Institute of High Energy Physics
Chinese Academy of Sciences

Circular Electron Positron Collider

CEPC partial double ring magnet error effects

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CEPC-SppC study group meeting

LEP Alignment parameters

Alignment of LEP components

Component	⟨y⟩ (mm)	⟨x⟩ (mm)	⟨tilt⟩ (mrad)
Dipole magnets	± 0.2	± 0.3	± 0.1
Quadrupole magnets	± 0.1	± 0.1	± 0.1
Low-beta quadrupoles	± 0.05	± 0.05	± 0.1
SC cavity modules	± 1	± 1	–
Cu cavities, 325.2 MHz	± 0.2	± 0.2	–
Electrostatic separators	± 0.5	± 0.5	± 1
Synchr. rad. masks at the IPs	± 0.3	± 0.3	–

From: LEP Design Report---------LEP2 P177

Magnet Field error 1

Tolerances on the random dispersion of the magnetic strength (r.m.s. values)

In dipole magnets	$\langle \Delta B/B \rangle < 5 \times 10^{-4}$
In quadrupole magnets	$\langle \Delta K/K \rangle < 5 \times 10^{-4}$
In sextupole magnets	$\langle \Delta K'/K' \rangle < 4 \times 10^{-3}$

From: LEP Design Report---------LEP P18

Magnet Field error 2

Tolerances on the systematic field components in lattice elements

Field component	Lattice element	Dipole $\lvert\Delta B/B\rvert_{59\ mm}$	Quadrupole $\lvert\Delta G/G\rvert_{59\ mm}$	Sextupole $\lvert\Delta K'/K'\rvert_{59\ mm}$
Quadrupole		8×10^{-4}		
Sextupole	$K' > 0$	2×10^{-4}	6×10^{-4}	
	$K' < 0$	5×10^{-4}		
Octupole		7×10^{-5}	5×10^{-4}	1.7×10^{-3}
Decapole		1.3×10^{-4}	6.9×10^{-4}	3.4×10^{-3}
Dodecapole		1.4×10^{-4}	1.0×10^{-3}	6.5×10^{-3}
18-pole				1.6×10^{-2}

From: LEP Design Report---------LEP P19

Magnet Field error 3

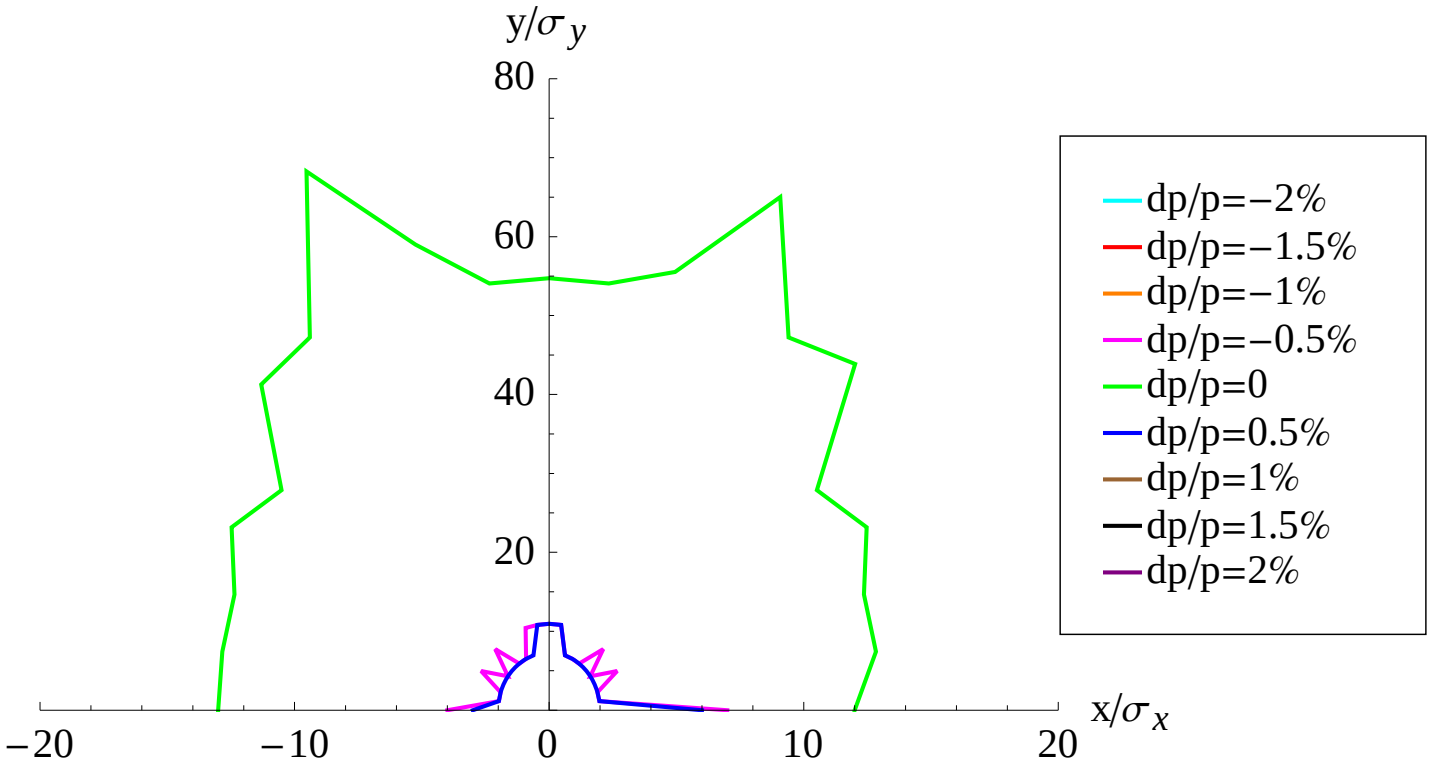
Tolerances on the random field components in lattice elements (r.m.s. values)

Field component \ Lattice element	Dipole $\langle \Delta B/B \rangle_{59\ mm}$	Quadrupole $\langle \Delta G/G \rangle_{59\ mm}$	Sextupole $\langle \Delta K'/K' \rangle_{59\ mm}$
Quadrupole	2×10^{-4}		
Sextupole	2.9×10^{-4}	1.2×10^{-3}	
Multipole	2×10^{-4}	10^{-3}	2×10^{-2}

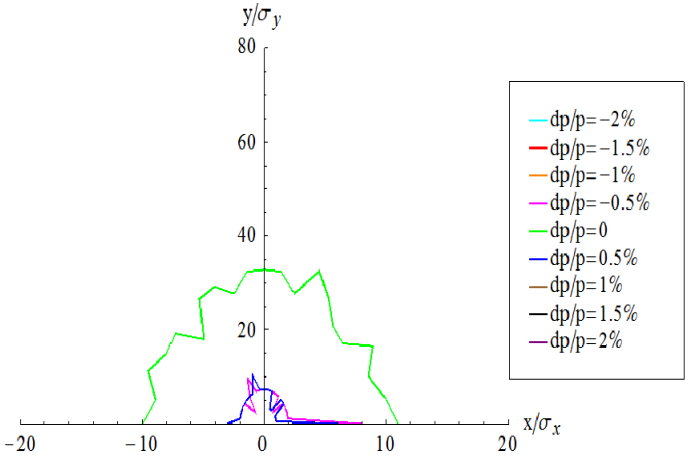
From: LEP Design Report---------LEP P19

DA without error

Lattice版本： CEPC-ARC1.0-PDR1.0-FFS (WD1.0)



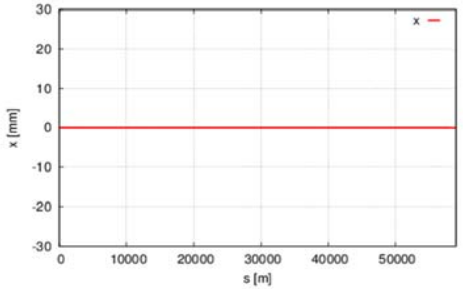
Quadrupole field error on DA



With quadrupole B*L error

(whole ring including FFS)

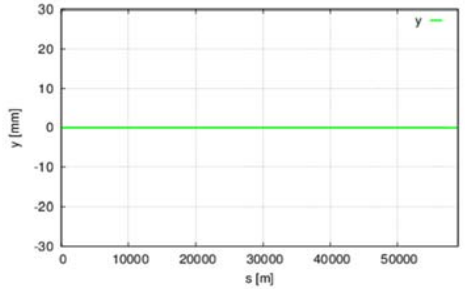
μ_x= 0.0793130 μ_y= 0.2740339



Orbit in X

With quad B*L error

(whole ring including FFS)



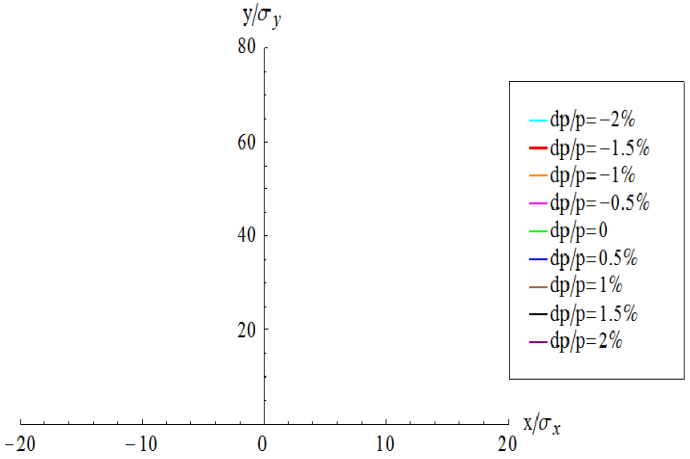
Orbit in Y

With quad B*L error

(whole ring including FFS)

- With quad magnet field errors, orbit has no change, but tune is changed a little bit
- Orbit correction is not needed
- With Quadrupole and sextupole field errors, orbit has no change.
- Tracking in 240 turns, coupling factor κ=0.003 for ε_y

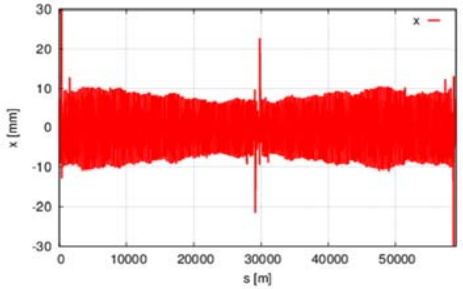
Bending magnets field error on DA



With bend B*L error

(whole ring including FFS)

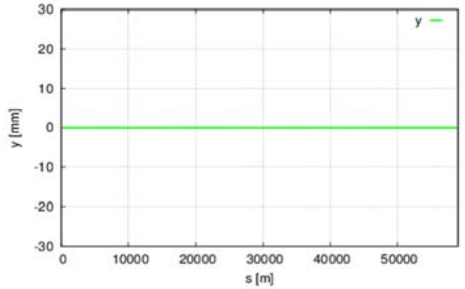
$\mu_x = 0$ $\mu_y = 0$



Orbit in X

With bend B*L error

(whole ring including FFS)



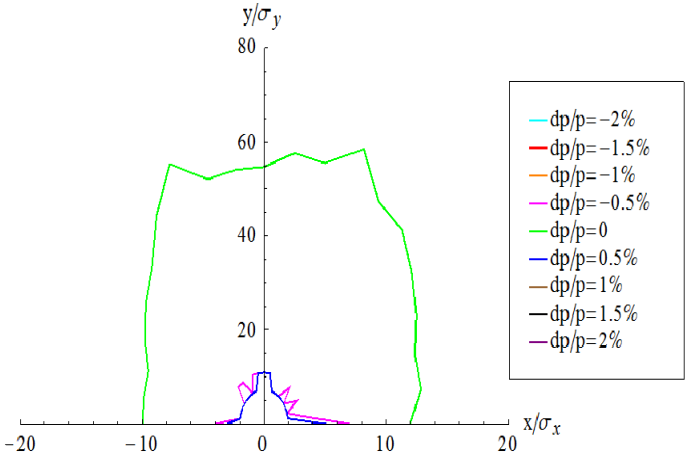
Orbit in Y

With bend B*L error

(whole ring including FFS)

- With bending magnet field errors, horizontal orbit has changed a lot, but vertical has no change
- Tune has changed to be an integer resonance, beam is not stable.
- Orbit correction is needed in horizontal
- Tracking in 240 turns, coupling factor κ=0.003 for ε_y

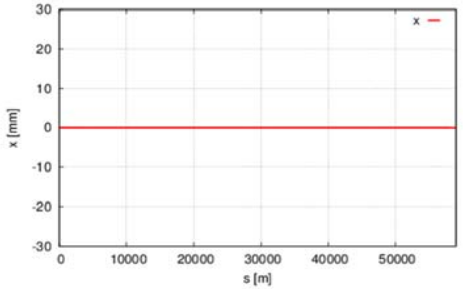
Sextupole field error on DA



With sextupole B*L error

(whole ring including FFS)

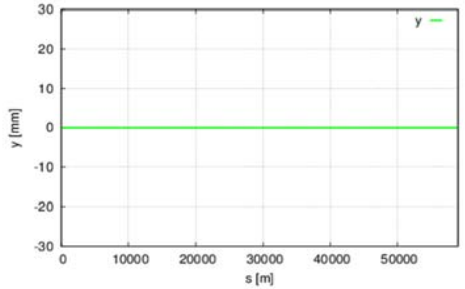
μ_x= 0.0799972 μ_y= 0.2198675



Orbit in X

With sextupole B*L error

(whole ring including FFS)



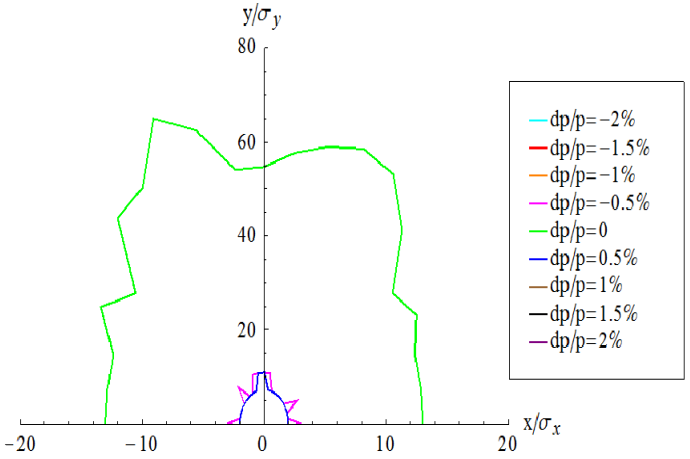
Orbit in Y

With sextupole B*L error

(whole ring including FFS)

- With sextupole magnet field errors, tune has no change.
- Orbit has no change and orbit correction is not needed.
- DA is reduced due to the the chromatic aberration.
- Tracking in 240 turns, coupling factor κ=0.003 for ε_y

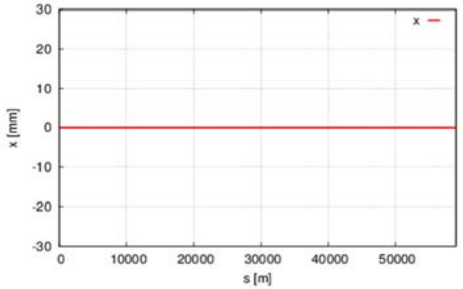
Bending magnets misalignment errors on DA



With bends misalignment error

(whole ring including FFS)

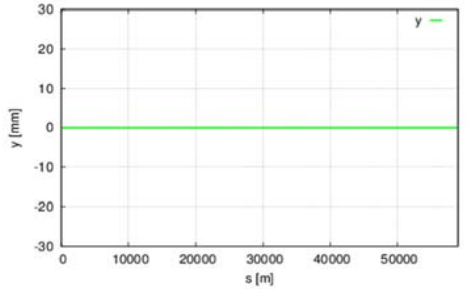
μ_x= 0.0799941 μ_y= 0.2198752



Orbit in X

With bends misalignment error

(whole ring including FFS)



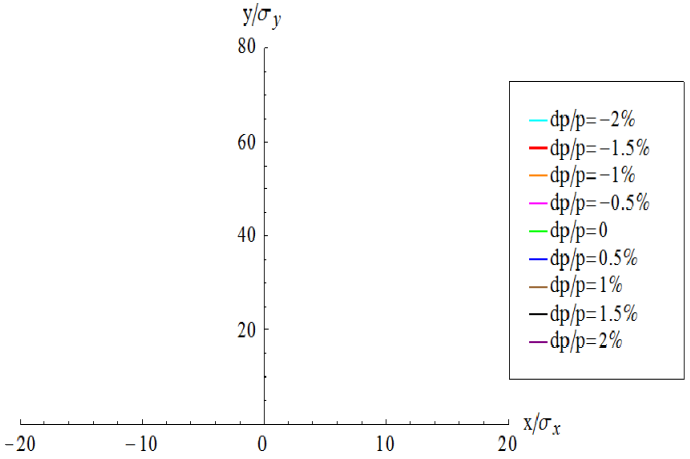
Orbit in Y

With bends misalignment error

(whole ring including FFS)

- With bends misalignment errors, tune has no change.
- Orbit has no change and orbit correction is not needed.
- DA seems not so sensitive to bends misalignment errors in CEPC partial double ring.
- Tracking in 240 turns, coupling factor κ=0.003 for ε_y

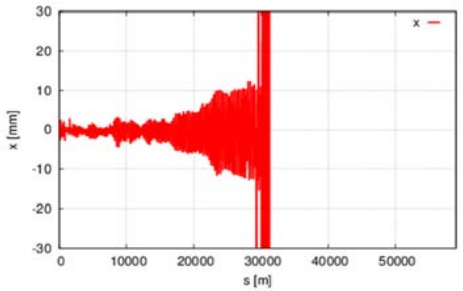
Quadrupole misalignment errors on DA



With quads misalignment error

(whole ring including FFS)

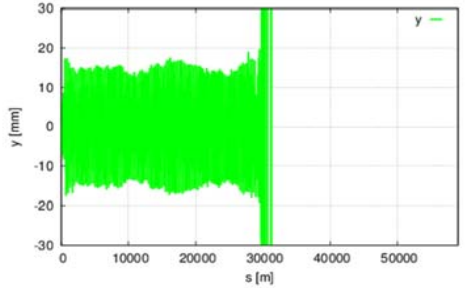
$\mu_x = 0$ $\mu_y = 0$



Orbit in X

With quads misalignment error

(whole ring including FFS)



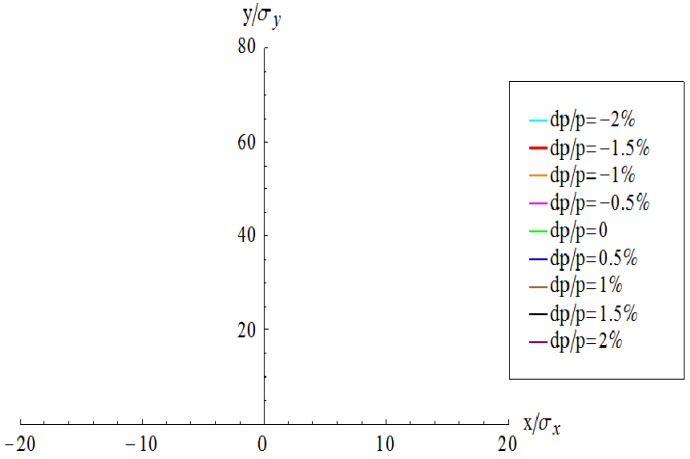
Orbit in Y

With quads misalignment error

(whole ring including FFS)

- With quads misalignment errors, both horizontal and vertical orbit have changed a lot.
- Tune has changed to be an integer resonance, beam is not stable.
- Orbit correction is needed.
- Tracking in 240 turns, coupling factor κ=0.003 for ε_y

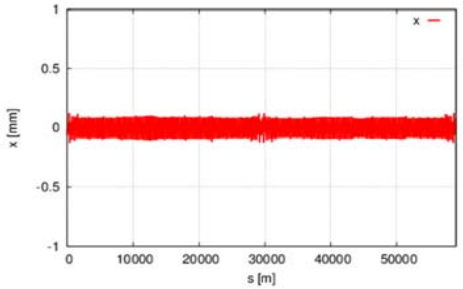
Sextupole misalignment errors on DA



With sextupole misalignment error

(whole ring including FFS)

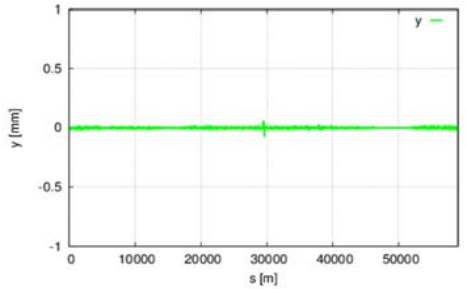
μ_x= 0.113601 μ_y= 0.5



Orbit in X

With quads misalignment error

(whole ring including FFS)



Orbit in Y

With quads misalignment error

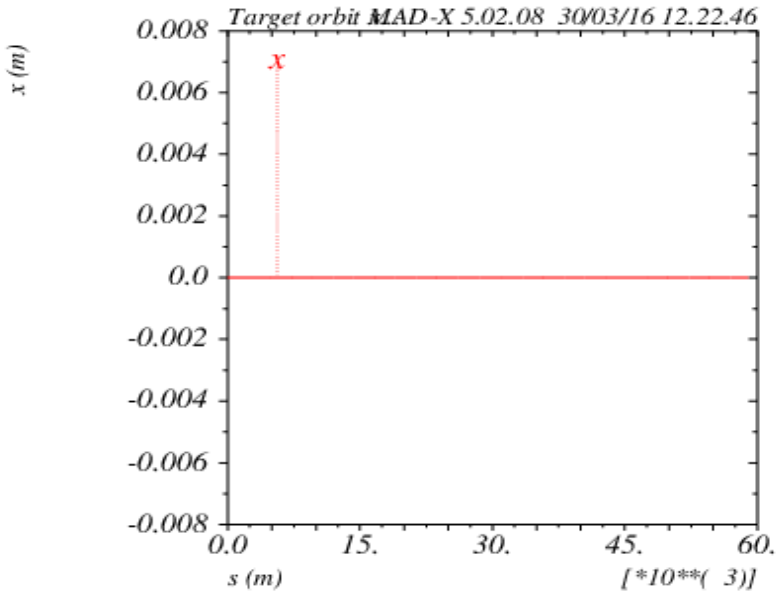
(whole ring including FFS)

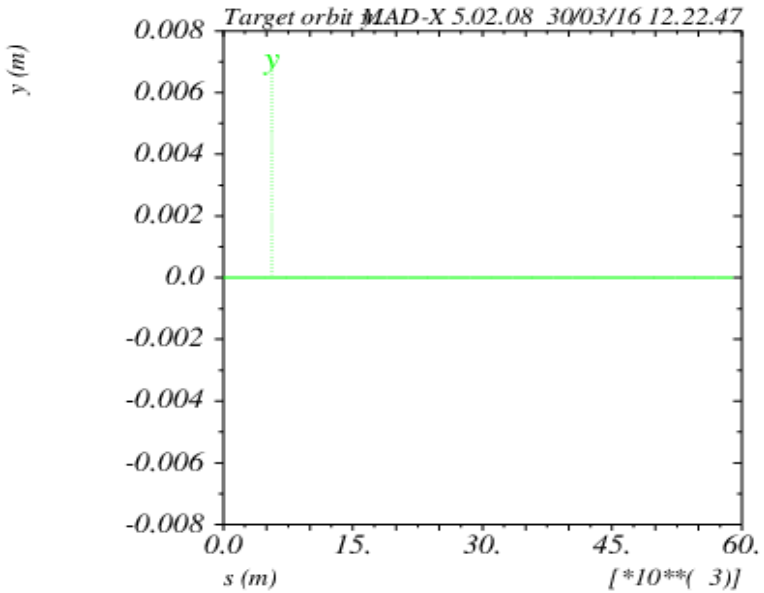
- With sextupole misalignment errors, both horizontal and vertical orbit have changed.
- Tune has changed to be a half integer resonance, beam is not stable.
- Orbit correction is needed.
- Tracking in 240 turns, coupling factor κ=0.003 for ε_y

Target orbit

no error

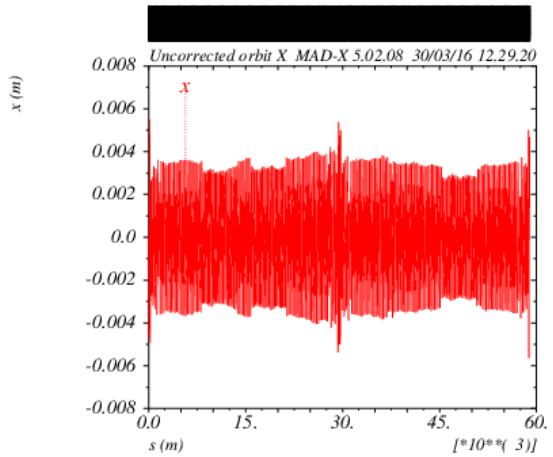
Lattice版本： CEPC-ARC1.0-PDR1.0-FFS (WD1.0)

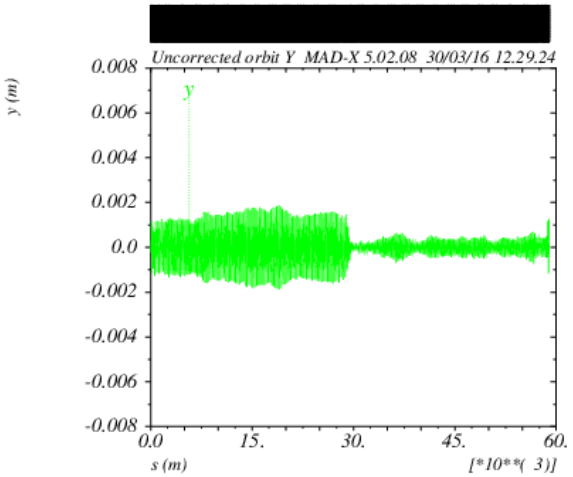




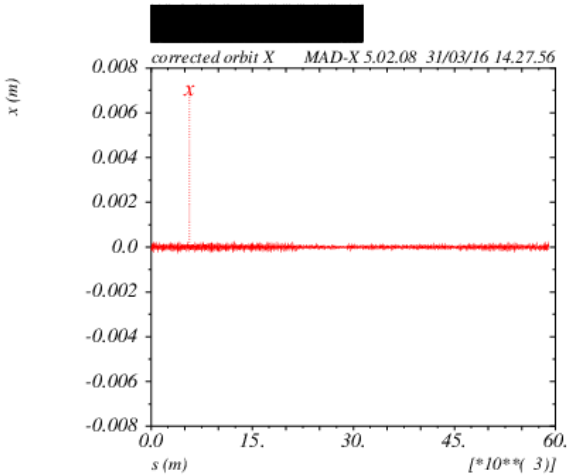
Orbit correction result

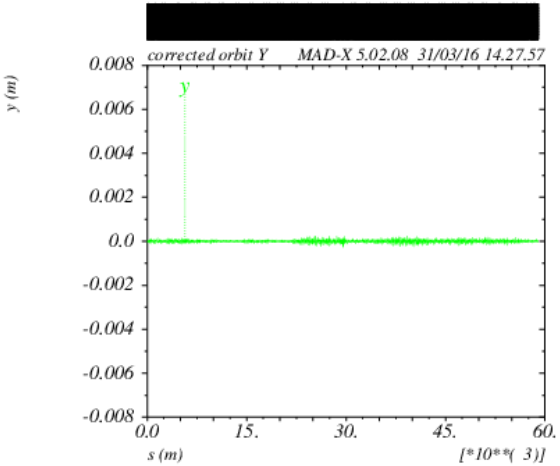
Before correction



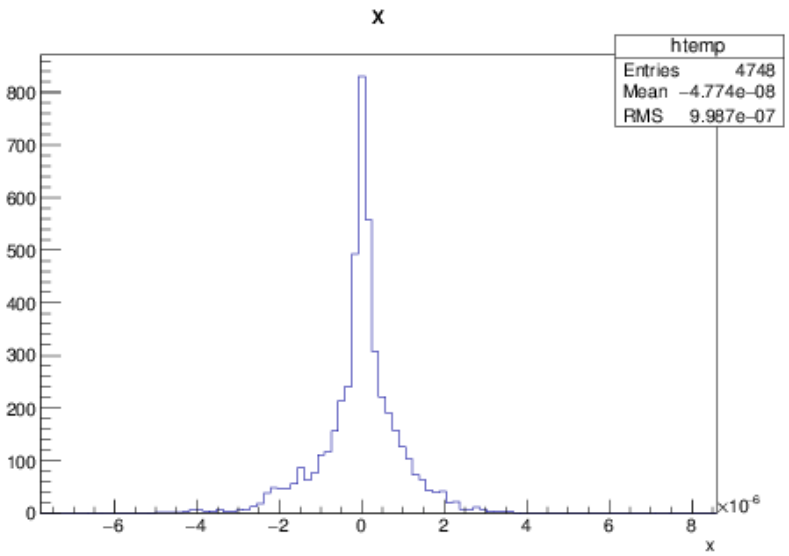


After correction

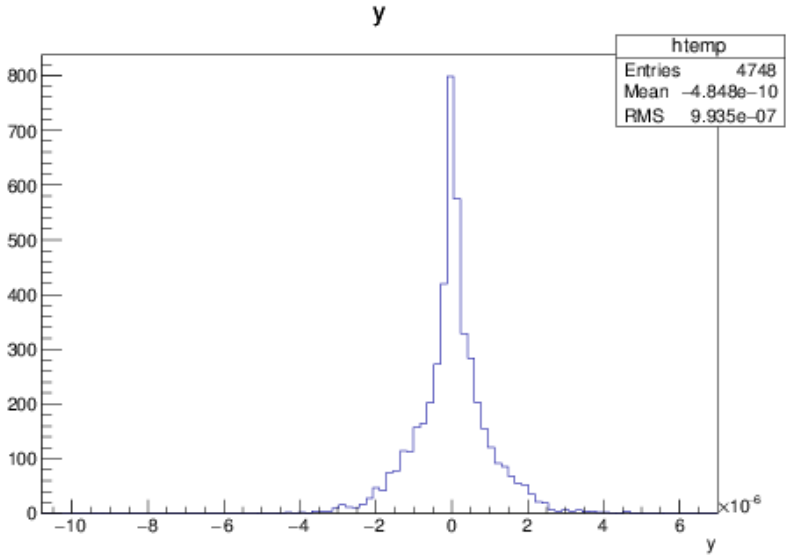




BPM readings statistic

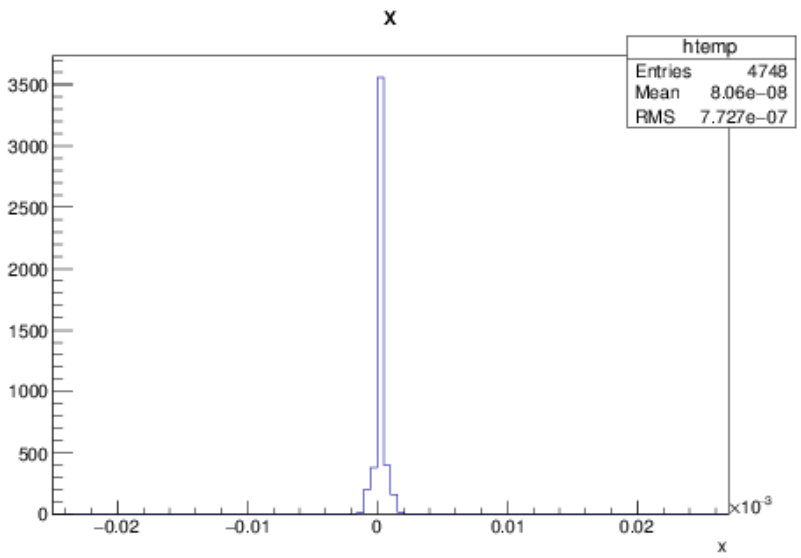


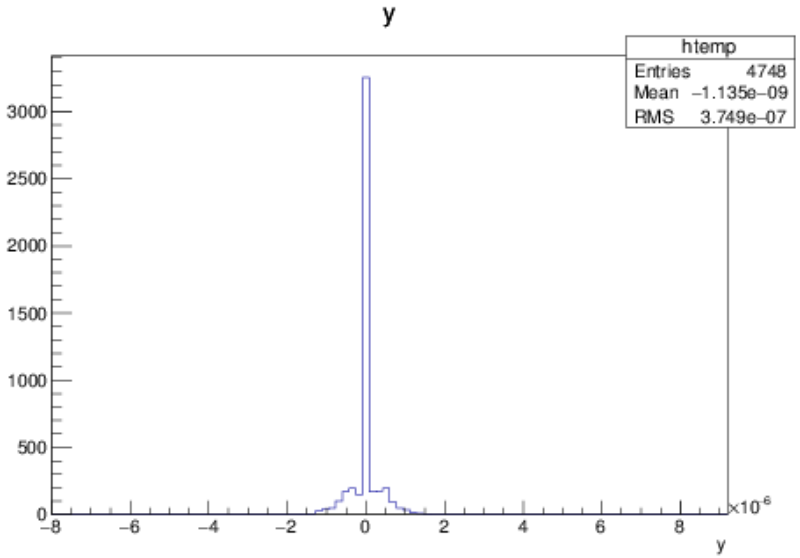
X CORRECTION
SUMMARY:
RMS before correction
2.127 mm
RMS after correction
0.0009987 mm



Y CORRECTION
SUMMARY:
RMS before correction
0.6423 mm
RMS after correction
0.0009935 mm

Correctors strength statistics





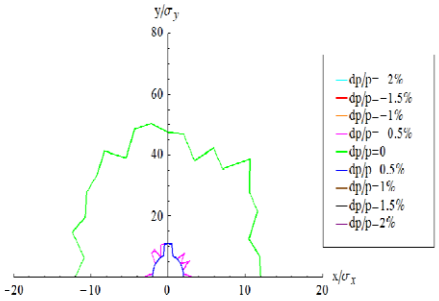
X CORRECTION:

about 1700 correctors used
Max strength ~ 23urad
RMS ~ 0.77urad

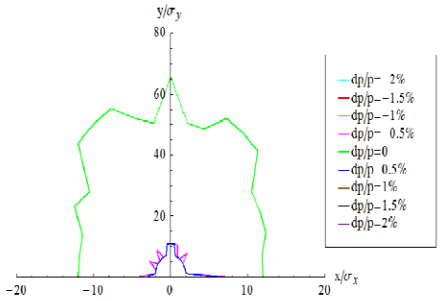
Y CORRECTION:

about 1700 correctors used
Max strength ~ 6.7urad
RMS ~ 0.37urad

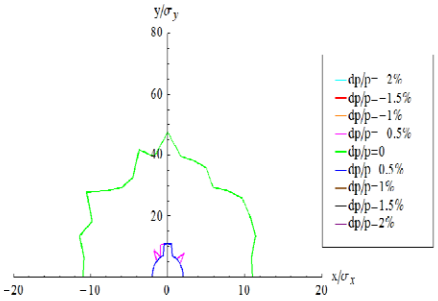
Multipole errors effect on DA



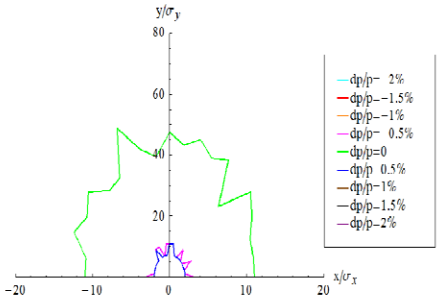
Multipole errors of all magnets



Multipole errors of bend



Multipole errors of quadurpoles



Multipole errors of sextupoles

- Multipole errors reduce DA a little bit , but not much. It seems to have not much effect on DA, especially of off-momentum DA.
- Orbit has no change due to multipole errors.

Conclusions and Prospects

- The LEP misalignment errors (bending magnets and quadrupoles) are used for the CEPC partial double ring.
- Orbit correction in CEPC partial double ring are executed using MICADO method, using about 1700 correctors. Correctors strength statistic are done and maximum strength of correctors are got.
- A DA program is working on to calculate DA from MADX tracking, and will be given the DA after orbit correction in the near future.
- Multipole errors are introduced to CEPC partial double ring, but may have not much effect on dynamic aperture.

Thank you