

Update on Vibration studies at FCC-ee IR

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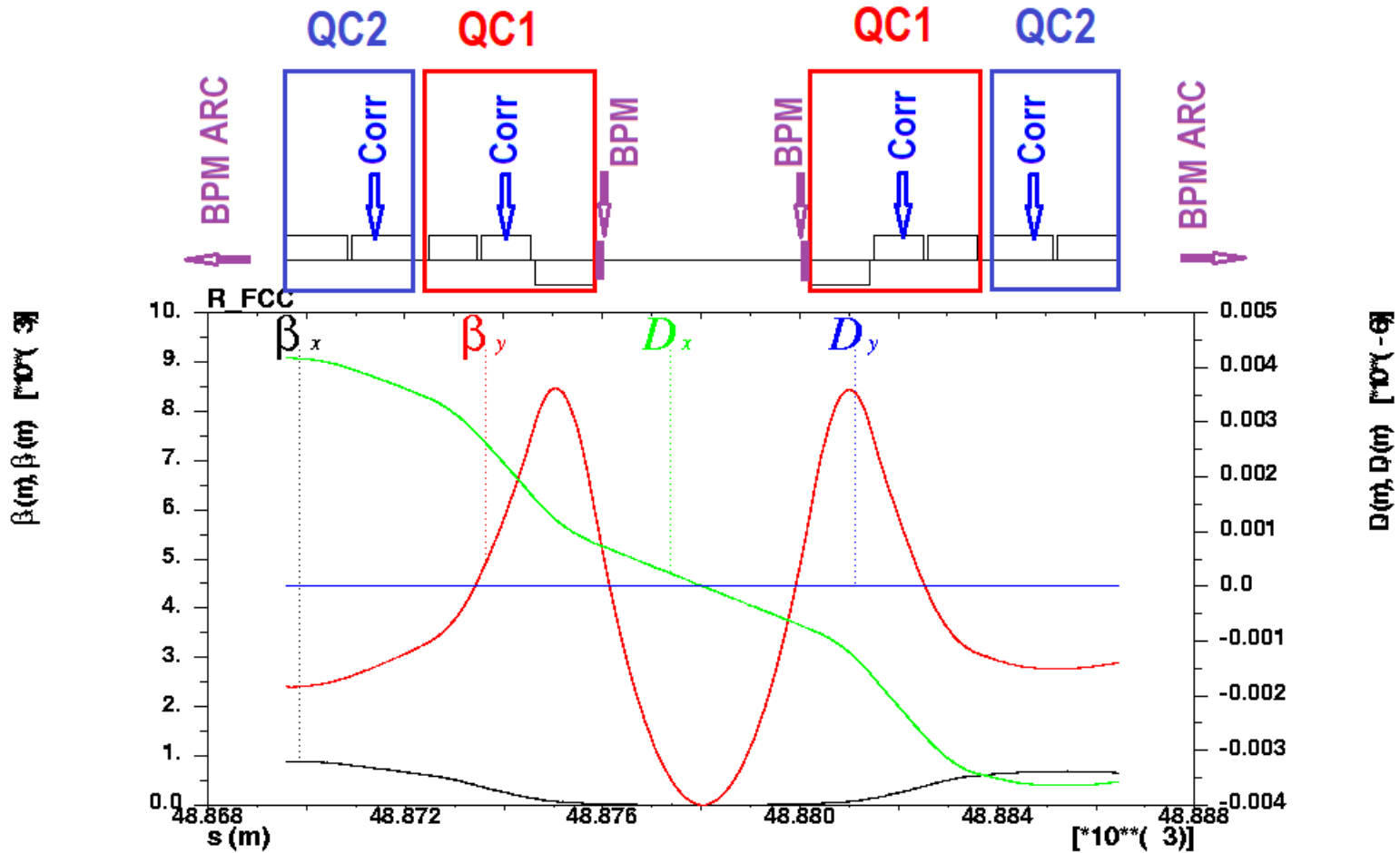
Task

- FF elements vibration:
 - Elements vibrate separately ($\sigma_{x,y} = 0.1 \mu\text{m}^*$).
 - Vibrations of element blocks ($\sigma_{x,y} = 0.1 \mu\text{m}^*$).
- No misalignments of other elements.
- BB kick is not included.
- COD is corrected by IR steering magnets in the FF quadrupoles.
- $N_{sample} = 100$
- [FCCee_z_213_nosol_18.seq](#)

FCC-ee parameters

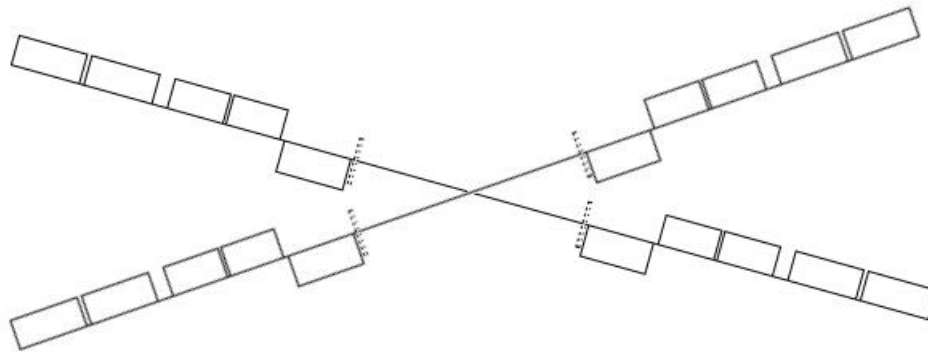
Parameter	Z	W	H(ZH)	ttbar
Beam energy [GeV]	45.6	80	120	182.5
Circumference [km]	97.756			
Arc cell options	60/60	90/90		
Hor. Emittance [nm*rad]	0.27	0.28	0.63	1.43
Ver. Emittance [pm*rad]	1	1	1.3	2.9
Hor.beta* [m]	0.15	0.2	0.3	1
Ver. Beta* [mm]	0.8	1	1	2
Hor. Size* [μm]	6.36	7.48	13.75	37.82
Ver. Size* [nm]	28.3	31.6	36.1	76.2
Energy acceptance [%]	1.9	1.9	2.3	4.7
Energy spread [%]	0.132	0.153	0.151	0.195
Bunch intensity [10^{11}]	1.7	1.5	1.5	2.8
N of bunches	16640	2030	401	40
Luminosity [$10^{34} \text{ cm}^{-2} \text{ s}^{-1}$]	230	34	8.5	1.9

Correction scheme



FF quads vibrations

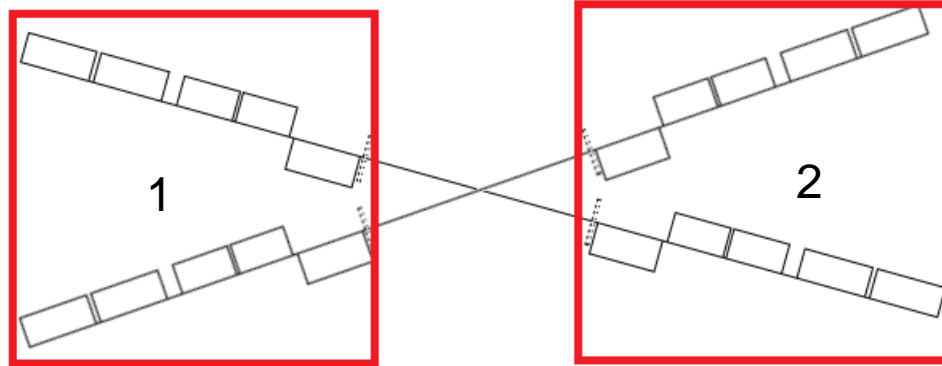
No correction. No block. (0)



- $N_{sample} = 100$.
- Individual random misalignments for each element.
- $\sigma_{x,y} = 0.1 \mu\text{m}$, truncated at 2σ .
- Correction is not applied.
- No errors of BPMs and ARC elements.

FF quads vibrations

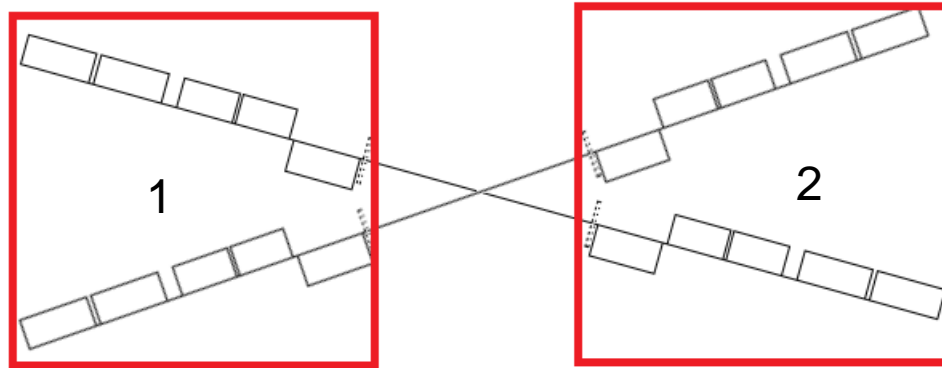
No correction. Block. (1)



- $N_{sample} = 100$.
- Individual random misalignments for each block.
- $\sigma_{x,y} = 0.1 \mu\text{m}$, truncated at 2σ .
- Correction is not applied.
- Block1: QC1L1.1, QC1L2.1, QC1L3.1, QC2L1.1, QC2L2.1, MON1L.1.
- Block2: QC1R1.1, QC1R2.1, QC1R3.1, QC2R1.1, QC2R2.1, MON1R.1.

FF quads vibrations

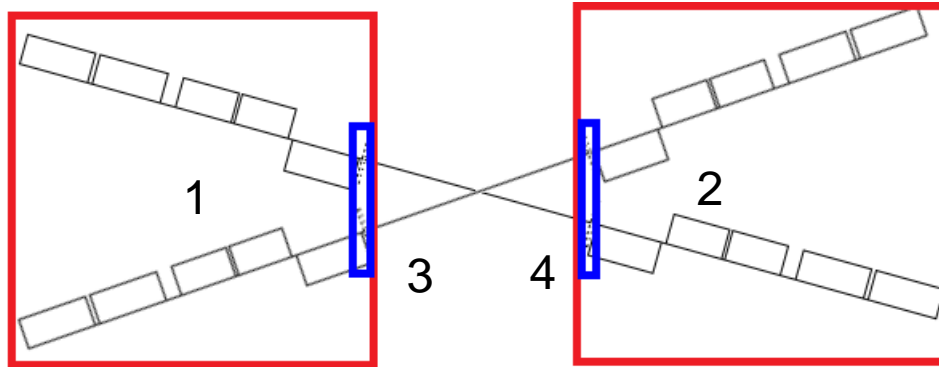
After correction. Block=Q+BPM. (2)



- $N_{sample} = 100$.
- Individual random misalignments for each block.
- $\sigma_{x,y} = 0.1 \mu\text{m}$, truncated at 2σ .
- COD is corrected by FF steering magnets.
- Block1: QC1L1.1, QC1L2.1, QC1L3.1, QC2L1.1, QC2L2.1, MON1L.1.
- Block2: QC1R1.1, QC1R2.1, QC1R3.1, QC2R1.1, QC2R2.1, MON1R.1.

FF quads vibrations

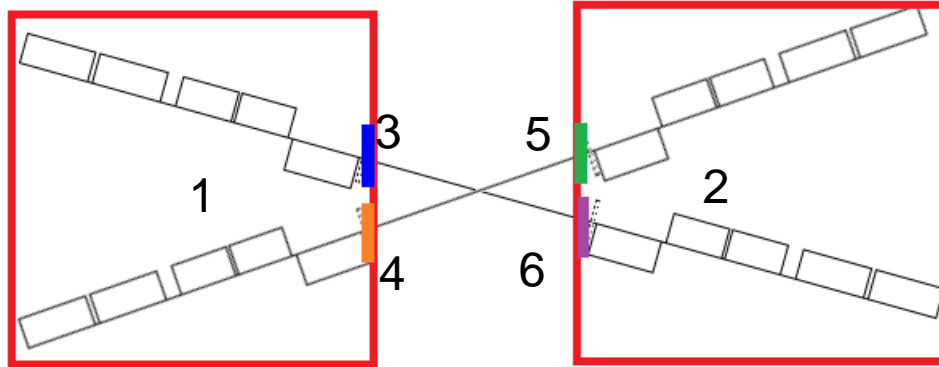
After correction. Block. (3)



- $N_{sample} = 100$.
- Individual random misalignments for each block.
- $\sigma_{x,y} = 0.1 \mu\text{m}$, truncated at 2σ .
- COD is corrected by FF steering magnets.
- Block1: QC1L1.1, QC1L2.1, QC1L3.1, QC2L1.1, QC2L2.1
- Block2: QC1R1.1, QC1R2.1, QC1R3.1, QC2R1.1, QC2R2.1
- Block3: MON1L.1
- Block4: MON1R.1

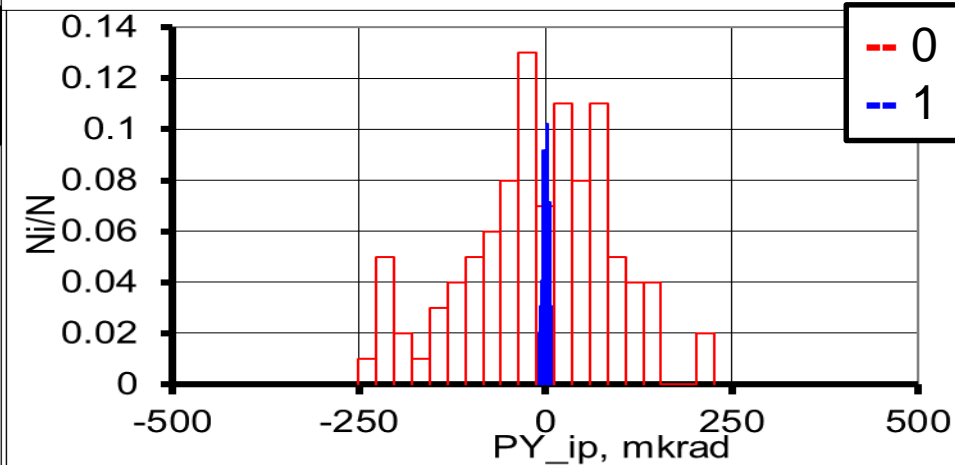
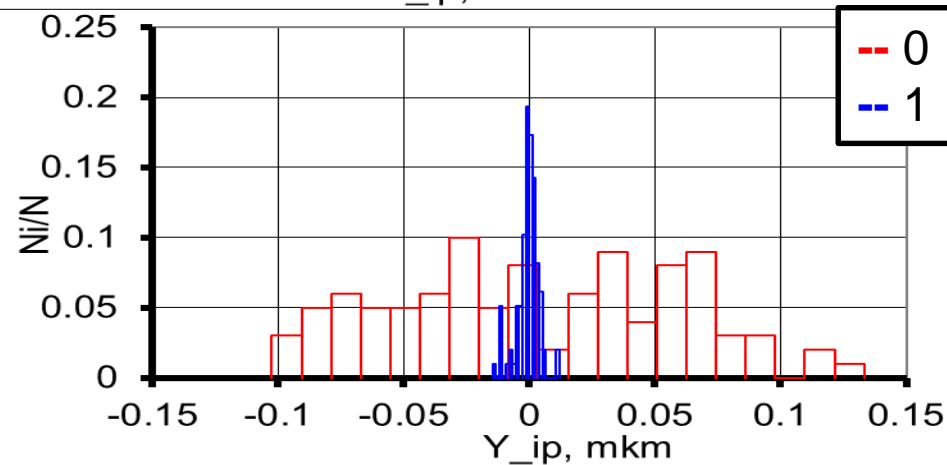
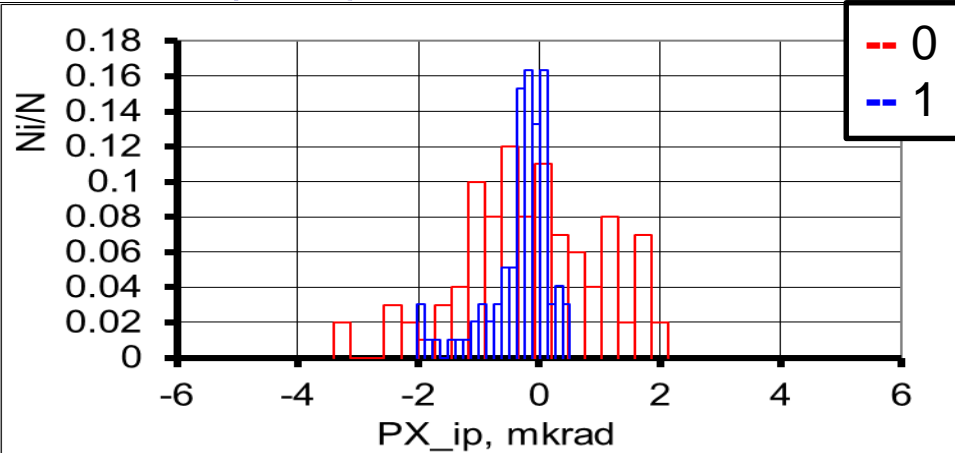
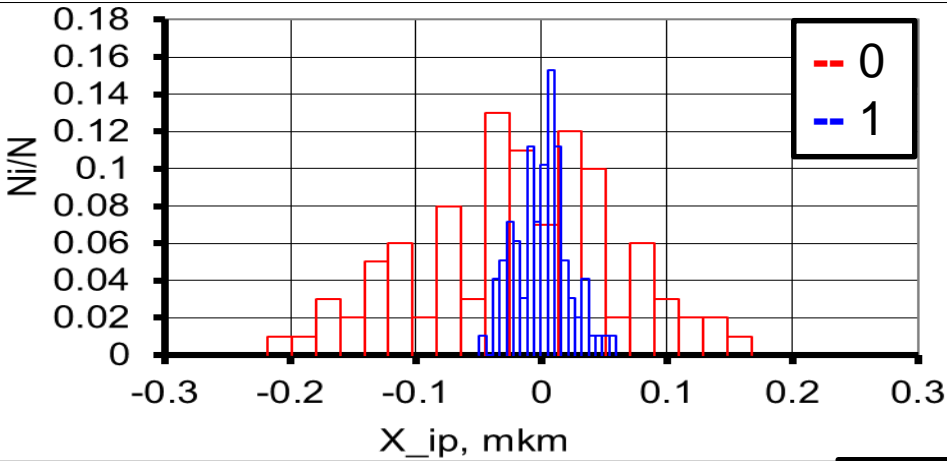
FF quads vibrations

After correction. Block. (4)



- $N_{sample} = 100$.
- Individual random misalignments for each block.
- $\sigma_{x,y} = 0.1 \mu\text{m}$, truncated at 2σ .
- COD is corrected by FF steering magnets.
- Block1: QC1L1.1, QC1L2.1, QC1L3.1, QC2L1.1, QC2L2.1
- Block2: QC1R1.1, QC1R2.1, QC1R3.1, QC2R1.1, QC2R2.1
- 3-6: Random misalignment of every BPM individually (reading errors).

Parameters at IP (0;1)

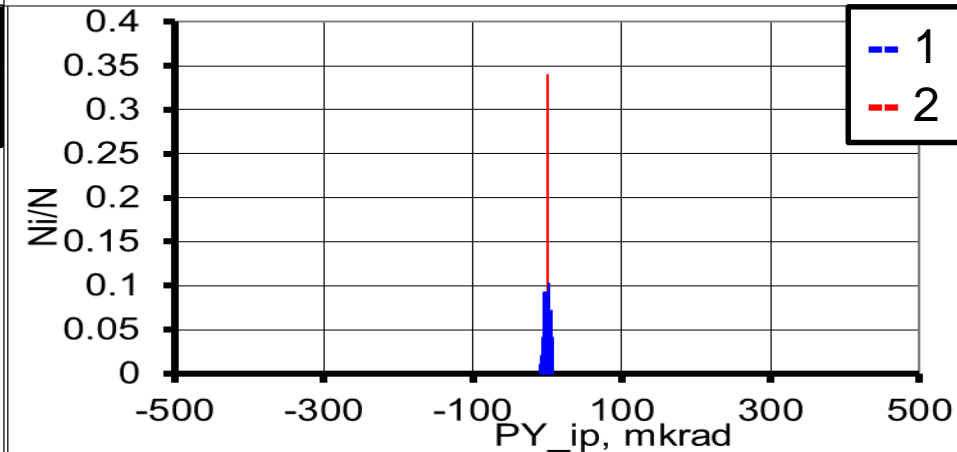
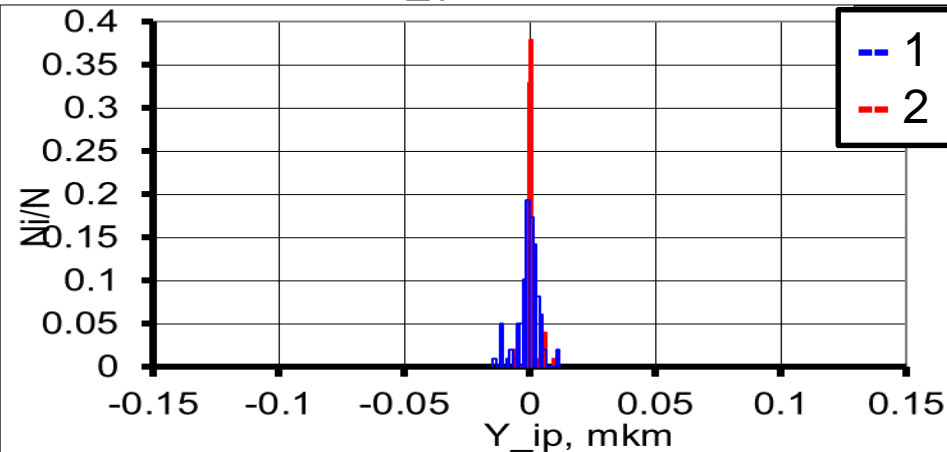
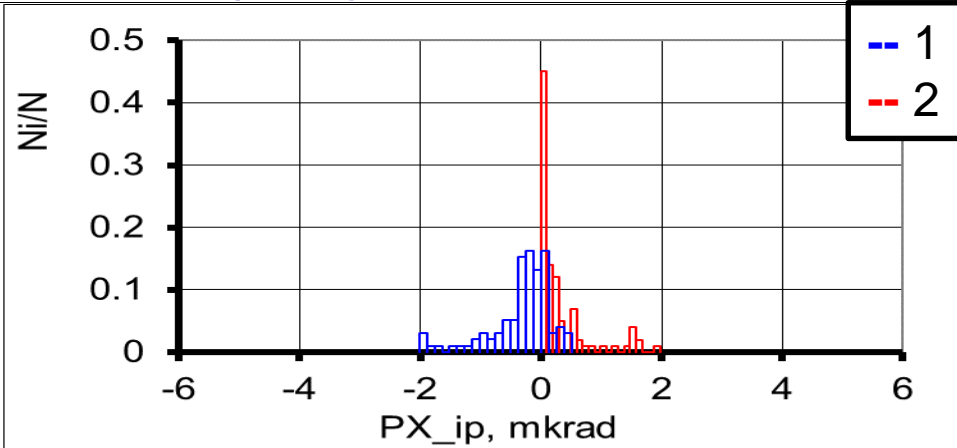
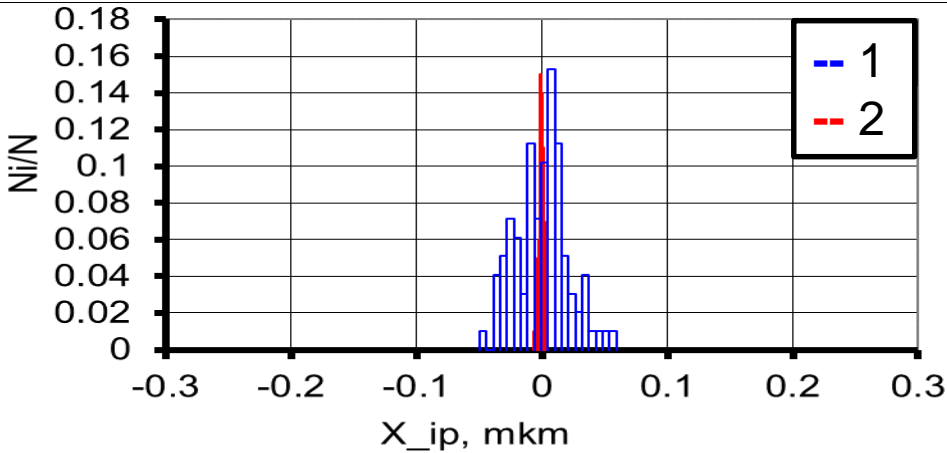


FF Quads (without correction): $\sigma_{x,y} = 0.1 \mu\text{m}$, $N_{\text{samples}} = 100$

0 – Separate vibration: $\sigma_X = 79 \text{ nm}$, $\sigma_{PX} = 1.1 \mu\text{rad}$, $\sigma_Y = 57 \text{ nm}$, $\sigma_{PY} = 98 \mu\text{rad}$.

1 – Orbit_{electron} – Orbit_{positron} – Block vibrations: $\sigma_X = 21.1 \text{ nm}$, $\sigma_{PX} = 0.529 \mu\text{rad}$, $\sigma_Y = 4.4 \text{ nm}$, $\sigma_{PY} = 4.01 \mu\text{rad}$.

Parameters at IP (1;2)

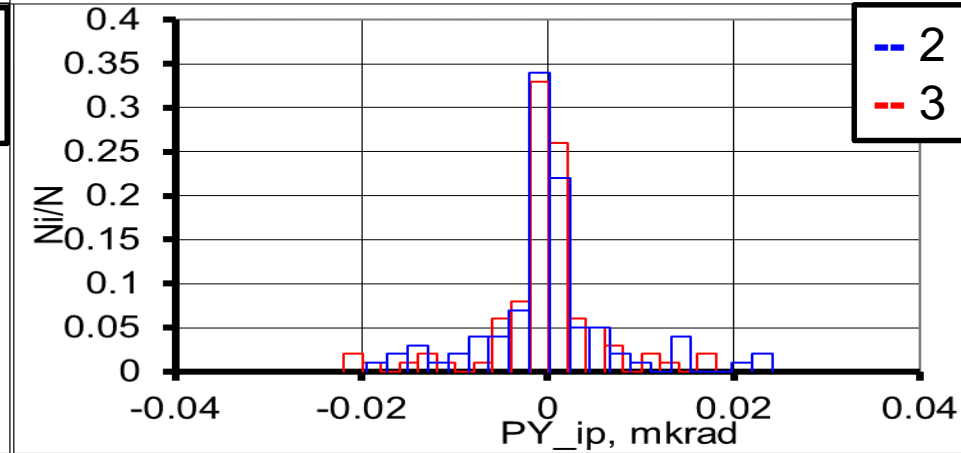
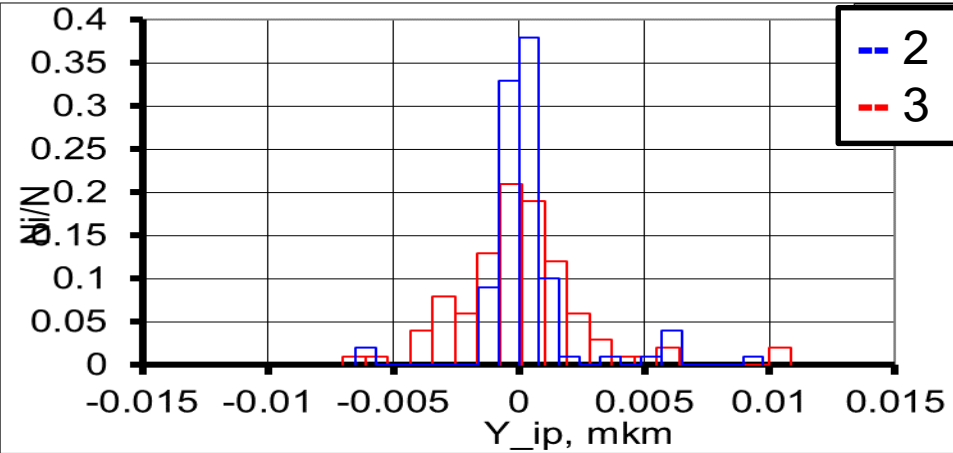
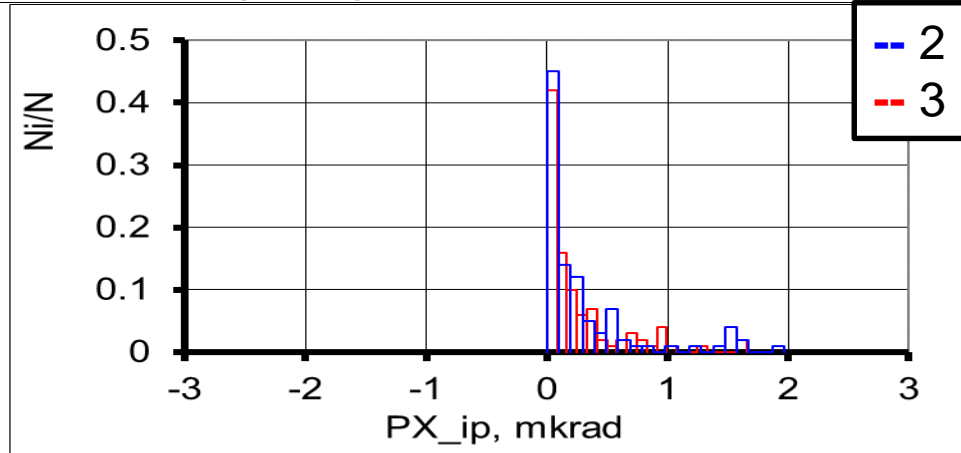
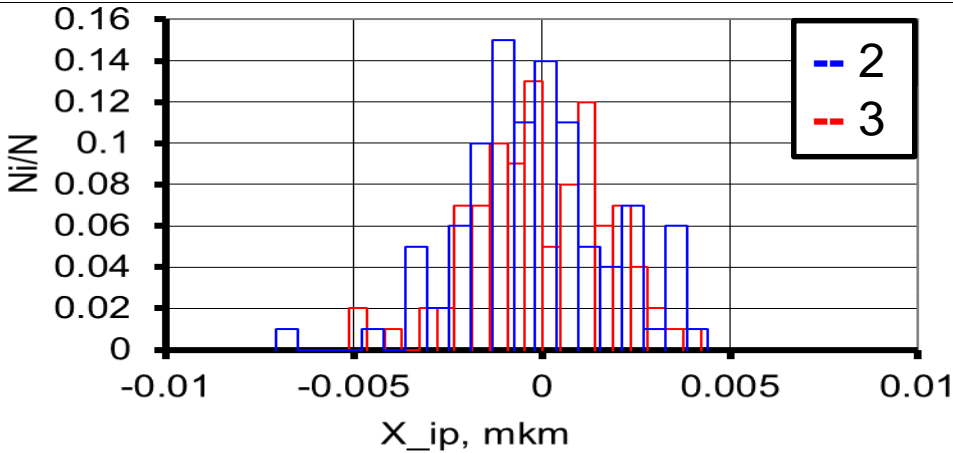


FF Quads: $\sigma_{x,y} = 0.1 \mu\text{m}$, $N_{\text{samples}} = 100$

1 – Orbit_{electron} – Orbit_{positron} – Block vibrations (before correction): $\sigma_X = 21.1 \text{ nm}$, $\sigma_{PX} = 0.529 \mu\text{rad}$, $\sigma_Y = 4.4 \text{ nm}$, $\sigma_{PY} = 4.01 \mu\text{rad}$.

2 – Orbit_{electron} – Orbit_{positron} – Block vibrations (after correction): $\sigma_X = 1.95 \text{ nm}$, $\sigma_{PX} = 0.445 \mu\text{rad}$, $\sigma_Y = 1.96 \text{ nm}$, $\sigma_{PY} = 0.007 \mu\text{rad}$.

Parameters at IP (2;3)

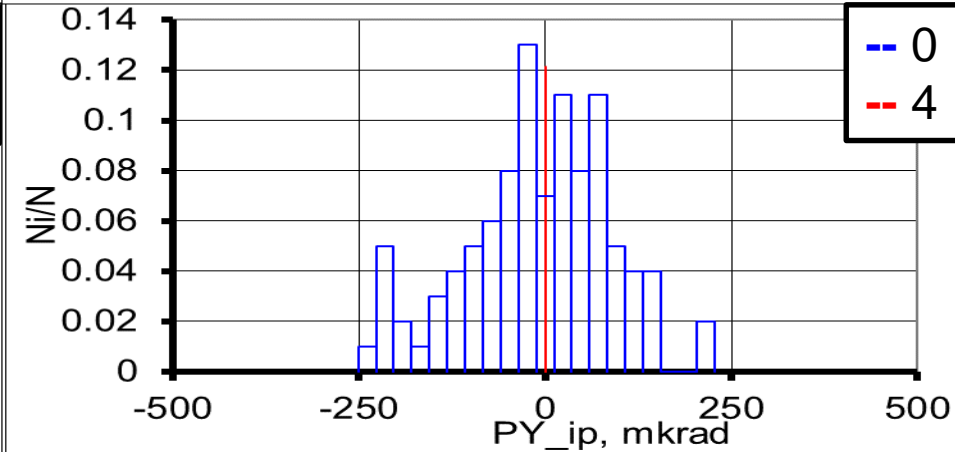
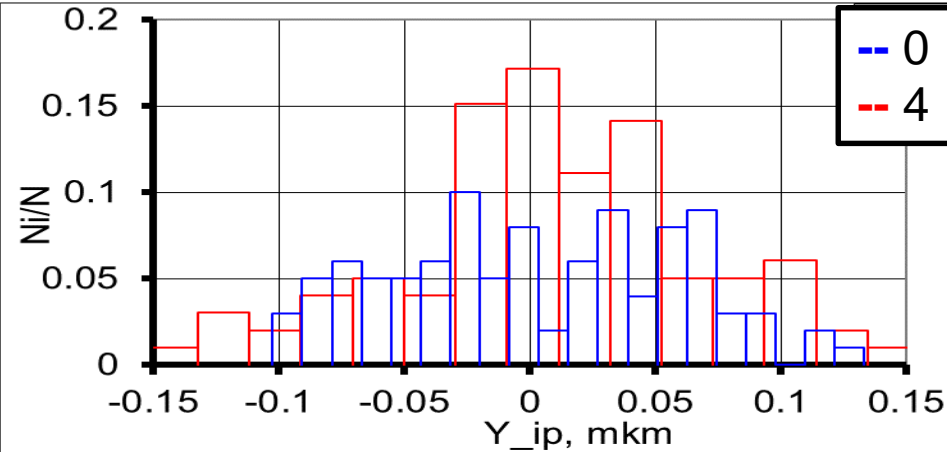
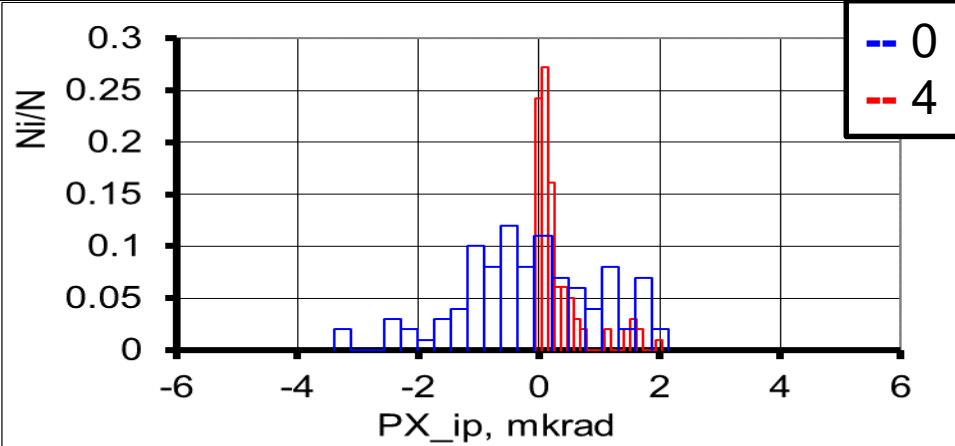
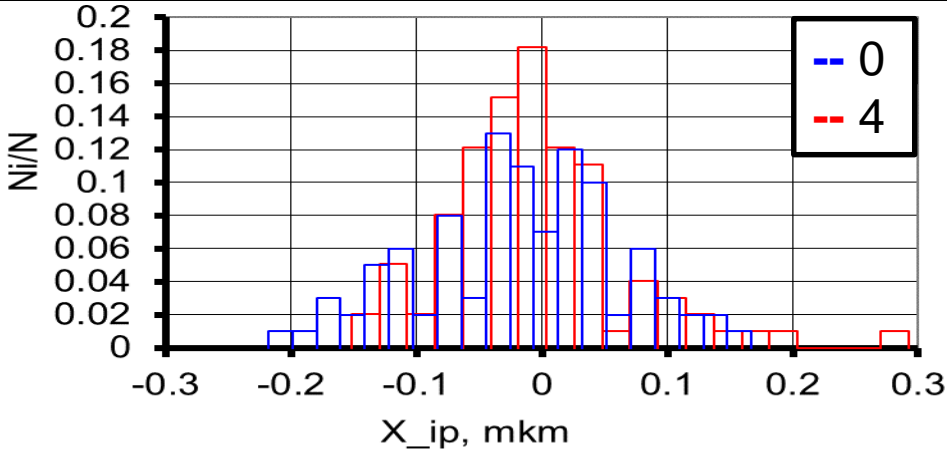


FF Quads: $\sigma_{x,y} = 0.1 \mu\text{m}$, $N_{\text{samples}} = 100$

2 – Orbit_{electron} – Orbit_{positron} – Block vibrations (after correction): $\sigma_X = 1.95 \text{ nm}$, $\sigma_{PX} = 0.445 \mu\text{rad}$, $\sigma_Y = 1.96 \text{ nm}$, $\sigma_{PY} = 0.007 \mu\text{rad}$.

3 – Orbit_{electron} – Orbit_{positron} – Block vibrations (after correction): $\sigma_X = 1.81 \text{ nm}$, $\sigma_{PX} = 0.347 \mu\text{rad}$, $\sigma_Y = 2.65 \text{ nm}$, $\sigma_{PY} = 0.006 \mu\text{rad}$.

Parameters at IP (0;4)



FF Quads: $\sigma_{x,y} = 0.1 \mu\text{m}$, $N_{\text{samples}} = 100$

0 – Separate vibration: $\sigma_X = 79 \text{ nm}$, $\sigma_{PX} = 1.1 \mu\text{rad}$, $\sigma_Y = 57 \text{ nm}$, $\sigma_{PY} = 98 \mu\text{rad}$.

4 – Orbit_{electron} – Orbit_{positron} – Block vibrations, reading errors (after correction):
 $\sigma_X = 71 \text{ nm}$, $\sigma_{PX} = 0.453 \mu\text{rad}$, $\sigma_Y = 70 \text{ nm}$, $\sigma_{PY} = 0.048 \mu\text{rad}$.

FCC-ee parameters (Z)

Parameter	0	1	2	3	4
Beam energy [GeV]	45.6				
Hor. Size* [μm]	6.36				
Ver. Size* [nm]	28.3				
Misalignments, μm	0.1	0.1	0.1	0.1	0.1
Block	-	+	+	+	+-
Correction	-	-	+	+	+
($X_{e^+} - X_{e^-}$)_IP, nm	79	21	2	1.8	71
($PX_{e^+} - PX_{e^-}$)_IP, nrad	1100	529	445	347	453
($Y_{e^+} - Y_{e^-}$)_IP, nm	57	4	2	2.7	70
($PY_{e^+} - PY_{e^-}$)_IP, nrad	98000	4010	7	6	48
<i>Lumi reduction, %</i>	100	3	0.5	0.9	100

Conclusion

- The beams do not collide with $0.1 \mu\text{m}$ vibrations of each FF Quads individually.
- The beams collide with $0.1 \mu\text{m}$ block vibrations of FF Quads.
- Feedback from IR BPMs reduces distortions of CO.
- Block of IR BPMs with FF quads provides best performance.
- It is impossible to use the IR BPMs for the feedback system with reading errors $\sigma_x = 0.1 \mu\text{m}$ (BB kick is not taken into account).