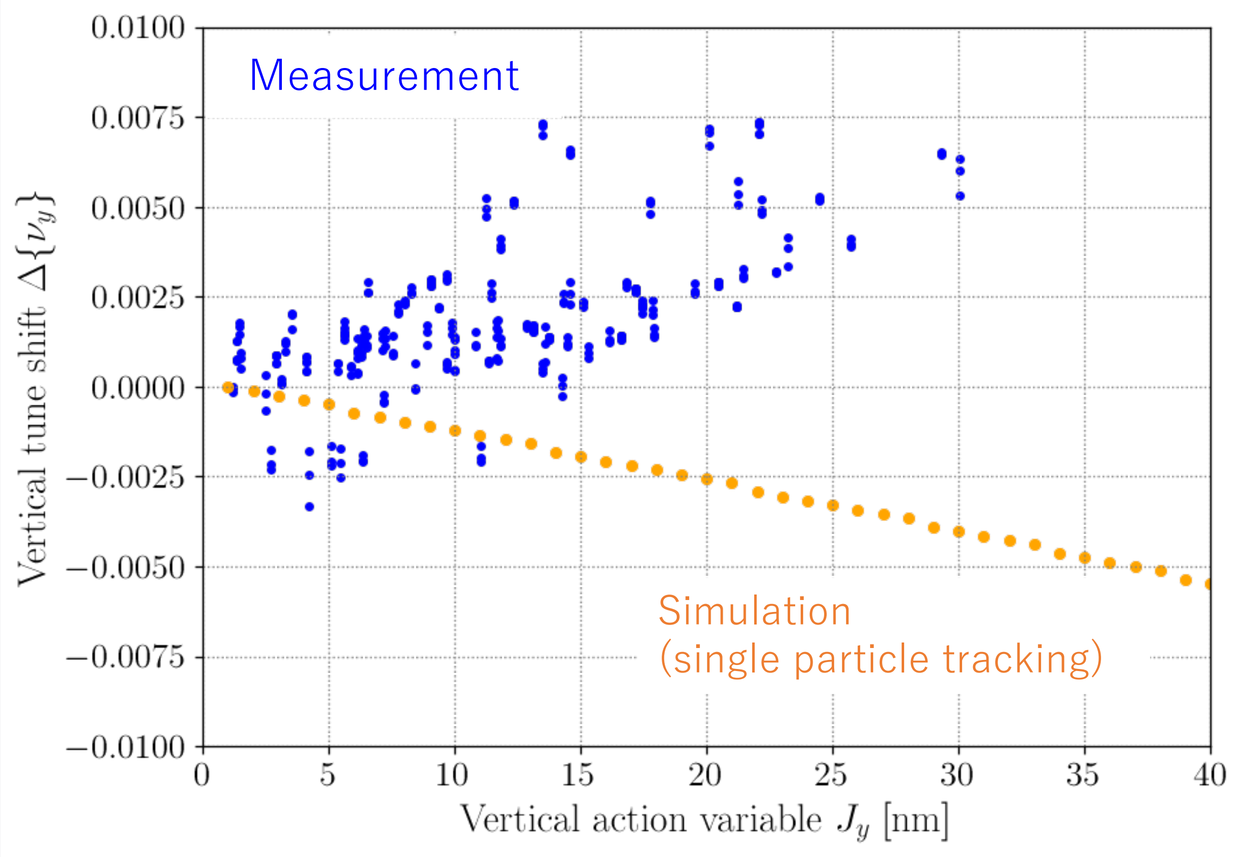
- Analysis of measurement data taken in the ring aperture measurement performed by Ohnishi-san.
- Vertical kick is applied to the storage beam with various kick amplitudes.
- Perform frequency analysis using NAFF for first a few hundred turns for several BPMs.
- Action variable is estimated by the amplitude of the fundamental mode together with the model beta-function at the BPM.



Estimation Results $(\beta_x^*, \beta_y^*) = (60, 1)$ mm No Craw Waist 03/14/2024

Preliminary

- Tune shift with amplitude $\nu_y = \nu_0 + \alpha_{yy} J_y + \alpha_{yx} J_x + \cdots$



- The measurement is not consistent with the model lattice.
- The detuning parameter α_{yy} of the model lattice is negative owing to octupole-like effects from SLY thickness and octupoles in IR

$$\alpha_{yy}^s \approx -\frac{1}{16\pi} K_2^2 (\beta_y^s)^2 L_s$$

$$\alpha_{yy}^o \approx \frac{1}{16\pi} K_3 (\beta_y^o)^2$$

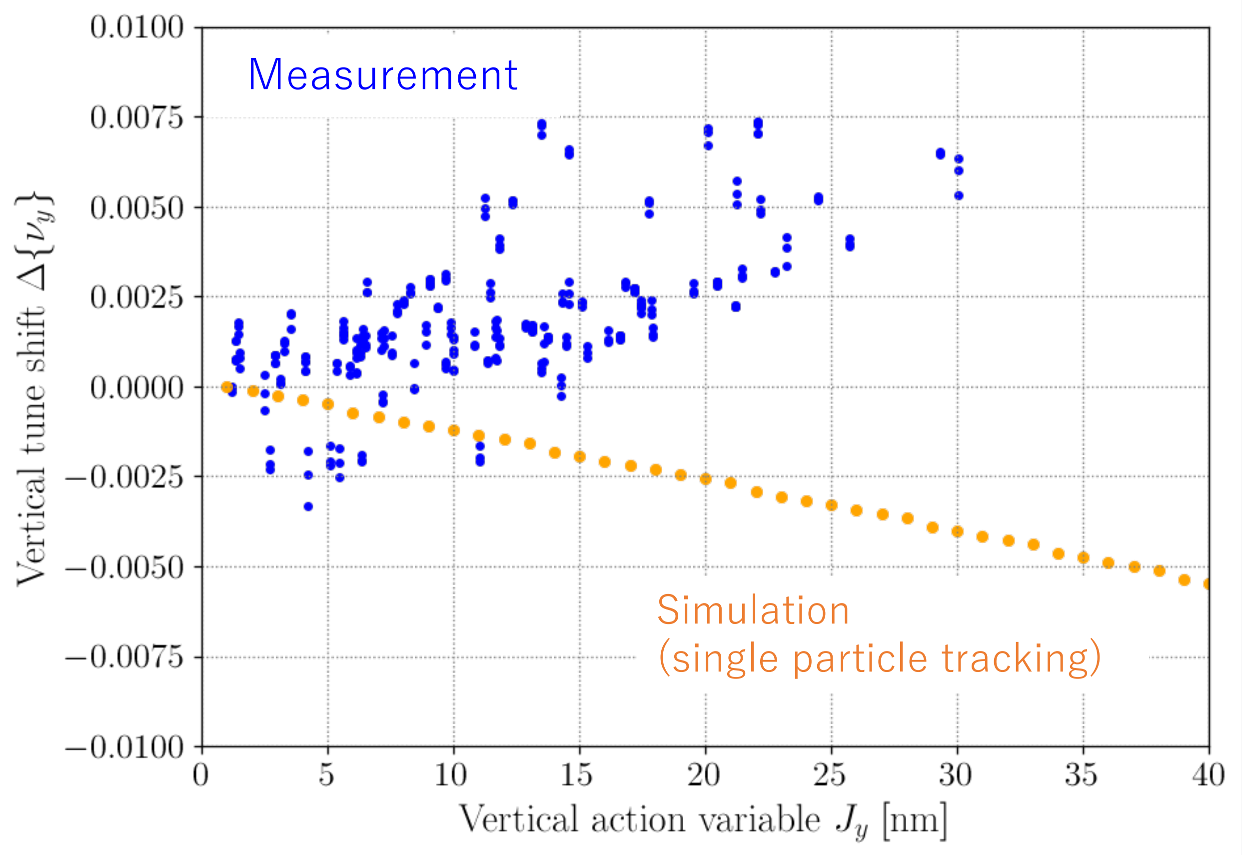
Results for Different β_y^*

No Craw Waist

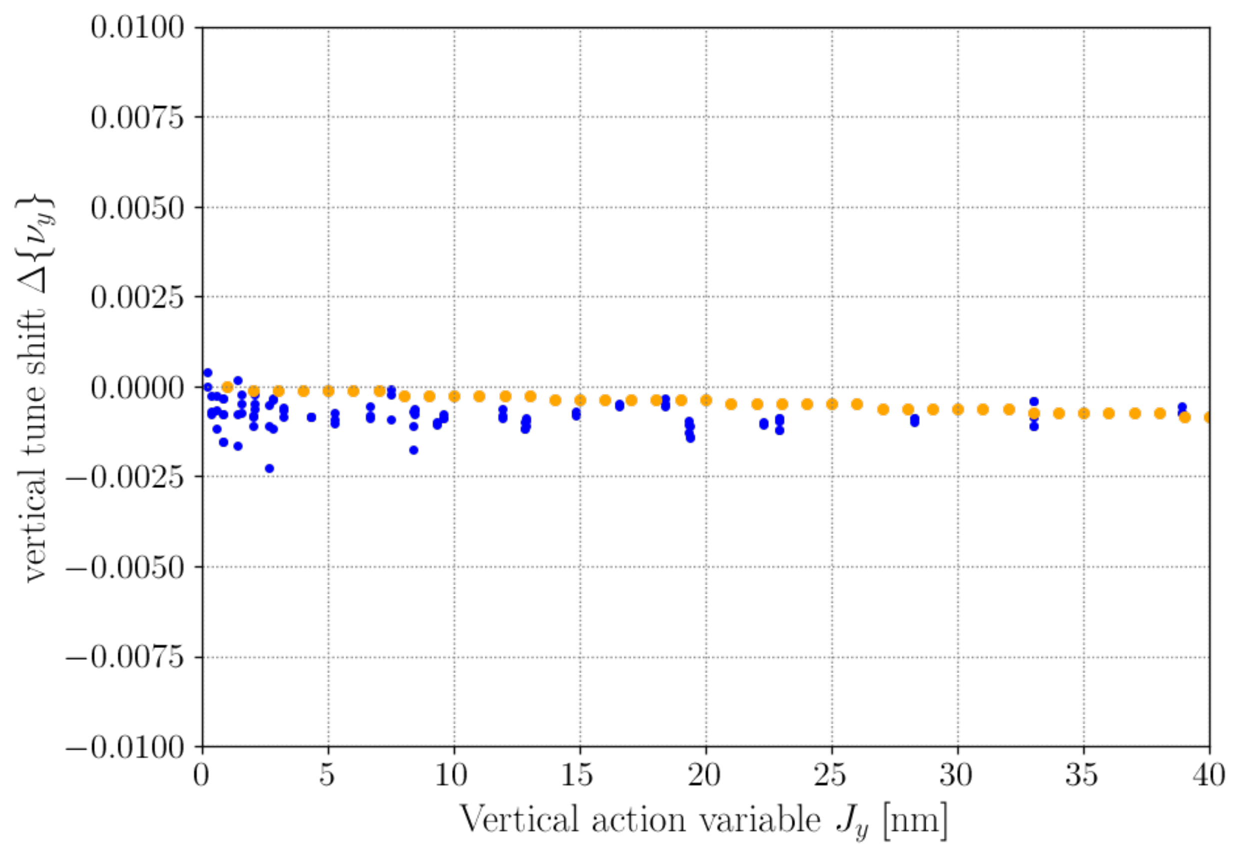
Preliminary

- The detuning is smaller for larger β_y^* as expected.

$(\beta_x^*, \beta_y^*) = (60, 1)$ mm 03/14/2024



$(\beta_x^*, \beta_y^*) = (100, 3)$ mm 02/29/2024

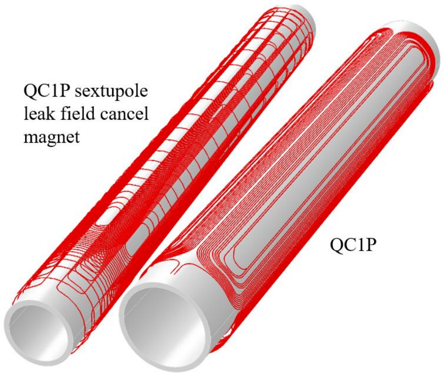


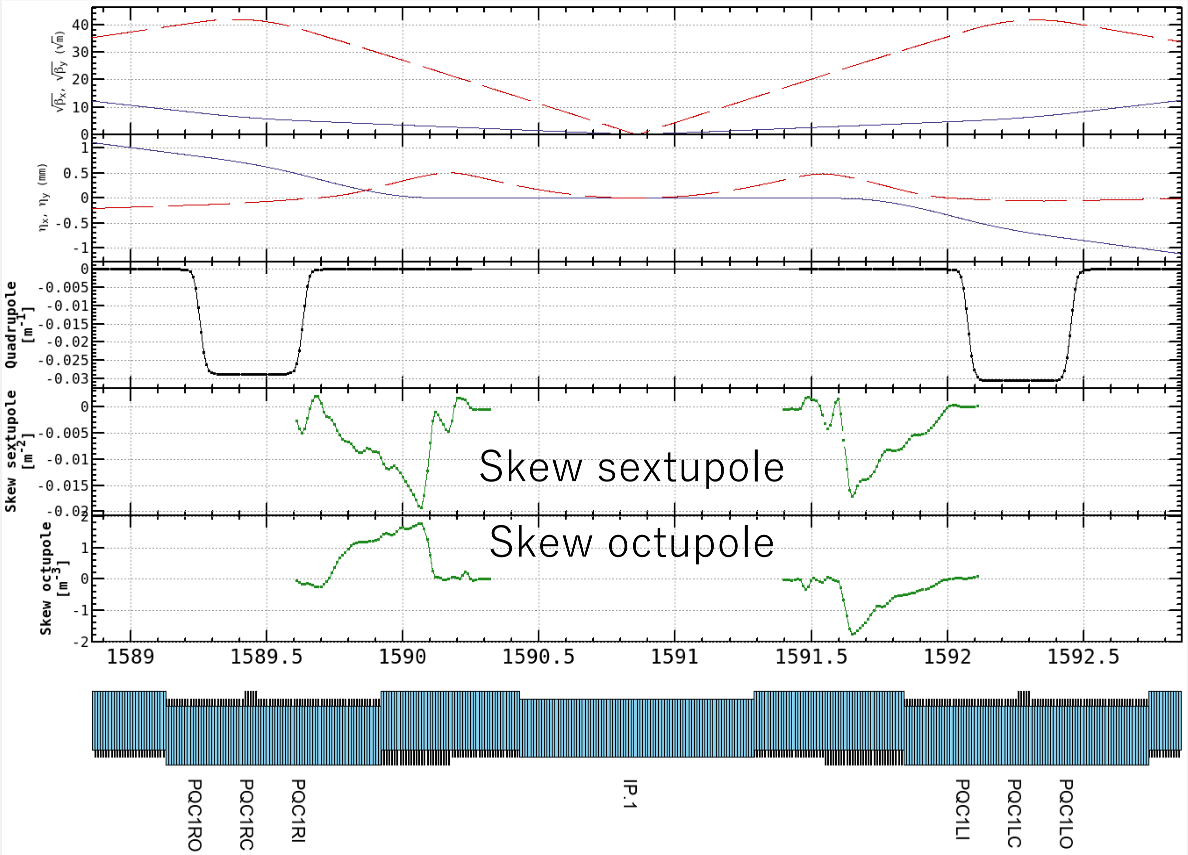
Error Fields in IR

- QC1P cancel coil in the HER beamline has manufacturing errors.
- It causes additional skew sextupol&octupole fields mainly.
- The error fields are not included in the IR model used in the operation yet.

Table 24: Measured integral leak fields at R_{ref}=10 mm

Mag. type	QCSL, Tm without cancelling	QCSL, Tm with cancelling	QCSR, Tm without cancelling	QCSR, Tm with cancelling
b_3	3.36×10^{-3}	2.32×10^{-5}	-3.53×10^{-3}	1.27×10^{-5}
b_4	-7.58×10^{-4}	-2.83×10^{-6}	8.02×10^{-4}	4.39×10^{-6}
b_5	1.57×10^{-4}	3.66×10^{-6}	-1.67×10^{-4}	-3.73×10^{-6}
b_6	-2.98×10^{-5}	7.8×10^{-7}	3.24×10^{-5}	2.35×10^{-6}
a_3	-2.42×10^{-4}	-3.88×10^{-4}	-2.52×10^{-4}	-4.93×10^{-4}
a_4	-5.88×10^{-5}	-1.16×10^{-4}	4.94×10^{-5}	1.71×10^{-4}
a_5	-1.48×10^{-5}	-1.48×10^{-5}	6.26×10^{-6}	-8.31×10^{-6}
a_6	1.88×10^{-5}	1.48×10^{-5}	-4.31×10^{-6}	-1.09×10^{-6}

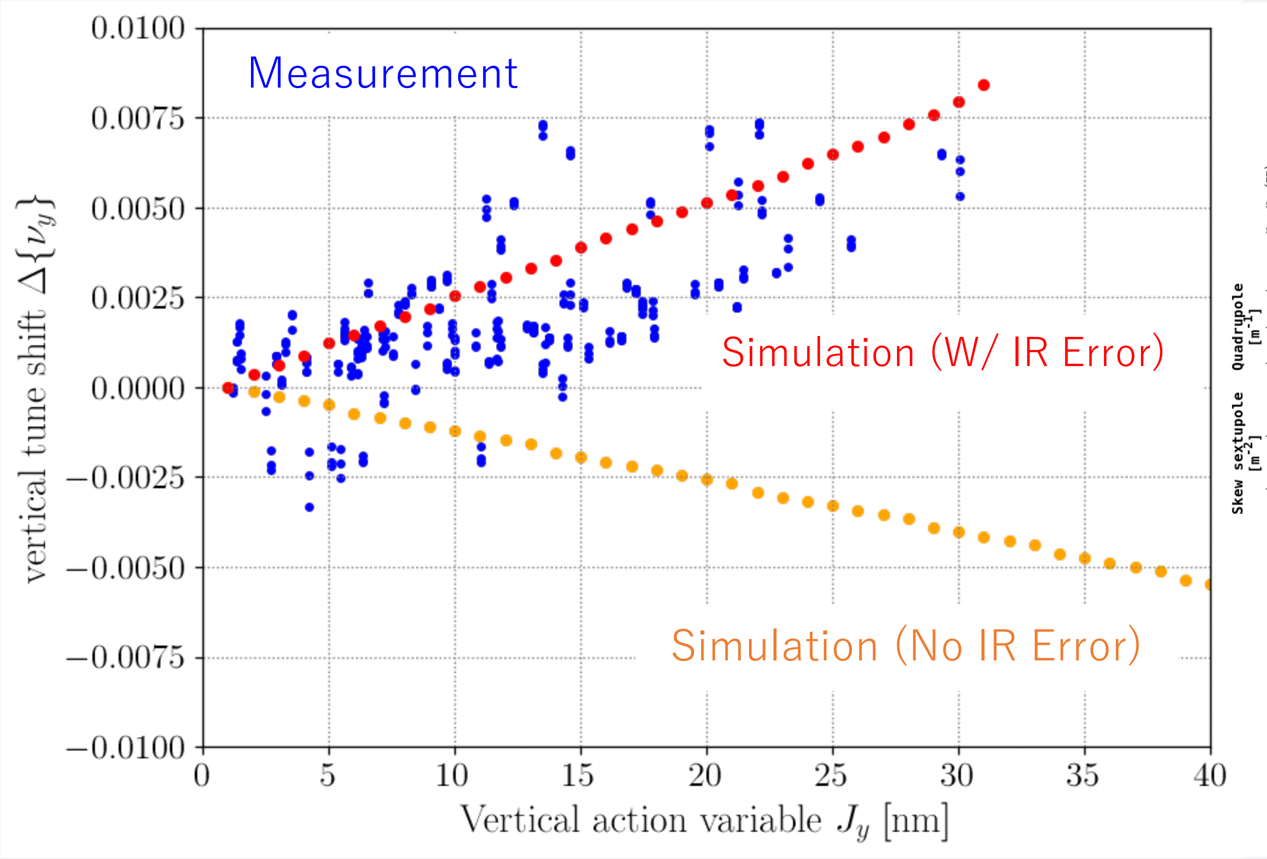


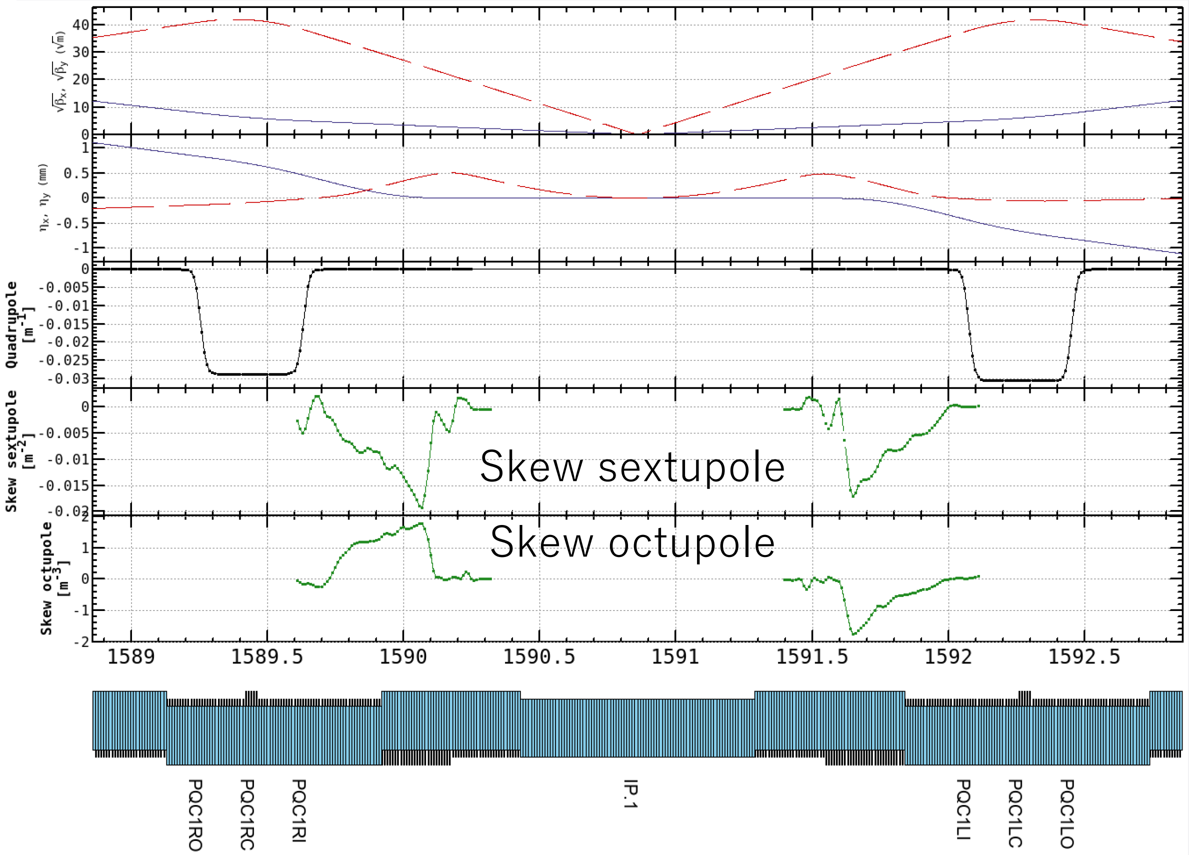


Effects of Error Fields in IR

Preliminary

- Detuning calculation with the error field in IR.
- It looks the error field explains the difference between model and real machine.
- It is interesting to change multipole correctors in IR.





Summary

- **Several Topics in 2024a Run**
  - We spend more time to establish smooth closed orbit.
  - Vertical emittance is 10 ~ 20 pm in both rings.
  - Vertical tune fluctuation is caused by inappropriate cooling water feedback loop.
    -> Fixed, but is there any other parameters to be monitored for stable operation?
  - Beam measurement with vertical and longitudinal kickers is now available.

- **Optics Tuning for Nonlinear Collimator (D05V1) in LER**
  - The startup of the system was finished.
  - Orbit at the skew sextupoles should be monitored carefully.
  - Uncertainly of betatron function at D05V1 due to lattice nonlinearity.
    -> We will have a chance to measure optics in case SK2=0.
  - The collimation performance is now under study -> The next speaker.

- **Estimation of Betaron Detuning in HER**
  - Preliminary results shows estimated betatron detunig is not consistent with the model.
  - It looks like the known error filed explains the discrepancy between the model and real machine.
  - Its is interesting to change multipole correctors of QCS and measure the its effects.