

AC-Dipole experience in SuperKEKB

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H. Sugimoto, M. Tobiyaama, R. Tomas, R. Yang**

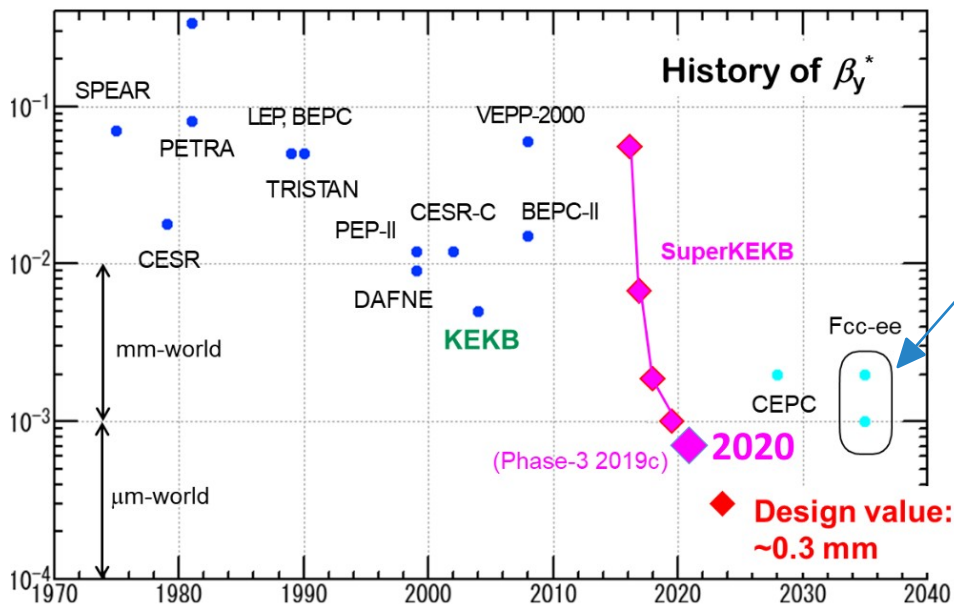
FCC Tuning Meeting 2022
22nd March 2022



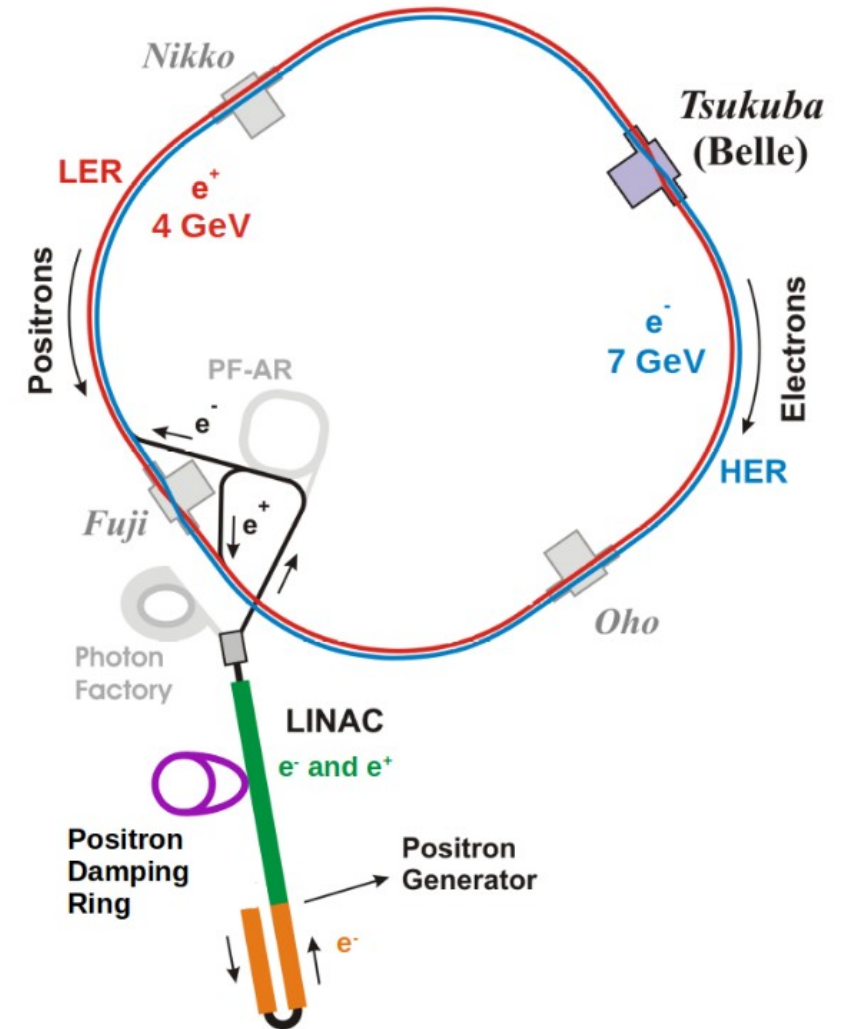
FCCIS – The Future Circular Collider Innovation Study.
This INFRADEV Research and Innovation Action project receives funding from the European Union's H2020 Framework Programme under grant agreement no. 951754.

SuperKEKB

- Lepton double ring collider and 1 interaction point
- 7 GeV electron ring (HER)
- 4 GeV positron ring (LER)
- Record low β_y^* of 0.8 mm



Lowest β_y^* for FCC-ee already reached in SuperKEKB

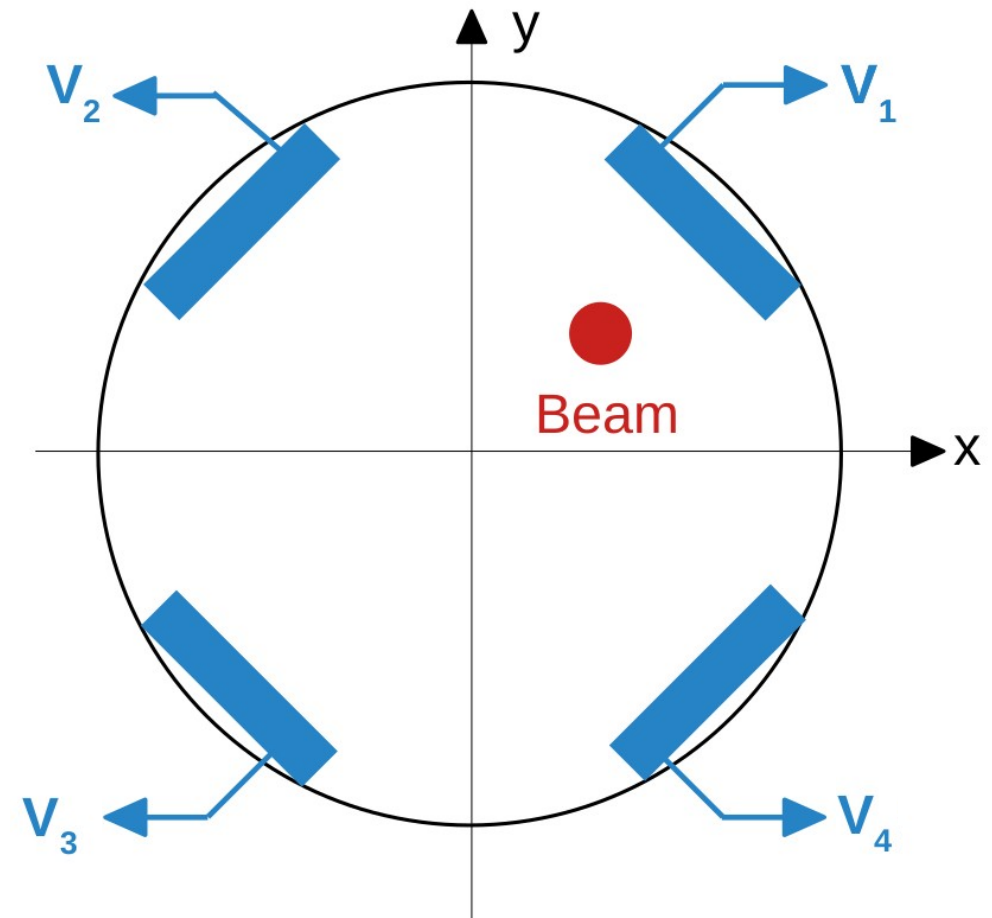


Optics Measurements

- Beam Position Monitors (BPMs) crucial
- Axis rotated by 45° due to synchrotron radiation

$$x = \frac{V_1 + V_4 - (V_2 + V_3)}{V_1 + V_2 + V_3 + V_4} \quad y = \frac{V_1 + V_2 - (V_3 + V_4)}{V_1 + V_2 + V_3 + V_4}$$

- Two recording possibilities
 - Average for Closed Orbit Distortion (COD)
 - Turn-by-Turn mode (TbT)
 - Single kicks with injection kicker (IK)
 - Driven motion with phase lock loop (PLL)



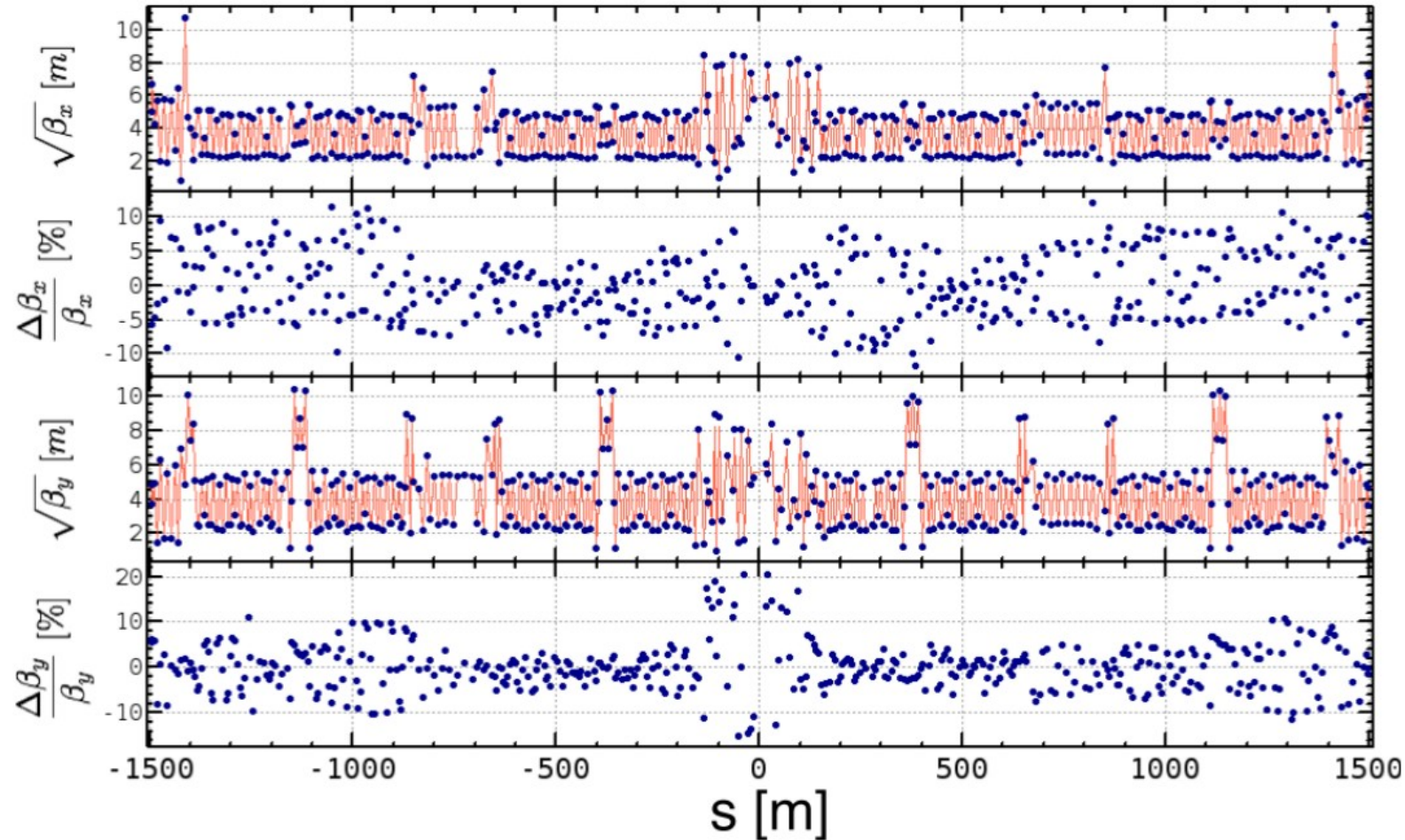
Why PLL?

- Crucial to measure vertical optics using TbT data since IK only horizontally

Parameter	Closed Orbit Distortion	Turn-by-Turn	
		Injection Kicker	Phase Lock Loop
BPMs in HER	466	68	68
BPMs in LER	444	70	70
Hor. optics measurement	yes	yes	yes
Ver. optics measurement	yes	no	yes
RDTs measurement	no	some	yes
Calibration independent	no	yes	yes
Status for measurements	stable	stable	being explored
Trigger to record data	yes	yes	no
Time for measurement	≈20 mins	≈2 mins	≈2 mins

Closed Orbit Distortion

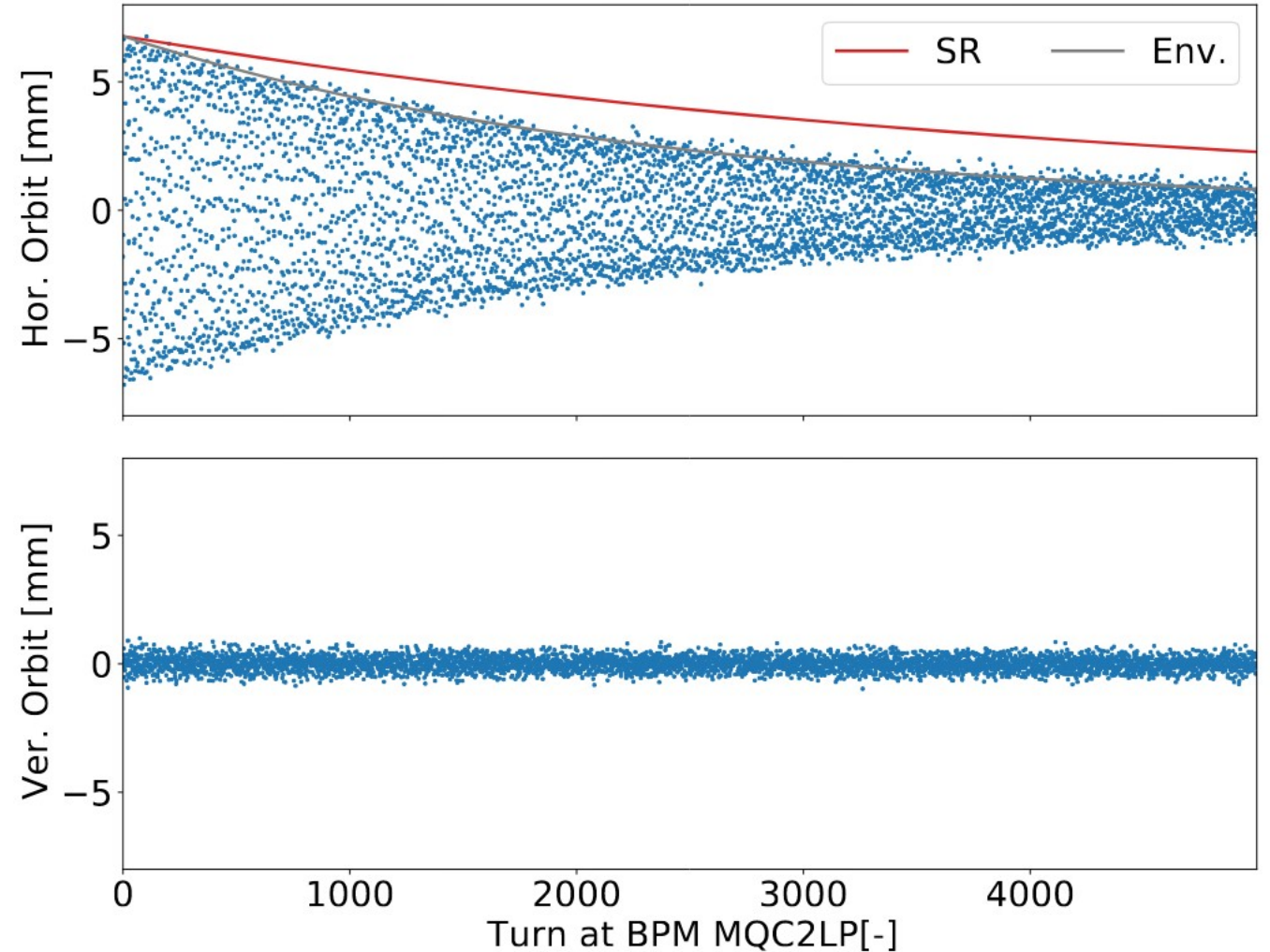
- 3 pairs of orbit correctors generate redundant set of 6 closed orbit distortions (CODs)
- Average orbit over several turns are recorded at about **450 BPMs**
- Large matrix generated
- Optics retrieved by analytical equations
- Optics measurements with COD used for optics corrections
- Regularly performed



Y. Ohnishi et al., IPAC'16, THPOR007, 2016.

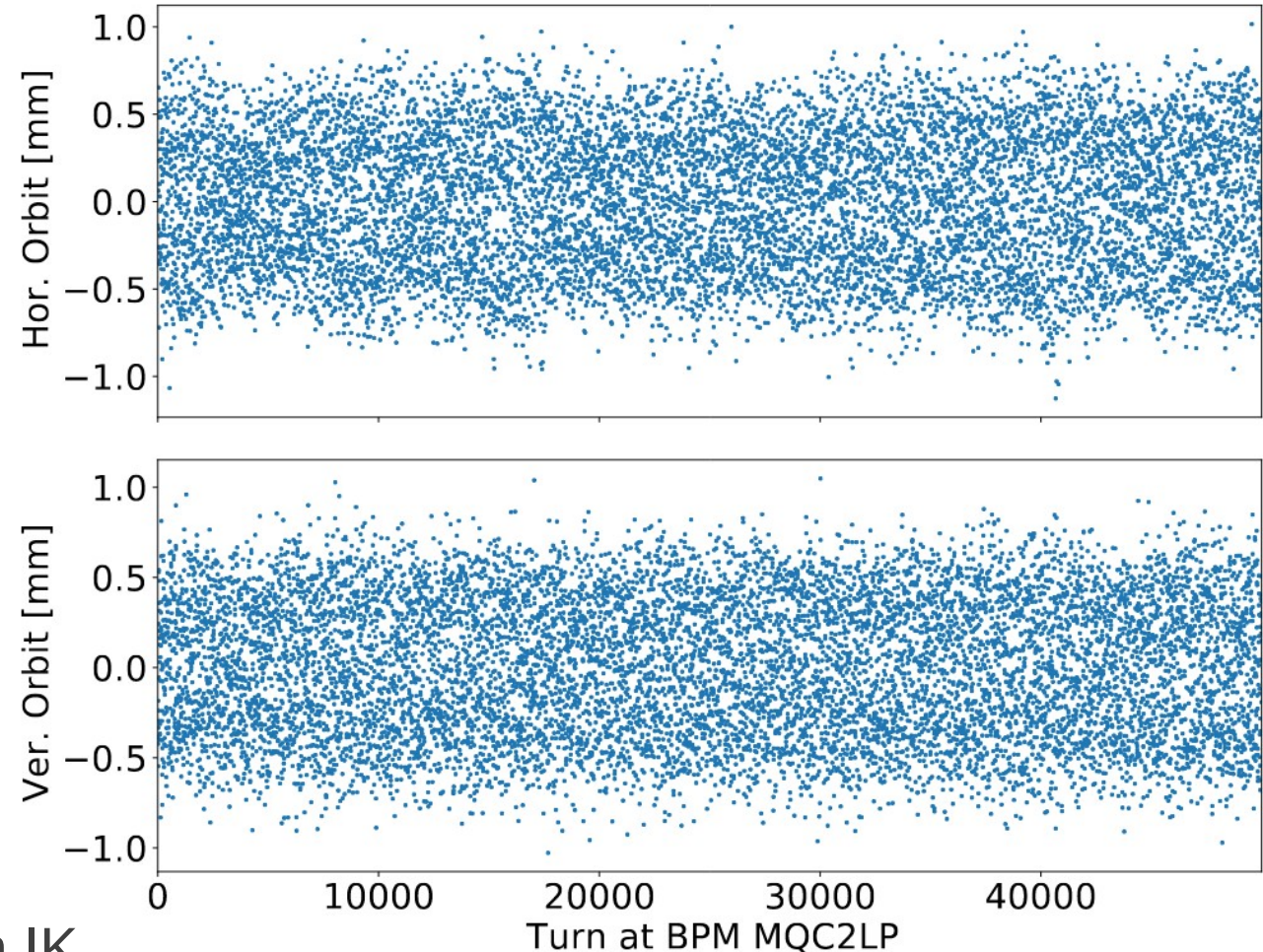
Turn-by-Turn IK

- About **70 BPMs** record TbT data
- Demands beam excitation
 - Single kick with IK
 - Only horizontal kicks



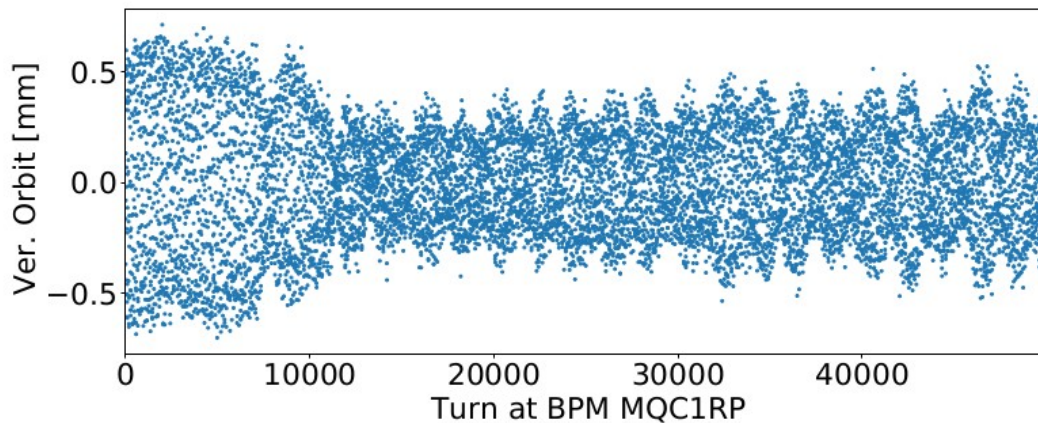
Turn-by-Turn PLL

- About **70 BPMs** record TbT data
- Demands beam excitation
 - Single kick with IK
 - Only horizontal kicks
 - Driven motion with PLL
 - Can excite both planes
 - No trigger to start measurements
 - Uses transverse feedback to find tune
 - Locks to the tune and amplifies
 - Up to 50000 turns recorded
 - Amplitude 5-10 times smaller than with IK

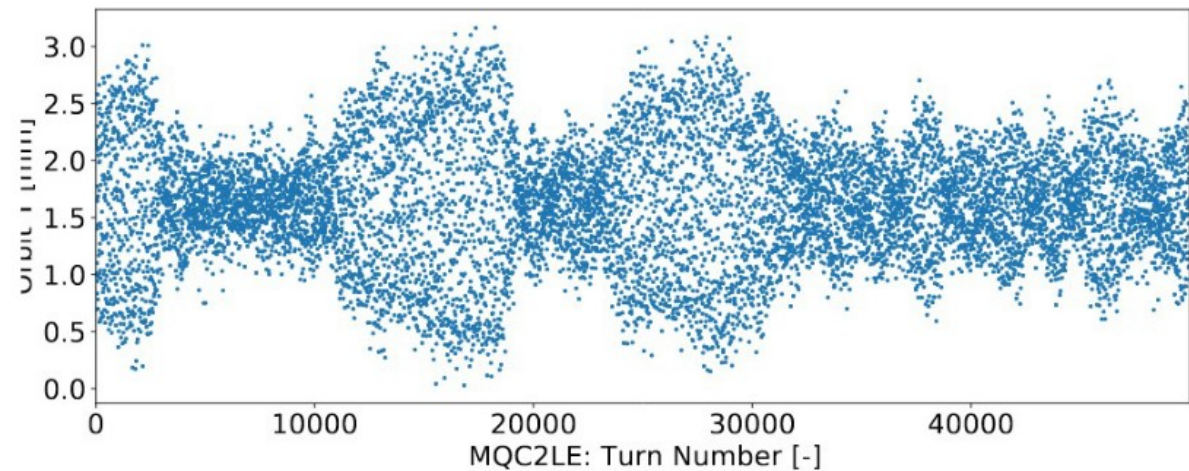
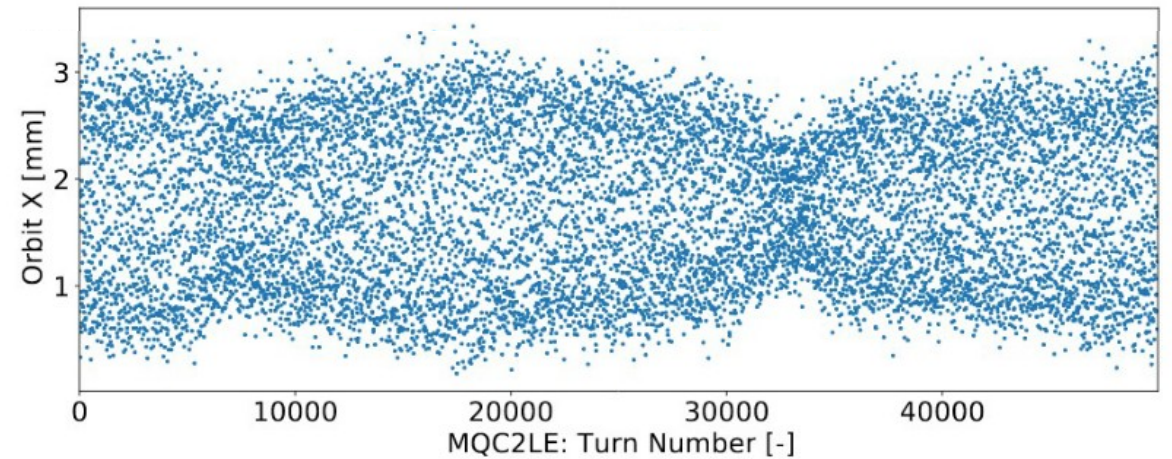


Measurement Quality

- Stabilization challenging, especially vertically
- Periodic pattern only in vertical plane
 - 50 Hz
 - For BPMs where $\beta_y > 250$ m
- Not constant amplitude \rightarrow Not used for optics measurements



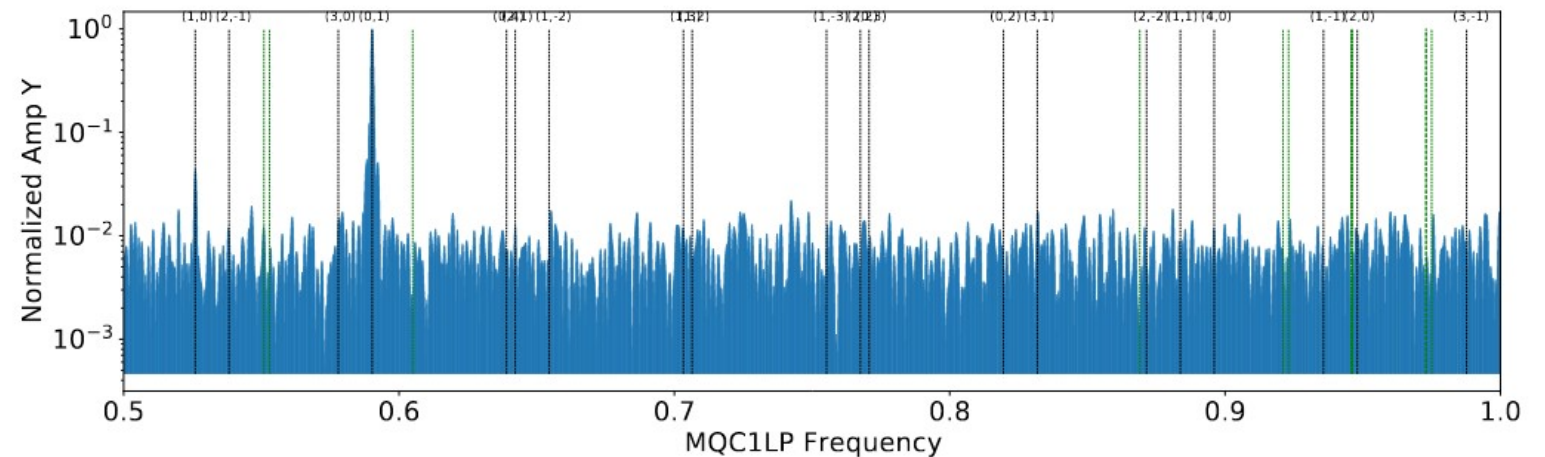
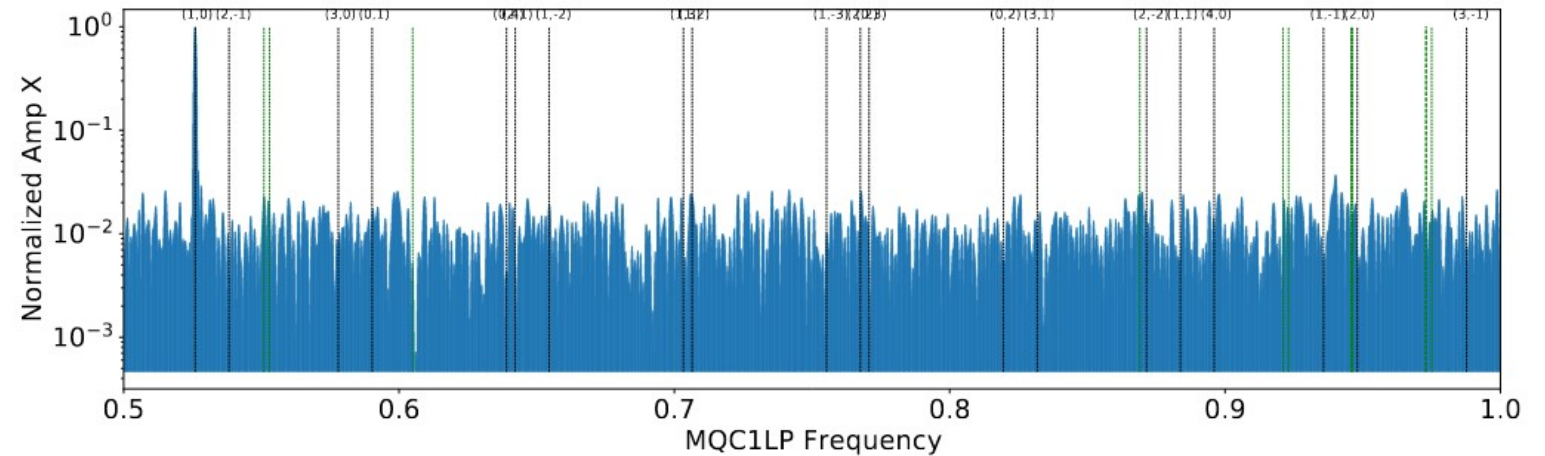
LER, PLL-HV, $\beta_{x,y}^ = 80,1$ mm*



HER, PLL-HV, $\beta_{x,y}^ = 80,1$ mm*

PLL Frequency Spectrum

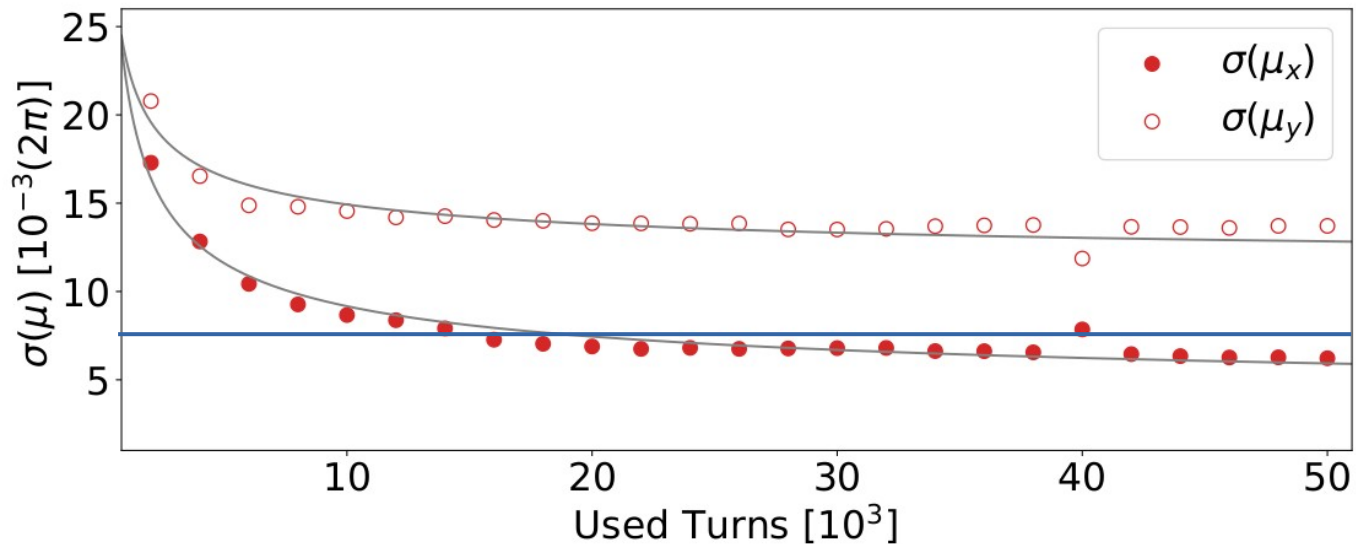
- Horizontally
 - Only Qx found
- Vertically
 - Qy and Qx found
 - In most measurements Qx in noise



LER, PLL-HV, $\beta_{x,y}^ = 80,1$ mm*

Optics Measurements with PLL

- Horizontal and vertical optics measurements possible using PLL, however:
- Rather large rms phase advance error with respect to model
- From about 7 measurement sets, only 3 stable for 50000 turns
- Error decreases with more turns



LER, PLL-HV, $\beta_{x,y}^ = 80,1$ mm*

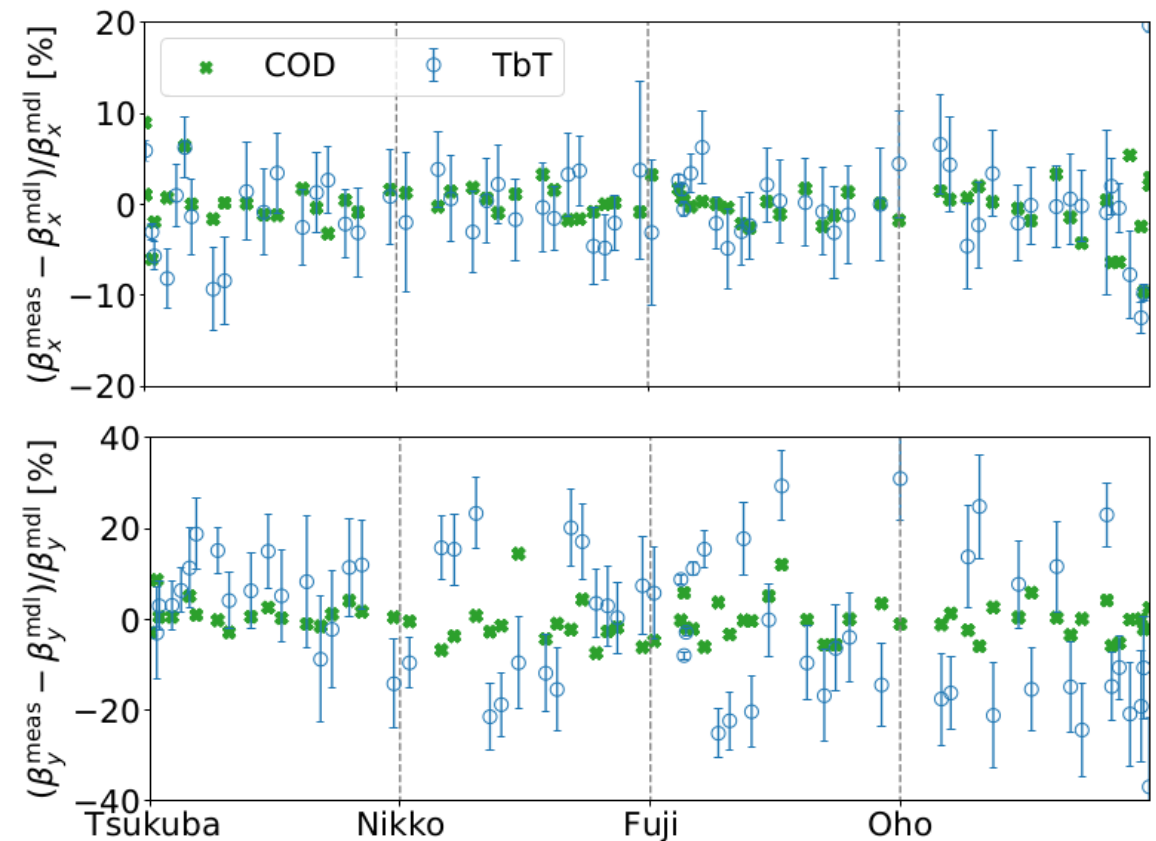
- Estimated BPM resolution for single bunch with 1 mA current
 - HER: 120 μm
 - LER: 250 μm

Rms phase advance error using IK and 2000 turns

Optics Measurements with PLL

- Horizontal and vertical optics measurements possible using PLL, however:
- Horizontally
 - Rms 2.8 % wrt model with COD
 - Rms 6.4 % wrt model with PLL
 - PLL errorbars 4 %
- Vertically
 - Rms 4.1 % wrt model with COD
 - Rms 14.6 % wrt model with PLL
 - PLL errorbars 9 %

Rms errors:
TbT-IK to COD ~6 %
TbT-PLL-H to COD ~14 %
TbT-PLL-V to COD ~20 %



$LER, PLL-HV, \beta_{x,y}^* = 80,1 \text{ mm}$

Comments

- Possibility to drive the beam in both transverse planes also simultaneously
- Very challenging to have constant excitation, especially vertically
- 50 Hz periodicity vertically (power converters?)
- No automatic trigger system → Recording of TbT data manually started
 - Requires also stable (~2 min) off-momentum driven optics for measurements
- Typically smaller driven vertical amplitude → higher amplitude could help measurements
 - However, very challenging to achieve

Thank you!

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Transverse Feedback System

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