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CEPC Parameter, Booster and Damping Ring Status

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on behalf of CEPC AP group

Many Thanks to: K. Oide, M. Koratzinos, N. Iida

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Outline

- New goals after CDR: higher lumi. for Higgs & Z
- Booster progress
  - Refine of CDR design
  - Lower emittance booster study
  - Feedback system design status
- Damping ring progress
  - Damping ring
  - EC / BC

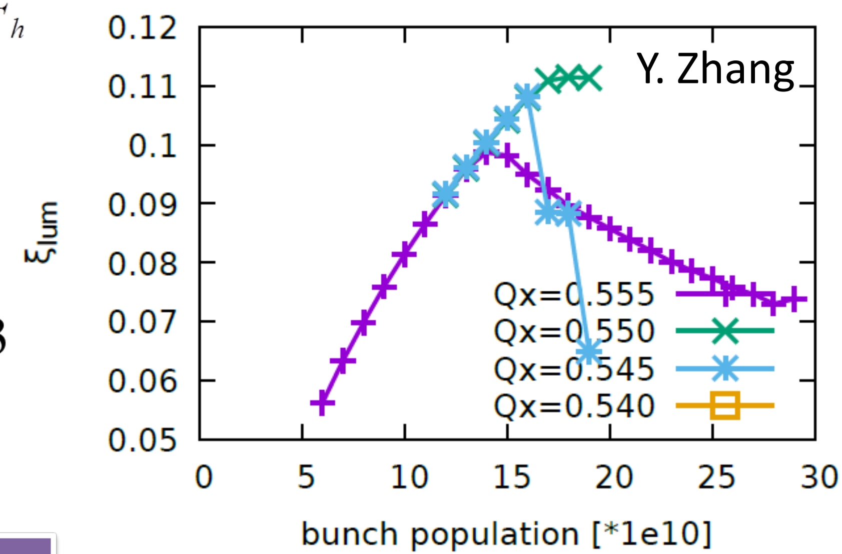
Beam-beam limit @Higgs

$$L_0[cm^{-2}s^{-1}] = 2.17\times10^{34}(1+r)\xi_y \frac{eE_0(GeV)N_bN_e}{T_0(s)\beta_y^*(cm)}F_h$$

$$\xi_y = \boxed{\frac{2845}{2\pi}\sqrt{\frac{U_0}{2\gamma E_0 N_{IP}}}}\times F_l \qquad \sim 0.113$$

Head on collision

Enhancement factor by crab waist (>1)



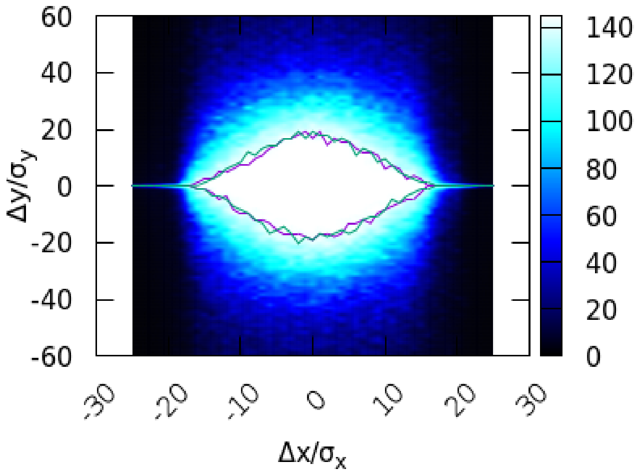
- Beam beam limit: ~0.113 (H)
- Analytical estimation agree well with beam-beam simulation.
- Reduce βy* and emittance synchronously

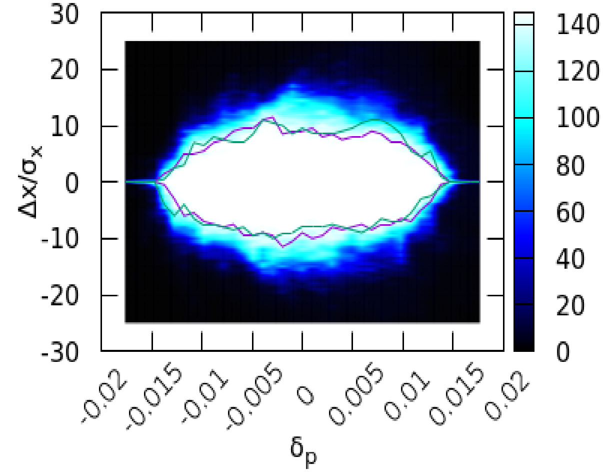
CEPC high lum. Higgs parameter after CDR

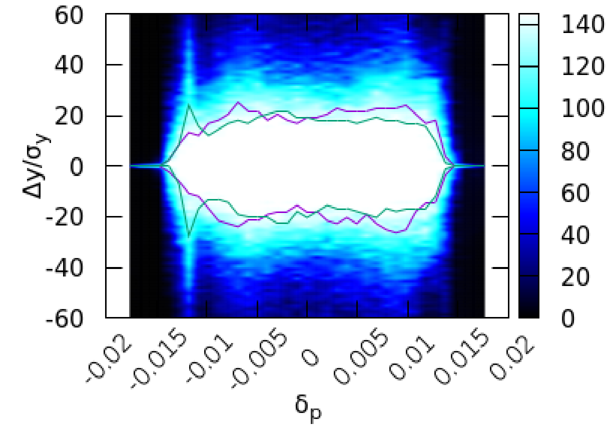
	Higgs	*W*	*Z* (3T)	*Z* (2T)
Number of IPs	2			
Beam energy (GeV)	**120**	**80**	**45.5**	
Circumference (km)	100			
Synchrotron radiation loss/turn (GeV)	1.68	0.33	0.035	
Crossing angle at IP (mrad)	16.5×2			
Piwinski angle	3.78	8.5	27.7	
Number of particles/bunch N_e (10^{10})	17.0	12.0	8.0	
Bunch number (bunch spacing)	**218 (0.76μs)**	**1568 (0.20μs)**	**12000 (25ns+10%gap)**	
Beam current (mA)	17.8	90.4	461.0	
Synchrotron radiation power /beam (MW)	**30**	**30**	**16.5**	
Bending radius (km)	10.7			
Momentum compact (10^{-5})	0.91			
β function at IP β_x^*/β_y^* (m)	**0.33/0.001**	**0.33/0.001**	**0.2/0.001**	
Emittance $\varepsilon_x/\varepsilon_y$ (nm)	0.89/0.0018	0.395/0.0012	0.13/0.003	0.13/0.00115
Beam size at IP σ_x/σ_y (μm)	17.1/0.042	11.4/0.035	5.1/0.054	5.1/0.034
Beam-beam parameters ξ_x/ξ_y	0.024/0.113	0.012/0.1	0.004/0.053	0.004/0.085
RF voltage V_{RF} (GV)	2.4	0.43	0.082	
RF frequency f_{RF} (MHz) (harmonic)	650 (216816)			
Natural bunch length σ_z (mm)	2.2	2.98	2.42	
Bunch length σ_z (mm)	3.93	5.9	8.5	
HOM power/cavity (2 cell) (kw)	0.58	0.77	**1.94**	
Energy spread (%)	0.19	0.098	0.080	
Energy acceptance requirement (%)	**1.7**	**0.90**	**0.49**	
Energy acceptance by RF (%)	3.0	1.27	1.55	
Photon number due to beamstrahlung	0.104	0.050	0.023	
Beamstruhlung lifetime /quantum lifetime* (min)	30/50	>400		
Lifetime (hour)	**0.22**	**1.2**	**3.2**	**2.0**
F (hour glass)	0.85	0.92	0.98	
Luminosity/IP L (10^{34}cm^{-2}s^{-1})	**5.2**	**14.5**	**23.6**	**37.7**

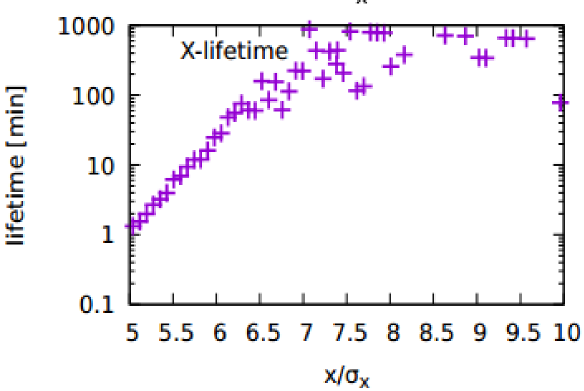
*include beam-beam simulation and real lattice

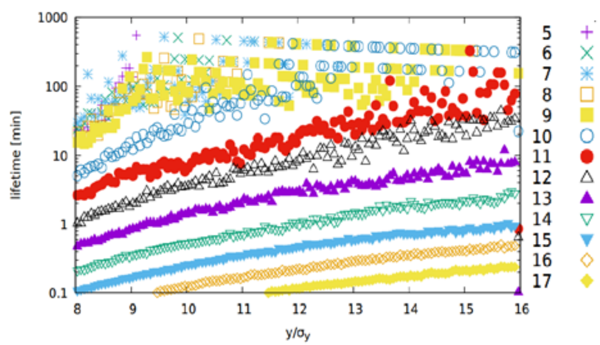
DA optimization for the ***β_y^* =1mm*** @ Higgs

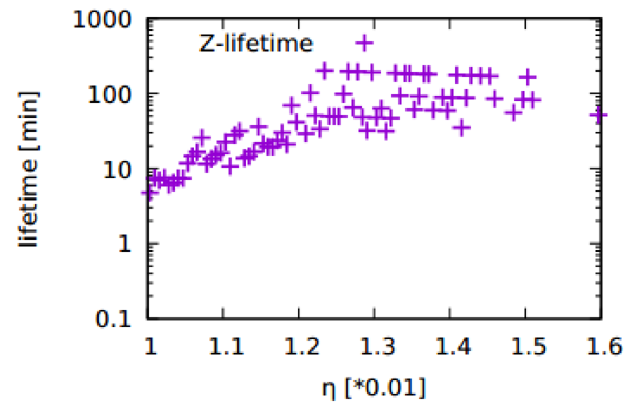












$$15\sigma_x \times 20\sigma_y \times 1.5\%$$

Strong limitation @ NP=11E10

We have strong requirement to understand fluctuation, beamstruhlung and beam-beam during the simulations.

- **Good for the injected beam**
- **Worse for the circulating beam**

CEPC high lum. Z parameter after CDR

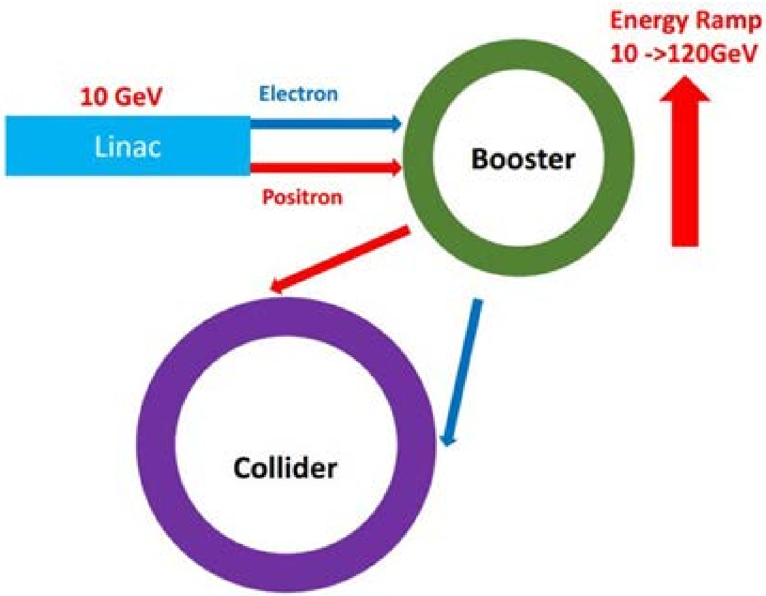
	CEPC-CDR	***CEPC-30MW***	***CEPC-39MW***
Number of IPs	2	2	2
Energy (GeV)	45.5	**45.5**	**45.5**
Circumference (km)	100	100	100
SR loss/turn (GeV)	0.036	0.036	0.036
Half crossing angle (mrad)	16.5	16.5	16.5
Piwinski angle	23.8	27.9	33.0
N_e/bunch (10^{10})	8.0	12.0	15.0
Bunch number	12000	**14564 (20.6ns+10%gap)**	**15000**
Beam current (mA)	461	839.9	1081.4
SR power /beam (MW)	**16.5**	**30**	**38.6**
Bending radius (km)	10.7	10.7	10.7
Momentum compaction (10^{-5})	1.11	1.11	1.11
β_{IP} x/y (m)	0.2/0.001	**0.2/0.001**	**0.2/0.001**
Emittance x/y (nm)	0.18/0.0016	0.18/0.0016	0.18/0.0016
Transverse σ_{IP} (um)	6.0/0.04	6.0/0.04	6.0/0.04
ξ_x/ξ_y/IP	0.004/0.079	0.004/0.093	0.004/0.098
V_{RF} (GV)	0.1	0.10	0.10
f_{RF} (MHz) (harmonic)	650	650	650
Nature bunch length σ_z (mm)	2.42	2.42	2.42
Bunch length σ_z (mm)	8.5	10.0	11.8
HOM power/cavity (kw)	1.94 (2cell)	**2.29 (1cell)**	**3.15 (1cell)**
Energy spread (%)	0.08	0.1	0.115
Energy acceptance (DA) (%)	1.5	**0.6**	**0.7**
Energy acceptance by RF (%)	1.7	1.7	1.7
Lifetime by rad. Bhabha scattering (hour)	2.9		
Lifetime (hour)	2.5	**2.0**	1.8
L_{max}/IP (10^{34}cm^{-2}s^{-1})	**32.1**	**74.5**	**101.6**

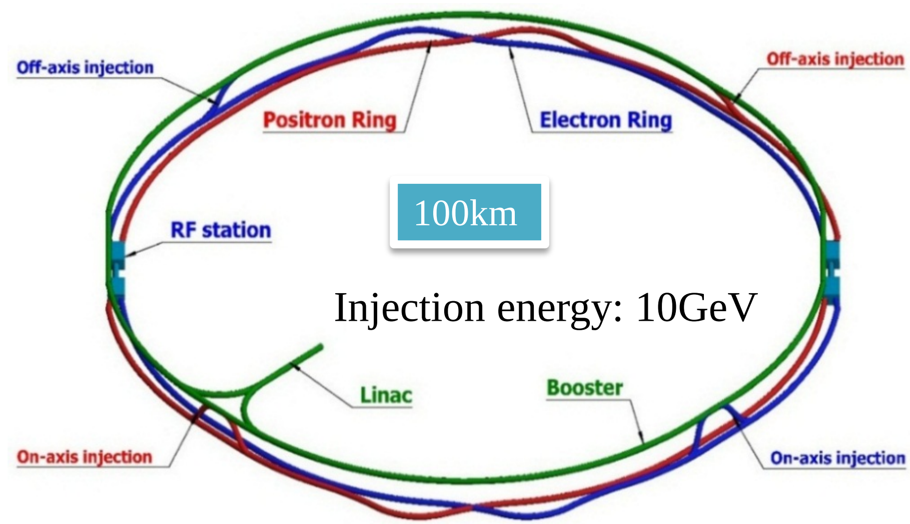
- Anti-chamber

→ **Higher cost**

Single cell cavities for Z are essential to control the HOM power.

CEPC injector chain





- 10 GeV linac provides electron and positron beams for booster.
- Top up injection for collider ring ~ 3% current decay
- Booster is in the same tunnel as collider ring, above the collider ring.
- Booster has the same geometry as collider ring except for the two IRs.
- Booster bypasses the collider ring from the outer side at two IPs.

Booster parameters (CDR)

Main parameters of CEPC booster at injection energy

		H	*W*	*Z*
Beam energy	GeV	10		
Bunch number		242	1524	6000
Threshold of single bunch current	μA	25.7		
Threshold of beam current (limited by coupled bunch instability)	mA	100		
Bunch charge	nC	0.78	0.63	0.45
Single bunch current	μA	2.3	1.8	1.3
Beam current	mA	0.57	2.86	7.51
Energy spread	%	0.0078		
Synchrotron radiation loss/turn	keV	73.5		
Momentum compaction factor	10^{-5}	2.44		
Emittance	nm	0.025		
Natural chromaticity	H/V	-336/-333		
RF voltage	MV	62.7		
Betatron tune $\nu_x/\nu_y/\nu_s$		263.2/261.2/0.1		
RF energy acceptance	%	1.9		
Damping time	s	90.7		
Bunch length of linac beam	mm	1.0		
Energy spread of linac beam	%	0.16		
Emittance of linac beam	nm	40~120		

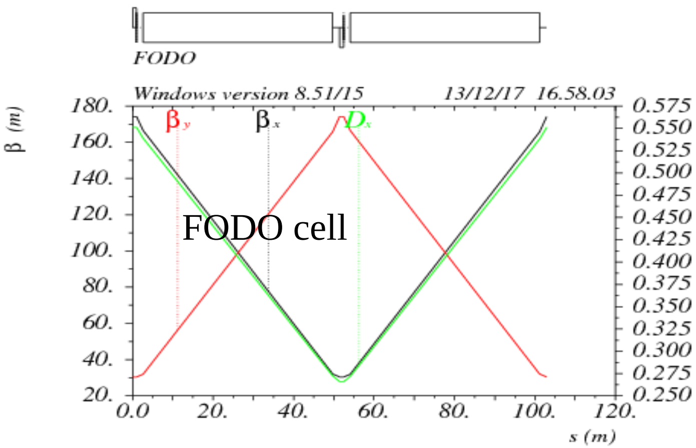
9 cell & 1.3GHz RF cavity

Main parameters of CEPC booster at extraction energy

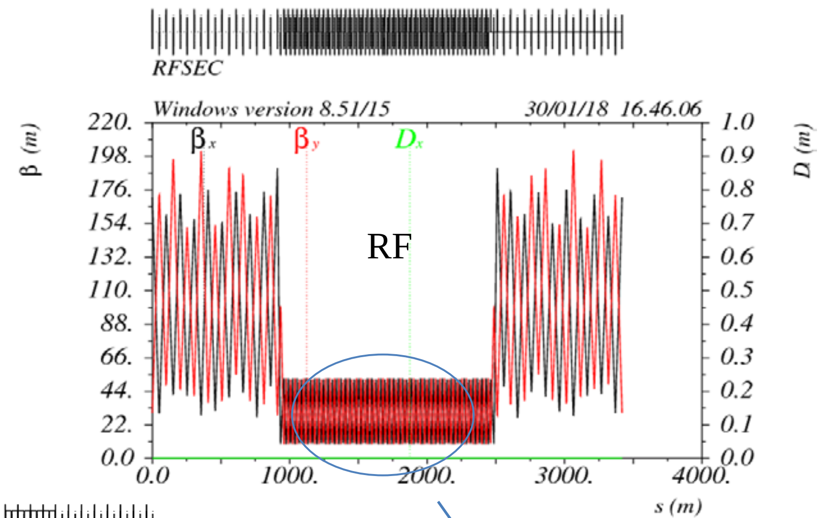
		H		*W*	*Z*
		Off axis injection	On axis injection	Off axis injection	Off axis injection
Beam energy	GeV	120		80	45.5
Bunch number		242	235+7	1524	6000
Maximum bunch charge	nC	0.72	24.0	0.58	0.41
Maximum single bunch current	μA	2.1	70	1.7	1.2
Threshold of single bunch current	μA	300			
Threshold of beam current (limited by RF power)	mA	1.0		4.0	10.0
Beam current	mA	0.52	1.0	2.63	6.91
Injection duration for top-up (Both beams)	s	25.8	35.4	45.8	275.2
Injection interval for top-up	s	47.0		153.0	504.0
Current decay during injection interval		3%			
Energy spread	%	0.094		0.062	0.036
Synchrotron radiation loss/turn	GeV	1.52		0.3	0.032
Momentum compaction factor	10^{-5}	2.44			
Emittance	nm	3.57		1.59	0.51
Natural chromaticity	H/V	-336/-333			
Betatron tune ν_x/ν_y		263.2/261.2			
RF voltage	GV	1.97		0.585	0.287
Longitudinal tune		0.13		0.10	0.10
RF energy acceptance	%	1.0		1.2	1.8
Damping time	ms	52		177	963
Natural bunch length	mm	2.8		2.4	1.3
Injection duration from empty ring	h	0.17		0.25	2.2

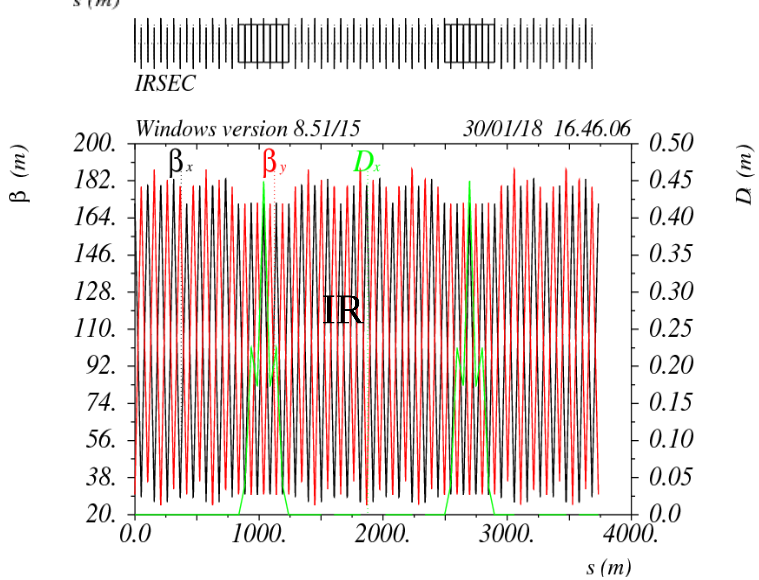
Booster optics (CDR)

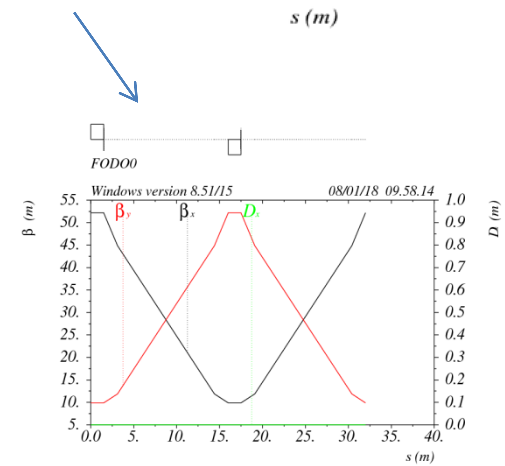
- 90°/ 90° FODO cell
- 2 cells @ booster = 3 cells @ collider
- Noninterleave sextupole scheme



- Low average beta to reduce the multi-bunch instability







- IR: booster bypasses the collider.
- 25m separation:
  - civil engineering
  - radiation protection
  - Synchronization w collider

Booster error studies

D. Ji

- Gaussian distribution and cut-off at 3σ
- Relax misalignment error: 50um→100um
- Relax field error for dipole: $3\times10^{-4}\rightarrow1\times10^{-3}$

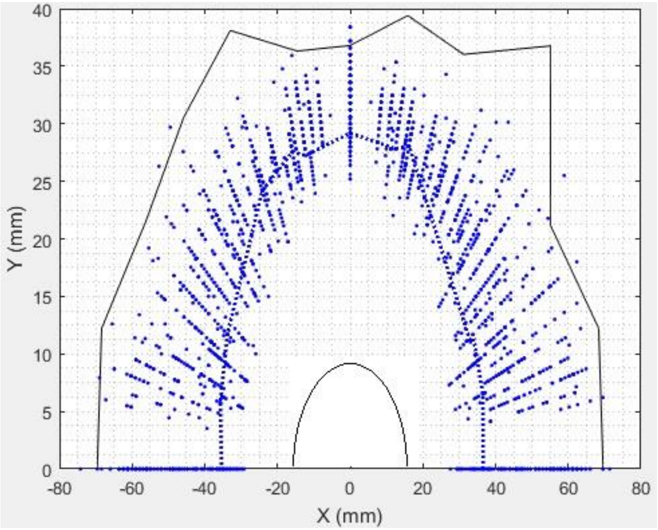
Errors Setting

Parameters	Dipole	Quadrupole	Sextupole
Transverse shift x/y (μm)	100	100	100
Longitudinal shift z (μm)	100	150	100
Tilt about x/y (mrad)	0.2	0.2	0.2
Tilt about z (mrad)	0.1	0.2	0.2
Nominal field	1×10^{-3}	2×10^{-4}	3×10^{-4}

	Accuracy (m)	Tilt (mrad)	Gain	Offset after BBA(mm)
BPM	1×10^{-7}	10	5%	30×10^{-3}

Dynamic aperture with errors

- With only COD corrections, DA is nearly two thirds of bare lattice
- At 120GeV, radiative damping and sawtooth was considered.
- DA requirement @ 10GeV determined by the beam stay clear region
- DA requirement @ 120GeV: 1) H- quantum lifetime, 2) V- re-injection process from the collider in the on-axis injection scheme



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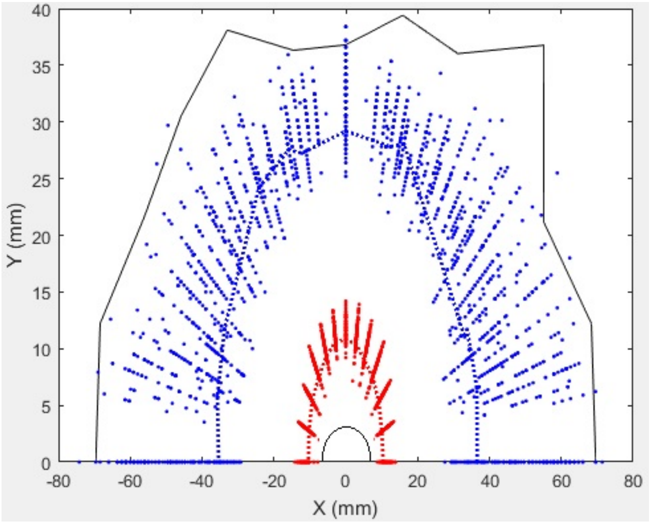
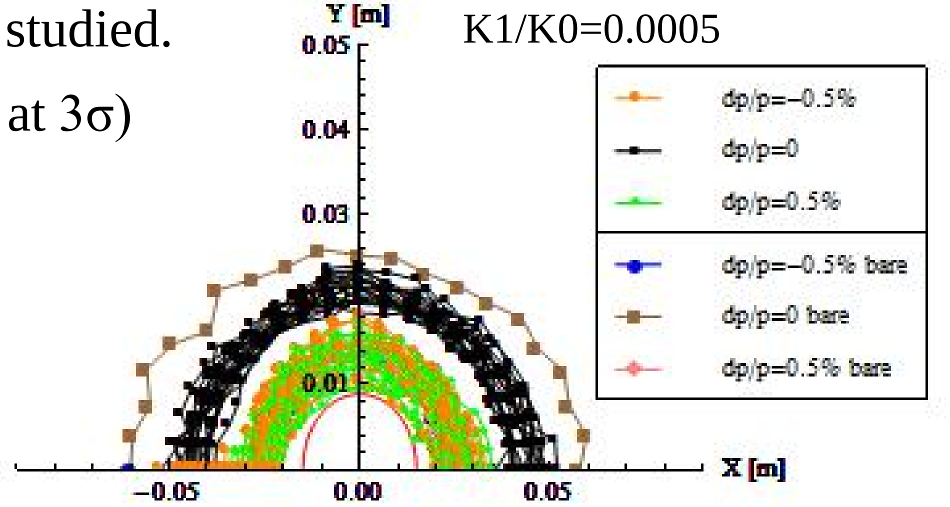


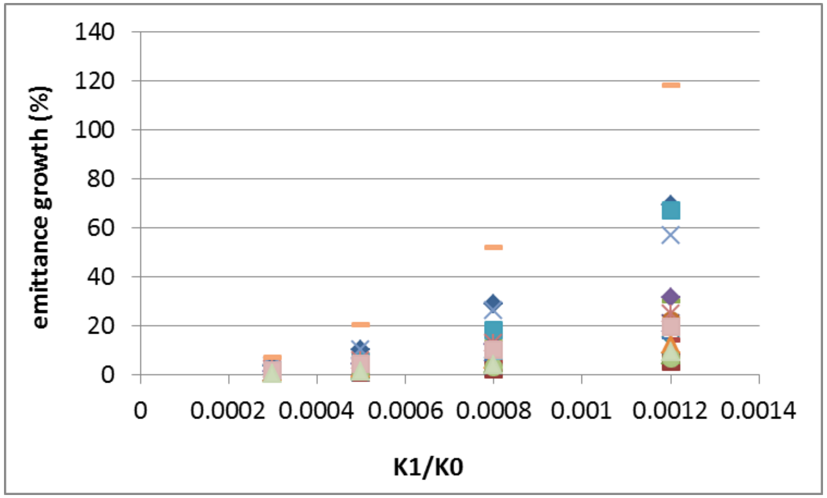
	DA requirement		**DA results**	
	H	V	H	V
10GeV ($\varepsilon_x = \varepsilon_y$ =40nm)	$4\sigma_x$ +5mm	$4\sigma_y$ +5mm	$12\sigma_x$ +5mm	$21\sigma_y$ +5mm
120GeV (ε_x=3.57nm, $\varepsilon_y = \varepsilon_x$*0.005)	$6\sigma_x$ +3mm	$49\sigma_y$ +3mm	$11.5\sigma_x$ +3mm	$173\sigma_y$ +3mm

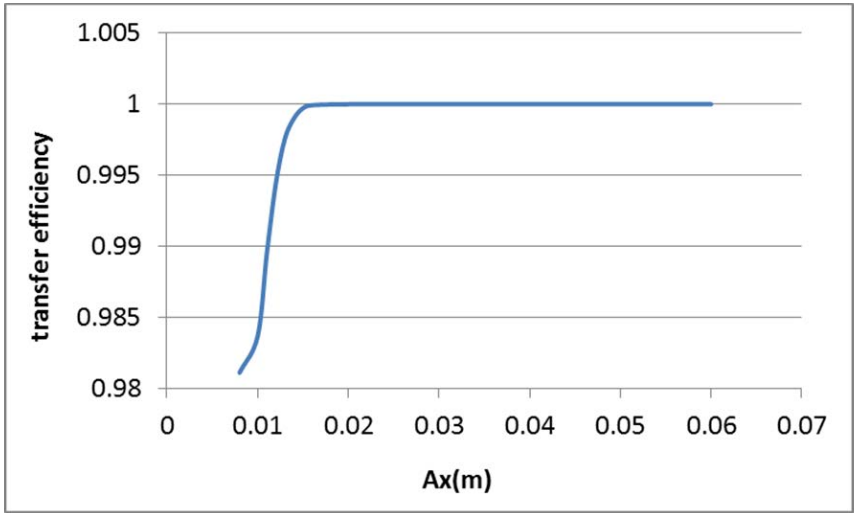
- RMS Orbit ~ 180um, RMS betabeat ~15%, RMS disp. ~29mm, RMS coupling: <0.5%

Dipole uniformity requirement@10Gev

- Quadrupole error on the dipoles was studied.
- Scan K1 to see the influence (cut-off at 3σ)
    - Working point – small change
    - Emittance growth
    - DA reduction
    - Transfer efficiency
- Emittance & DA was tested w/o optics correction

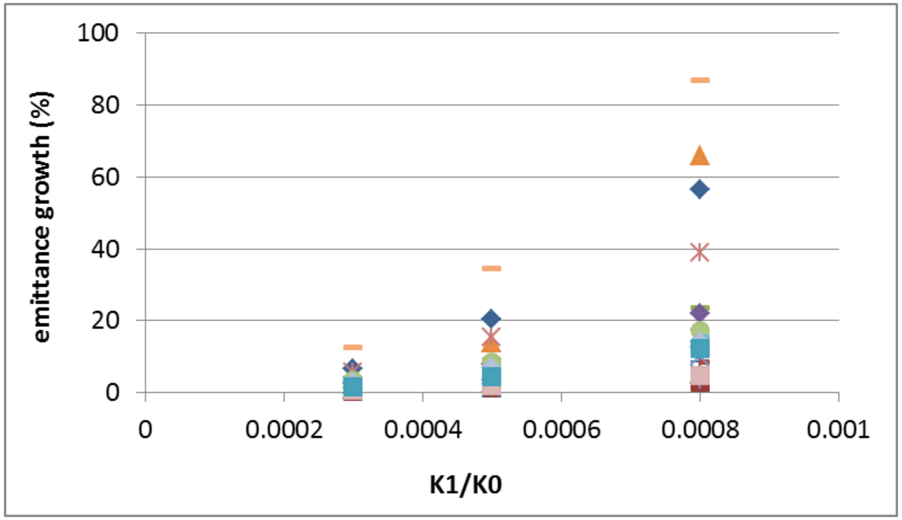


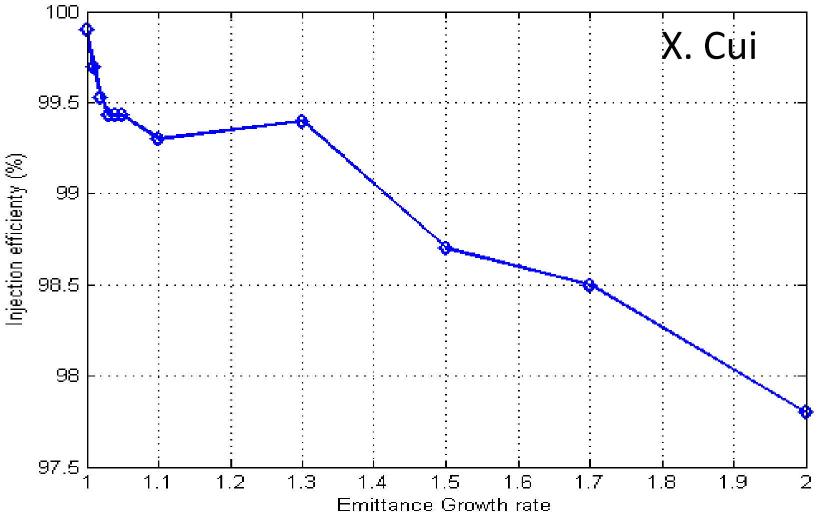




Dipole uniformity requirement@120Gev

- Quadrupole error on the dipoles was studied.
- Scan K1 to see the influence (cut-off at 3σ)
  - Working point – small change
  - Emittance growth
  - DA reduction – small (radiation damping & fluctuation included)
  - injection efficiency (Off-axis injection, DA for collider: $15\sigma_x \times 20\sigma_y$)
- Emittance & injection efficiency was tested w/o optics correction

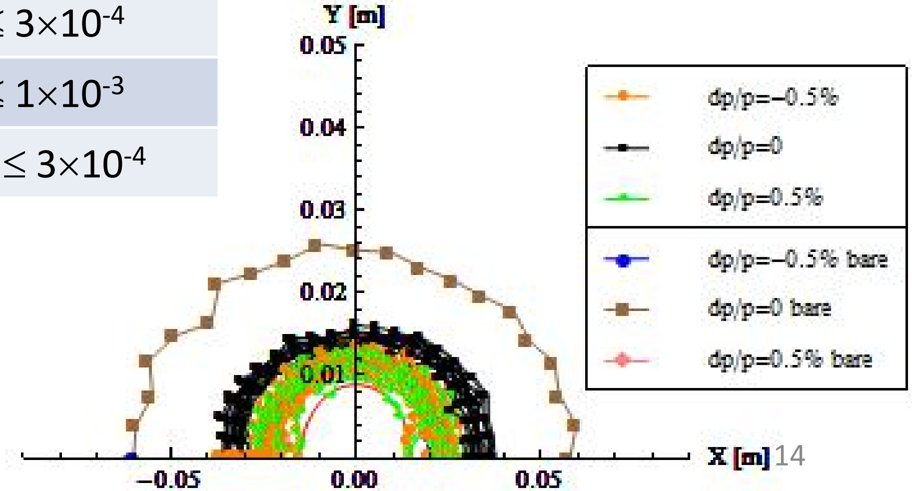




Multipole errors @ booster

- 10GeV
- Reference radius: 27.5mm
- w/o optics correction

dipole	quadrupole	sextupole
$B1/B0 \le 3\times10^{-4}$		
$B2/B0 \le 2\times10^{-4}$	$B2/B1 \le 4\times10^{-4}$	
$B3/B0 \le 2\times10^{-5}$	$B3/B1 \le 1\times10^{-4}$	$B3/B2 \le 1\times10^{-3}$
$B4/B0 \le 8\times10^{-5}$	$B4/B1 \le 1\times10^{-4}$	$B4/B2 \le 3\times10^{-4}$
$B5/B0 \le 2\times10^{-5}$	$B5/B1 \le 1\times10^{-4}$	$B5/B2 \le 1\times10^{-3}$
$B6/B0 \le 8\times10^{-5}$	$B6/B1 \le 5\times10^{-5}$	$B6/B2 \le 3\times10^{-4}$
$B7/B0 \le 2\times10^{-5}$	$B7/B1 \le 5\times10^{-5}$	$B7/B2 \le 1\times10^{-3}$
$B8/B0 \le 8\times10^{-5}$	$B8/B1 \le 5\times10^{-5}$	$B8/B2 \le 3\times10^{-4}$
$B9/B0 \le 2\times10^{-5}$	$B9/B1 \le 5\times10^{-5}$	$B9/B2 \le 1\times10^{-3}$
$B10/B0 \le 8\times10^{-5}$	$B10/B1 \le 5\times10^{-5}$	$B10/B2 \le 3\times10^{-4}$



Dipole reproducibility requirement@10Gev

- Increase/decrease the strength of all the dipoles by the same amount.
- Decrease/increase the strength of quadrupoles & sextupoles → energy mismatch
- Evaluate the influence: working point, closed orbit, DA, energy acceptance
- Working point should not pass through the lower order resonance
- No shrink for dynamic aperture
- **Reproducibility requirement for dipoles: ~0.02%**
- **Stability requirement for power supply: ~0.01%**

	original	+0.01%	-0.01%	+0.05%	-0.05%
nux	263.18	263.12	263.25	262.84	263.52
nuy	261.28	261.21	261.34	260.94	261.61
Δx (um)	0	-54	54	-270	270
DA (%)	100	100	100	90	90

Power supply stability@120Gev

- Increase/decrease the strength of all the dipoles by the same amount.
- Decrease/increase the strength of quadrupoles & sextupoles → energy mismatch
- Evaluate the influence: working point, closed orbit, DA, energy acceptance
- Working point should not pass through the lower order resonance
- No shrink for dynamic aperture
- Including SR damping, excitation and sawtooth effect
- **Stability requirement: ~0.02%**

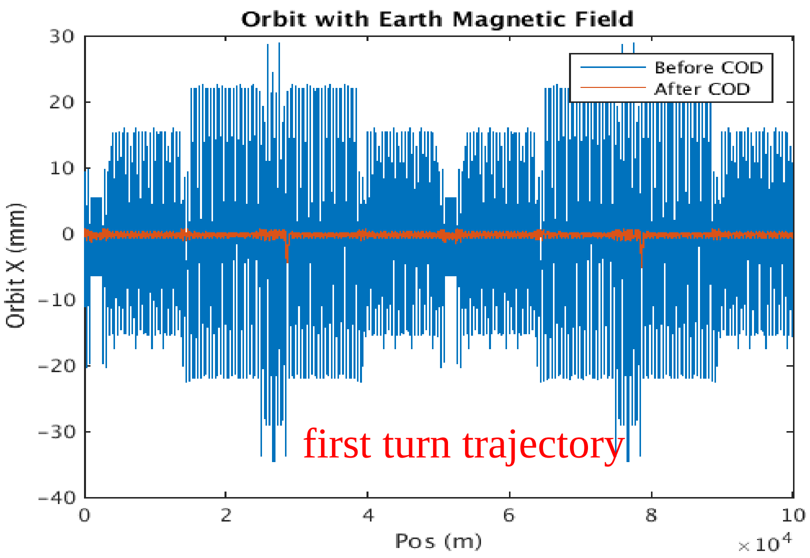
	original	+0.01%	-0.01%	+0.02%	+0.02%	+0.05%	-0.05%
nux	263.18	263.12	263.25	263.32	263.05	262.84	263.52
nuy	261.28	261.21	261.35	261.41	261.15	260.95	261.61
Δx (um)	0	0	0	0	0	0	0
DA (%)	100	100	100	100	100	100	100

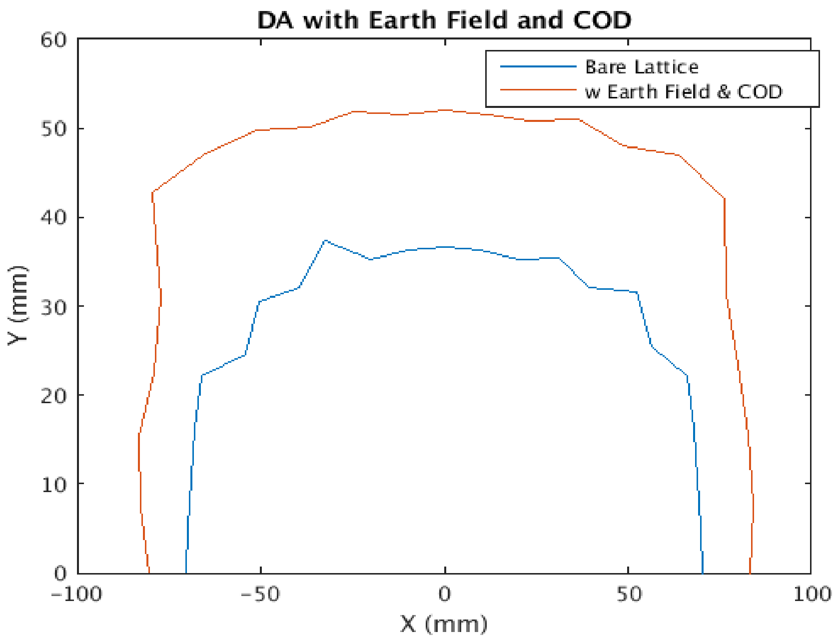
Effect of earthfield @10GeV

D. Ji

- ~20% vacuum pipe (drift) is exposed in earthfield directly.
- treat drifts as week dipole to simulate the effect of earthfield
- Assume earthfield: 0.3~0.6 gauss (simple model: perpendicular component only)
- Working point can be corrected by weaken the dipoles systematically (-0.07%)
- Global COD correction was tested for 0.3 gauss earthfield.
- DA is acceptable after COD correction.

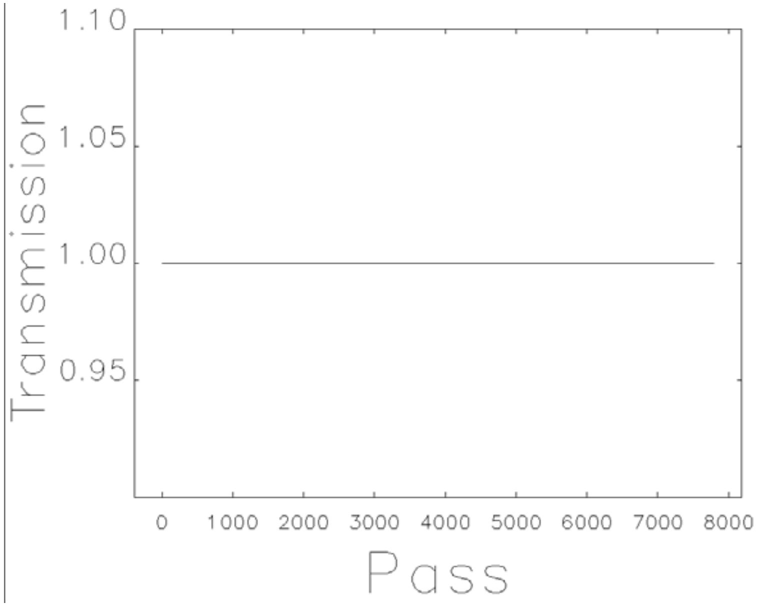
0.3 gauss

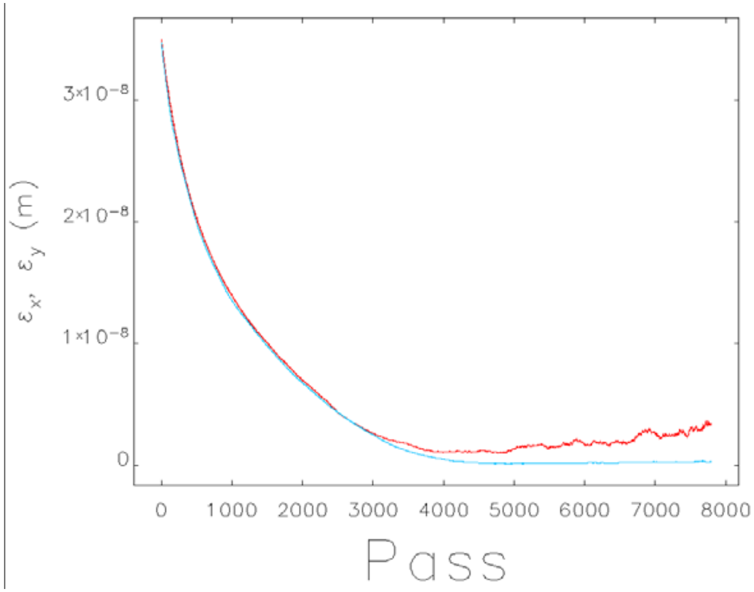


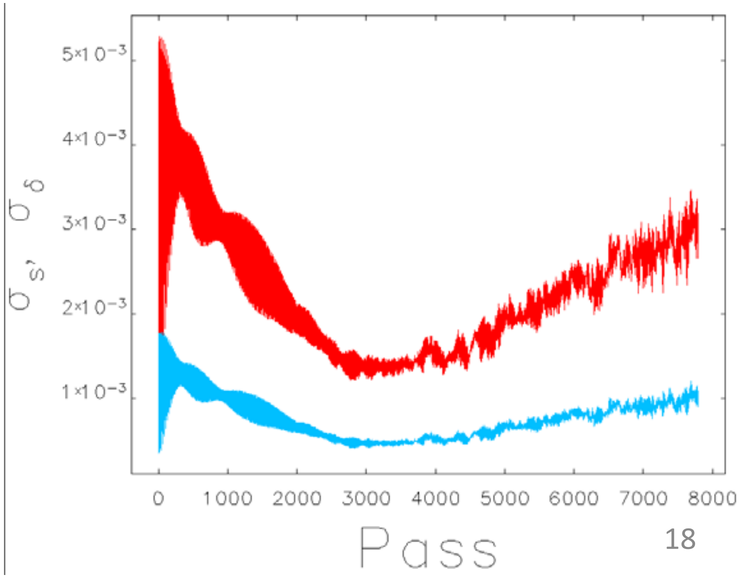


Ramping dynamic simulation

- Energy: **10GeV ~ 120 GeV** by **2.6s**
- Tracking by **elegant**, w/o error
- 360 particles
- Linear ramping for magnets
- RF ramping curve: νs=0.13
- including **SR damping** & **excitation**





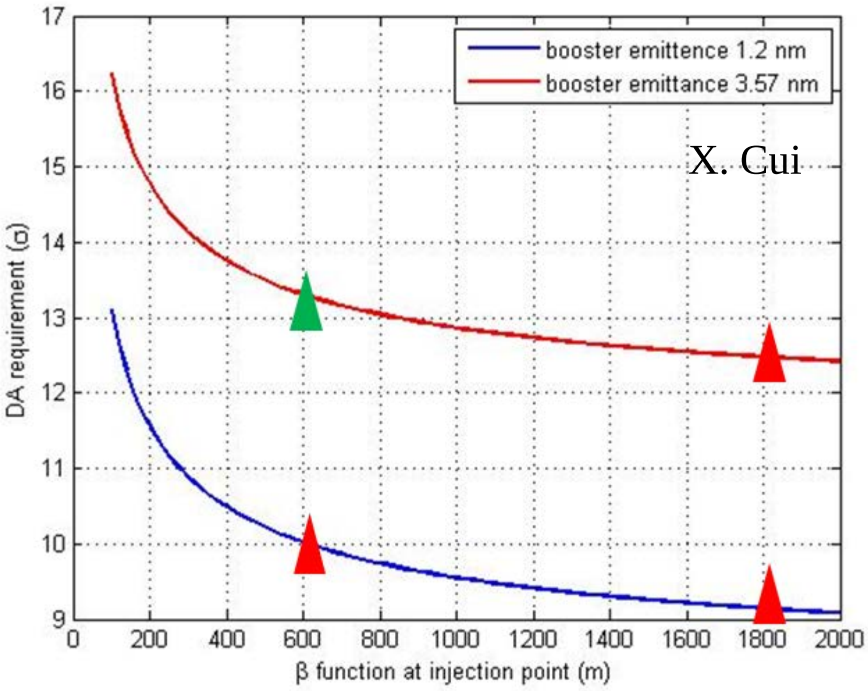


Reduction the size of beam pipe

- use smaller beam pipe thanks to smaller Linac emittance with DR
  - Emittance of Linac: 120nm → 40nm
  - BSC: 4σ+5mm → d= 34mm
  - Size of beam pipe: 55mm→ 44mm
- 44mm inner diameter is enough for future high lum. Z
  - Max bunch current potential: 2.2 uA
  - Max beam current potential: 16.2mA
  - Instability was checked at both 10GeV & 120GeV
- Power for magnets and power supply is reduced by **~50%**
- Cost of power supply is reduced by **~30%**

Lower emittance booster study

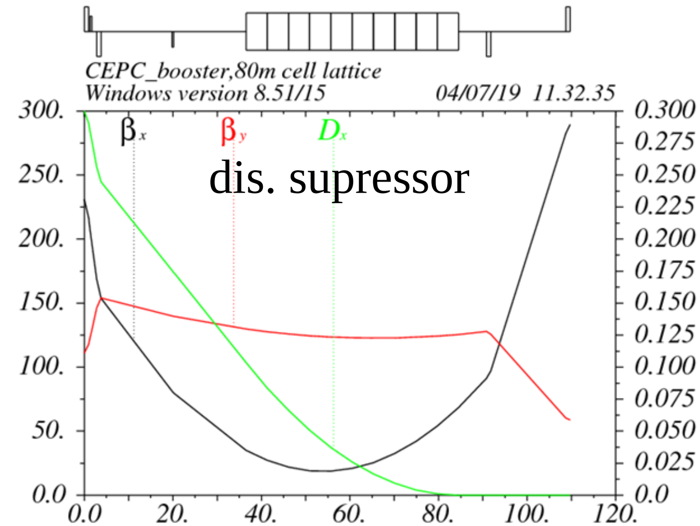
- ***off-axis injection for collider (Higgs mode in CDR) can work***
- ***on-axis injection for collider (Higgs high lumi. mode) can work***

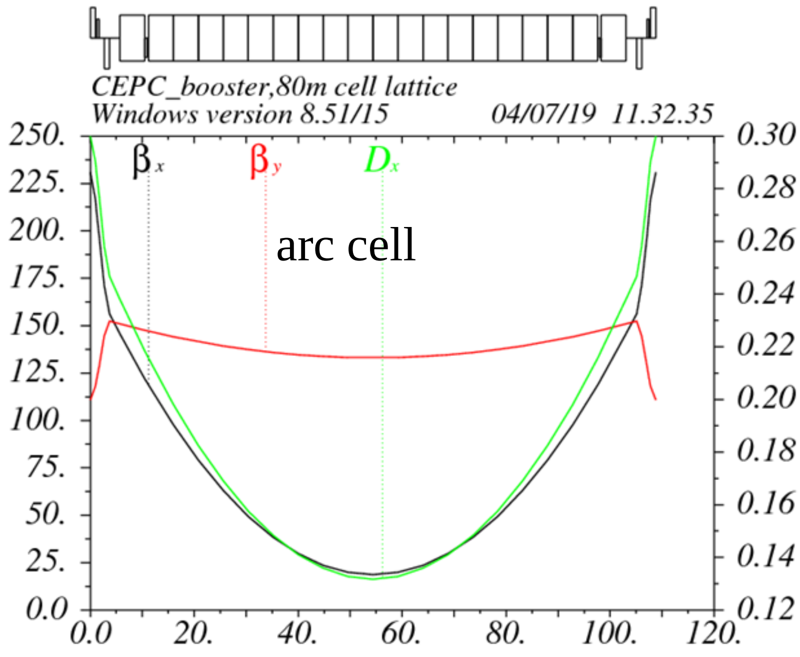


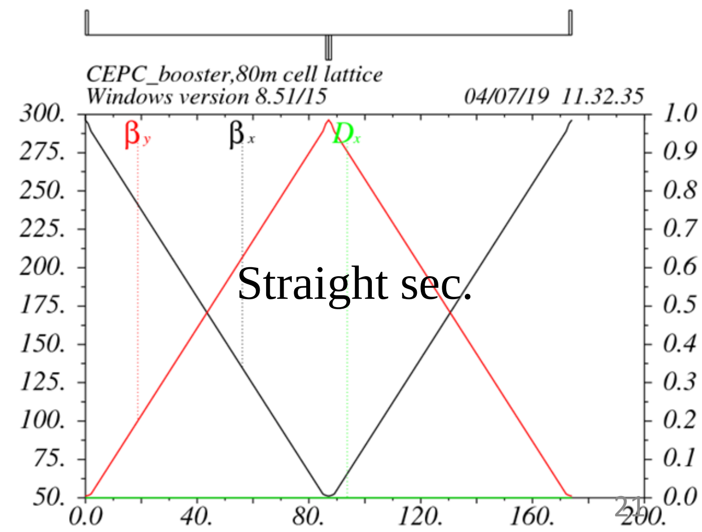
- Emittance: 3.57nm → 1.29nm
- Coupling requirement: 0.5% → 1.4%

New lattice design based on TME

- emittance=**1.29nm** @120GeV
- TME lattice
- Cell length: 110m
- Interleave sextupole scheme

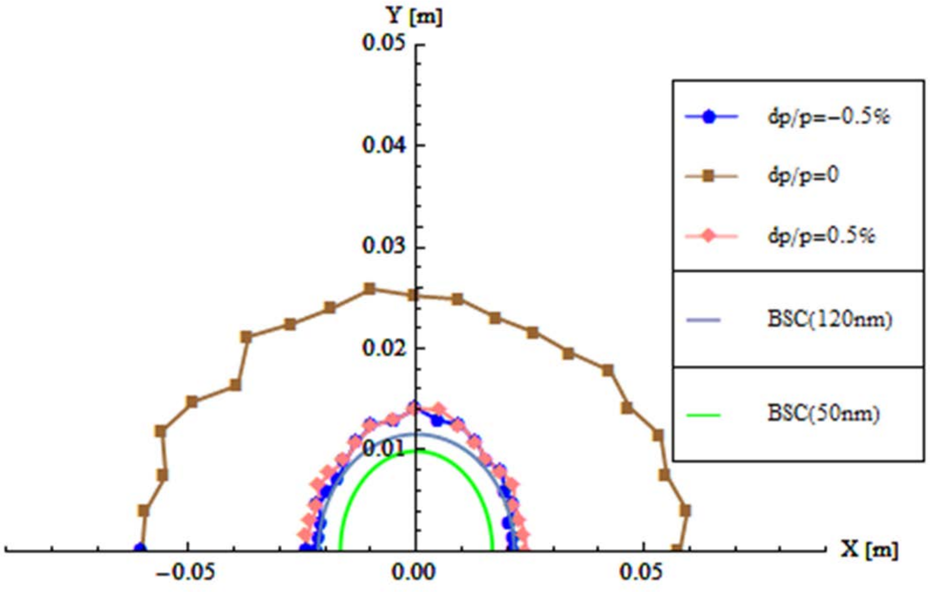




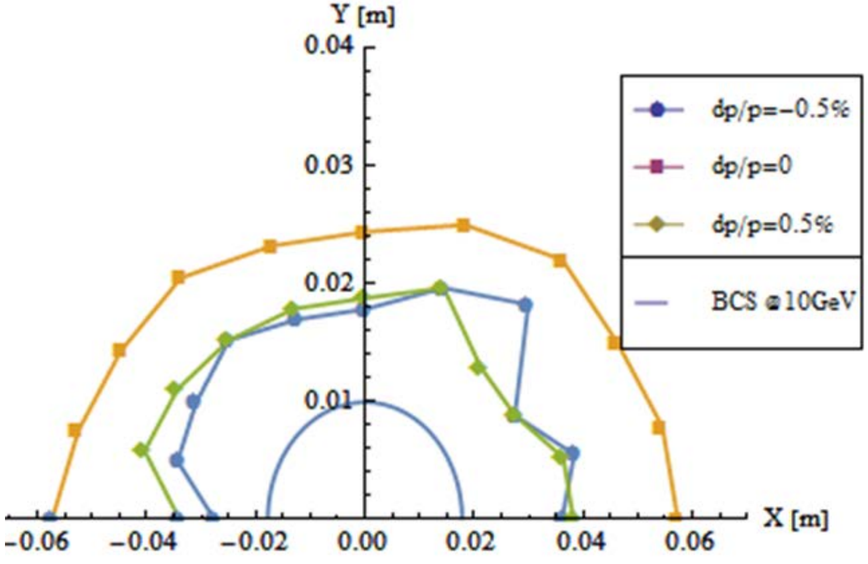


DA of booster new lattice

CDR



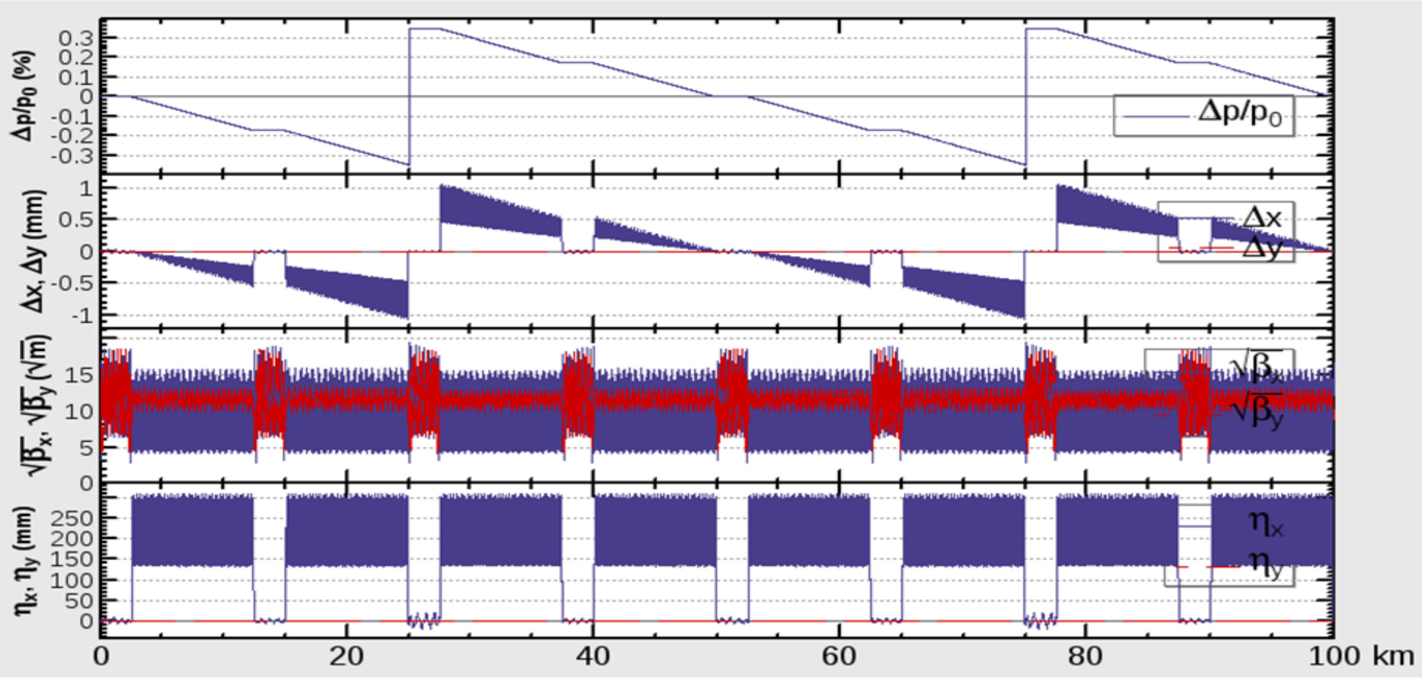
new



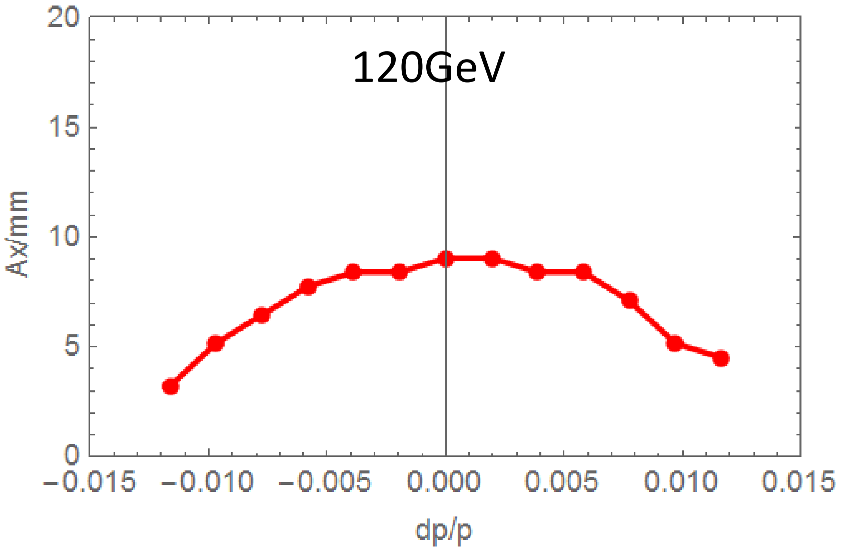
- Same DA for on-momentum particles
- Two times of off-momentum DA

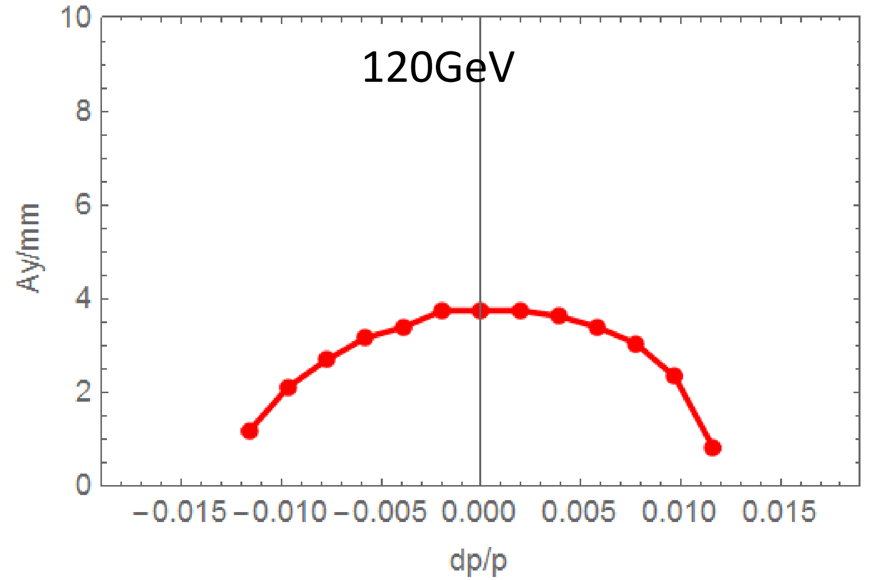
Sawtooth effect @120GeV

- 2 RF stations
- Maximum sawtooth orbit: 1.1 mm
- Maximum optics distortion: ~1.5%, Maximum dispersion distortion: ~20 mm
- Emittance growth: ~1.7% (1.288nm→1.310nm)
- No DA reduction due to sawtooth effect
- **Magnets energy tapering is unnecessary**



Dynamic aperture w/o errors



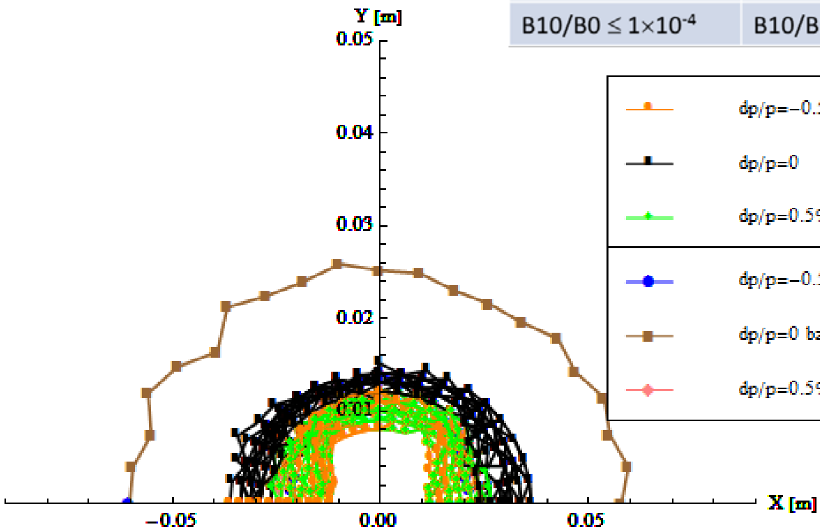


	DA requirement		DA results	
	H	V	H	V
10GeV ($\varepsilon_x = \varepsilon_y$ =40nm)	$4\sigma_x$ +5mm	$4\sigma_y$ +5mm	$14\sigma_x$ +5mm	$18\sigma_y$ +5mm
120GeV (ε_x=1.29nm, $\varepsilon_y = \varepsilon_x$*0.014)	$6\sigma_x$ +3mm	$13\sigma_y$ +3mm	$9.4\sigma_x$ +3mm	$22\sigma_y$ +3mm

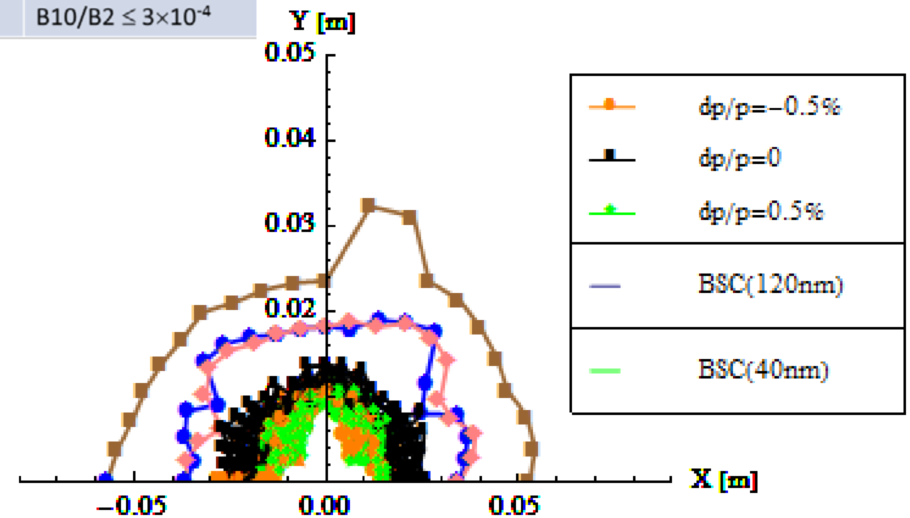
Multipole errors for new lattice

dipole	quadrupole	sextupole
B2/B0 ≤ 5×10^{-4}	B2/B1 ≤ 5×10^{-4}	
B3/B0 ≤ 2×10^{-5}	B3/B1 ≤ 1×10^{-4}	B3/B2≤ 2×10^{-3}
B4/B0 ≤ 1×10^{-4}	B4/B1 ≤ 1×10^{-4}	B4/B2 ≤ 3×10^{-4}
B5/B0 ≤ 2×10^{-5}	B5/B1 ≤ 1×10^{-4}	B5/B2 ≤ 2×10^{-3}
B6/B0 ≤ 1×10^{-4}	B6/B1 ≤ 5×10^{-5}	B6/B2 ≤ 3×10^{-4}
B7/B0 ≤ 2×10^{-5}	B7/B1 ≤ 5×10^{-5}	B7/B2 ≤ 2×10^{-3}
B8/B0 ≤ 1×10^{-4}	B8/B1 ≤ 5×10^{-5}	B8/B2 ≤ 3×10^{-4}
B9/B0 ≤ 2×10^{-5}	B9/B1 ≤ 5×10^{-5}	B9/B2 ≤ 2×10^{-3}
B10/B0 ≤ 1×10^{-4}	B10/B1 ≤ 5×10^{-5}	B10/B2 ≤ 3×10^{-4}

CDR



new



- Requirement of field uniformity for low field dipoles is harder than CDR lattice
- Analyze multipole error effect order by order
- Further DA optimization

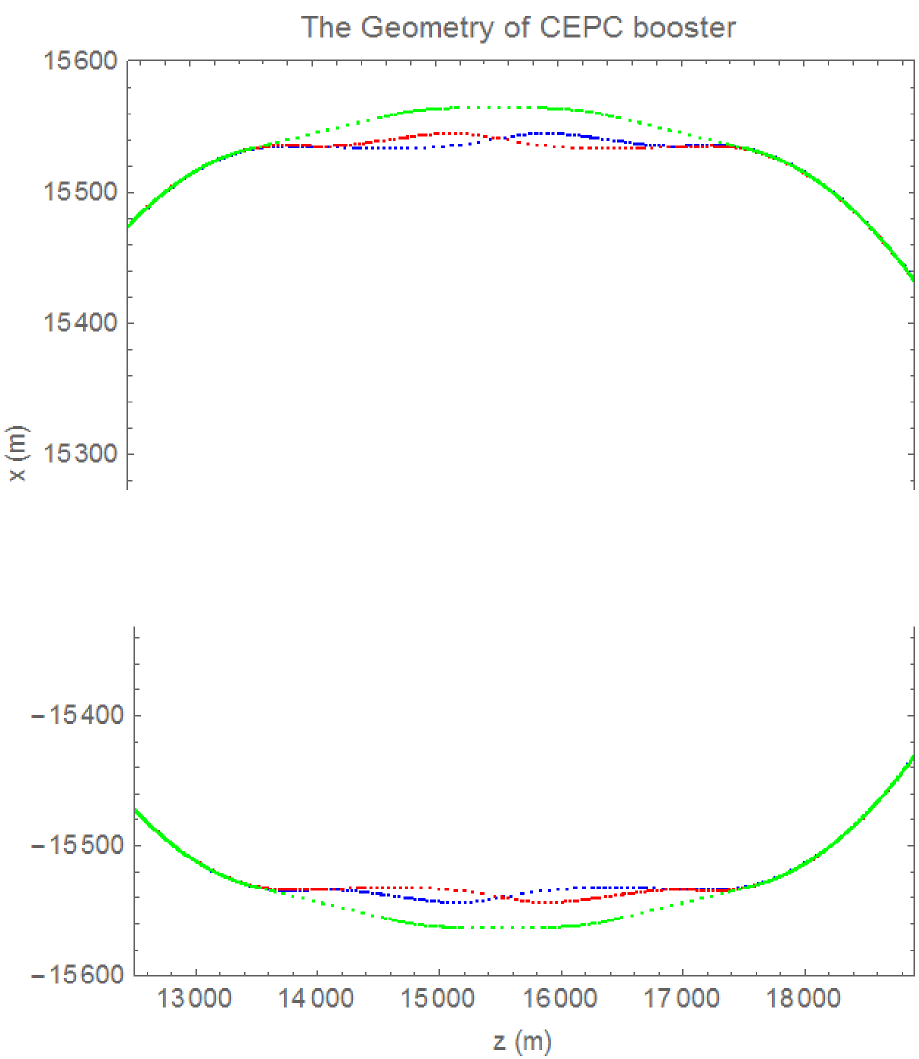
Booster new parameters

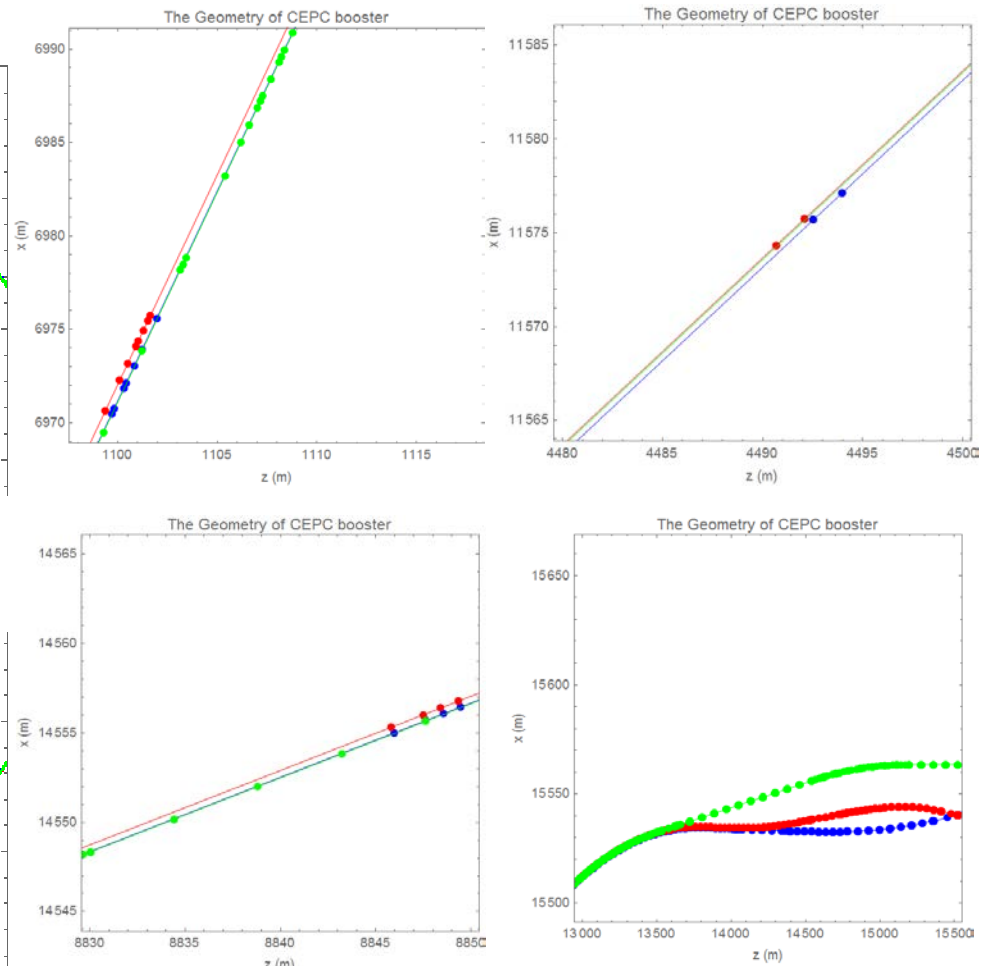
Diameter of beam pipe: 44mm

Injection		*H*	*W*	*Z*
Beam energy	GeV	10		
Bunch number		242	1524	6000
Threshold of single bunch current	μA	3.06		
Threshold of beam current (limited by coupled bunch instability)	mA	33.3		
Bunch charge	nC	0.78	0.63	0.45
Single bunch current	μA	2.3	1.8	1.3
Beam current	mA	0.57	2.86	7.51
Energy spread	%	0.0081		
Synchrotron radiation loss/turn	keV	79.5		
Momentum compaction factor	10^{-5}	1.064		
Emittance	nm	0.00895		
Natural chromaticity	H/V	-610/-228		
RF voltage	MV	78.7	38.2	
Betatron tune ν_x/ν_y		319.14/131.23		
Longitudinal tune		0.076	0.053	
RF energy acceptance	%	3.29	2.29	
Damping time	s	83.9		
Bunch length of linac beam	mm	1.0		
Energy spread of linac beam	%	0.16		
Emittance of linac beam	nm	40		

		H		*W*	*Z(3T)*	*Z(2T)*
Extraction		Off axis injection	On axis injection	Off axis injection	Off axis injection	
Beam energy	GeV	120		80	45.5	
Bunch number		242	235+7	1524	6000	
Maximum bunch charge	nC	0.72	24.0	0.58	0.41	
Maximum single bunch current	μA	2.1	70	1.7	1.2	
Threshold of single bunch current	μA	77.33				
Threshold of beam current (limited by RF power)	mA	1		4	10	
Beam current	mA	0.52	1.0	2.63	6.91	
Injection duration for top-up (Both beams)	s	26.6	35.8	51.9	275.8	
Injection interval for top-up	s	47.0		153.0	504.0	276.0
Current decay during injection interval		3%				
Energy spread	%	0.098		0.065	0.037	
Synchrotron radiation loss/turn	GeV	1.65		0.326	0.0326	
Momentum compaction factor	10^{-5}	1.064				
Emittance	nm	1.29		0.57	0.18	
Natural chromaticity	H/V	-610/-228				
Betatron tune ν_x/ν_y		319.14/131.23				
RF voltage	GV	1.97		0.45	0.177	
Longitudinal tune		0.076		0.053	0.053	
RF energy acceptance	%	1.0		1.0	1.96	
Damping time	ms	48.7		164	920.7	
Natural bunch length	mm	2.15		2.08	1.18	
Injection duration from empty ring	h	0.17		0.25	2.2	

Geometry design of new lattice





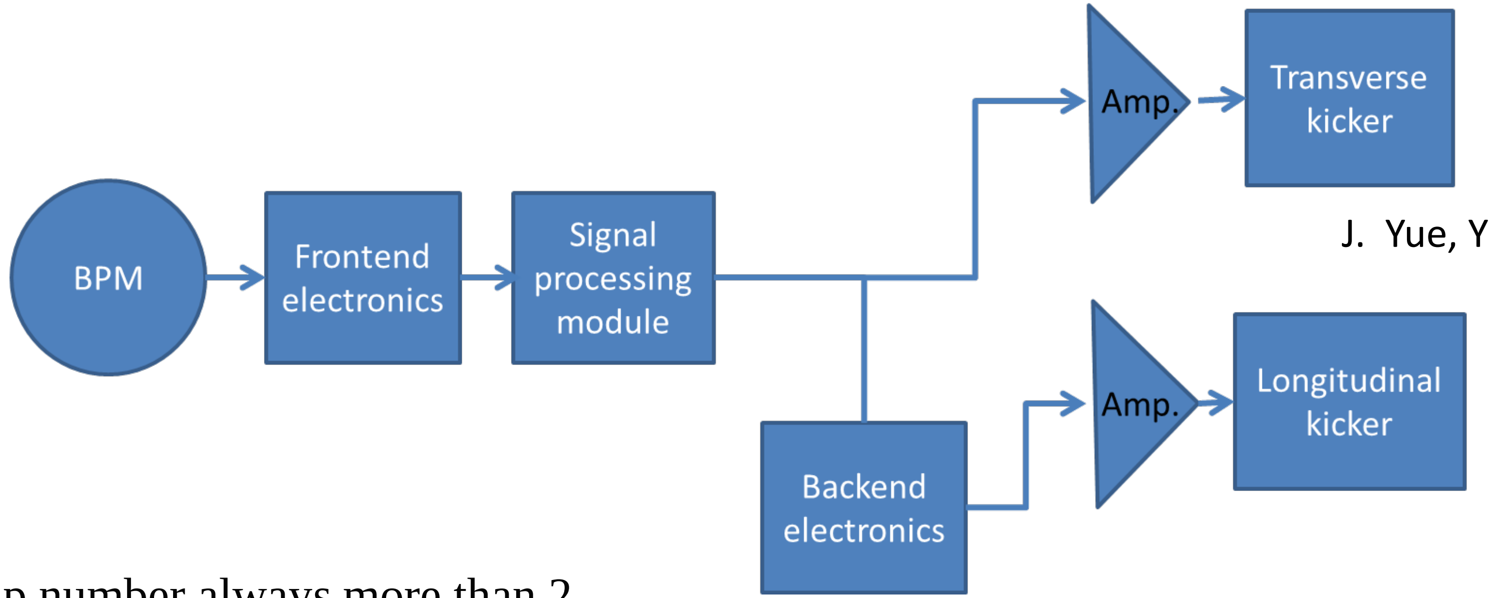
- Exact match for three rings
  -- error=±0.17m

Multi-bunch instability

- **Feedback system is essential @10 GeV.**
  - Damping time: 90s
  - Growth time (T): 3.1ms
  - Growth time (L): 6.3ms

CEPC Booster TESLA 9-cavity HOM CBI growth time

				H-injection	W-injection	Z-injection
TM011	2.45	156	5.9E4	149	29.6	11.3
TM012	3.845	44	2.4E5	82.7	16.4	6.3
TE111	1.739	4283	3.4E3	609	120.9	46.1
TM110	1.874	2293	5.0E4	77.4	15.4	5.9
TM111	2.577	4336	5.0E4	40.9	8.1	3.1
TE121	3.087	196	4.4E4	1028.4	204.1	77.8



J. Yue, Y Sui et al.

- tap number always more than 2.
- Quick feedback + large ring → low order filter

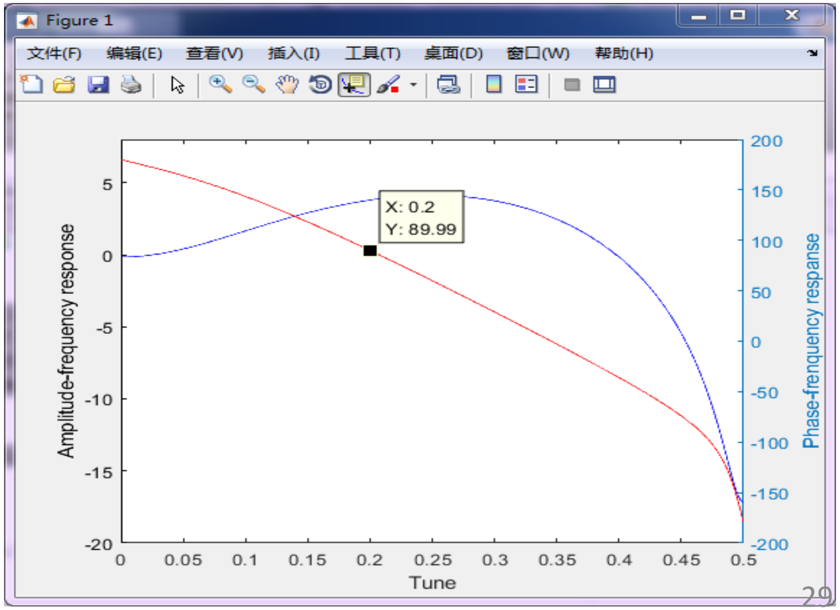
Transverse feedback status

J. Yue, Y Sui et al.

parameter	Value
tune	263.2/261.2
Beta function（m）	120
Energy（GeV）	10
Rising time（ms）	3.1
Revolution time（ms）	0.33
Bunch spacing（ns）	25
Bunch frequency（MHz）	40
Kicker shunt impedance（kΩ）	125@40MHz
Damping time（ms）	1.78
Amplitude of oscillation（mm）	0.3

$$\frac{1}{\tau_{FB}} = \frac{f_{rf}\sqrt{\beta_m \beta_k}}{2 \cdot h \cdot E/e} \cdot G \qquad P = \frac{1}{2} \cdot \frac{\Delta V_{FB}^2}{R_K}$$

E=10GeV， $\beta_m=\beta_k$=120m， Δx=0.3mm, τ_{FB} =1.45 ms， so $\Delta V_{FB\perp}$=9.27kV, P=344w.



- 4-tap filter was considered
- One BPM and One kicker, 90 degree phase shift and DC rejection both are got in FPGA.
- 2 amplifiers, 300W for each

Longitudinal feedback status

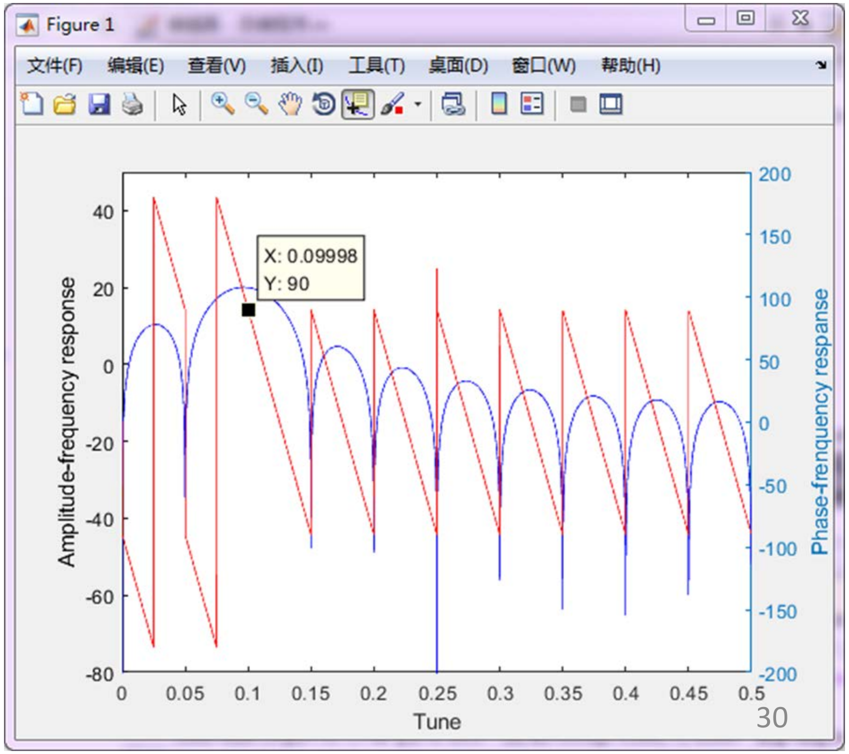
J. Yue, Y Sui et al.

Energy (GeV)	10
RF frequency (GHz)	1.3
Alphap (10^{-5})	2.44
Transverse tune	260/260
Longitudinal tune	0.1
Growth time (ms)	6.5 $\rightarrow$ 65

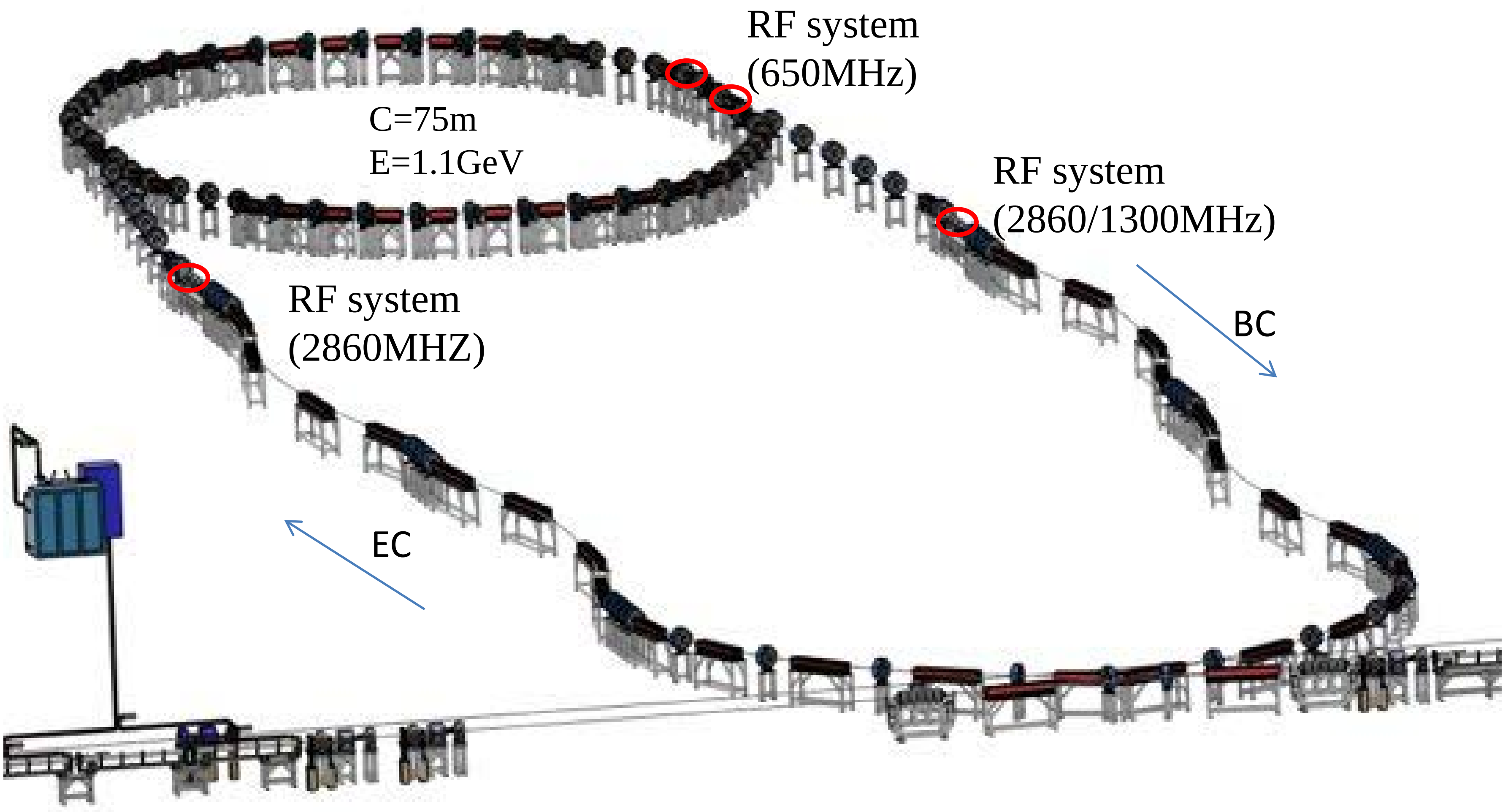
$$\frac{1}{\tau_{FB}} = \frac{f_{rf}\alpha}{2\nu_s E/e} \cdot G \qquad P = \frac{1}{2} \cdot \frac{\Delta V_{FB}^2}{R_K}$$

E=10GeV， α=0.0000244， νs=0.1, τ_{FB} =50 ms， so $\Delta V_{FB||}$ =2144V， P=884W.

- 20-tap filter was considered
- One BPM and One kicker
- 90 degree phase shift and DC rejection both are got in FPGA.
- 4 amplifiers, 250W for each

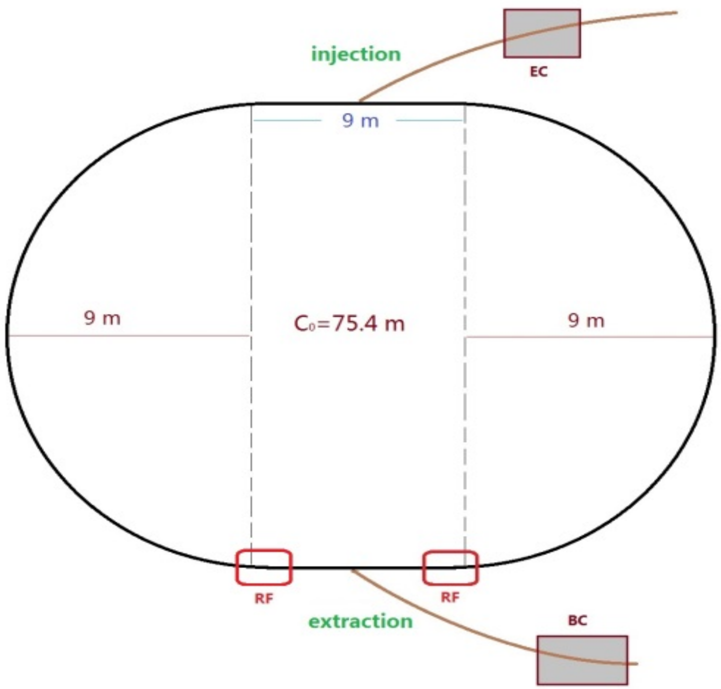


Layout of damping ring system



DR parameters

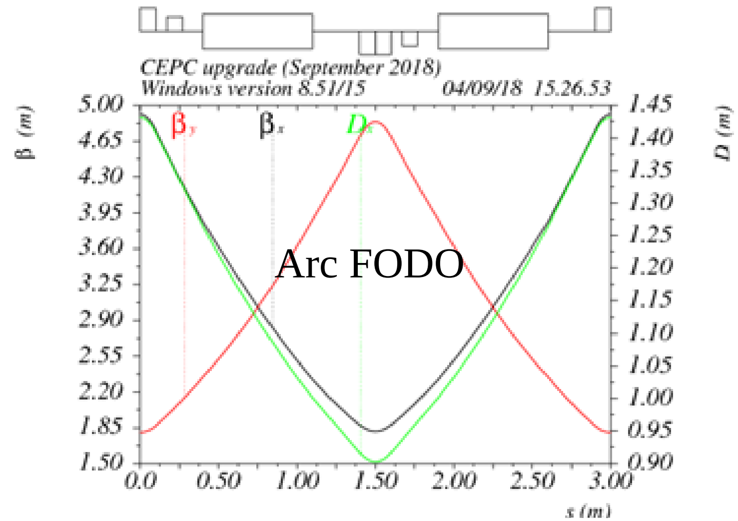
- Linac repetition: 100Hz
- two-bunch storage scheme
- Storage time: 20 ms
- Emittance (norm.): 2500→ 530 mm.mrad
- Large trans. acceptance→ inj. efficiency

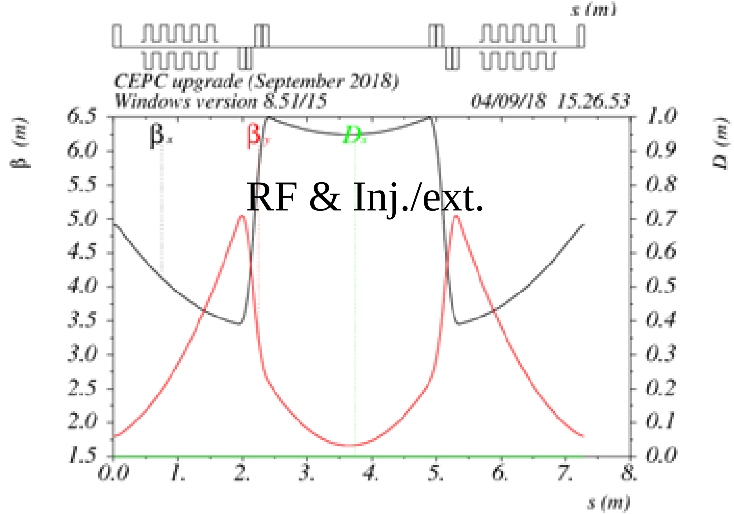


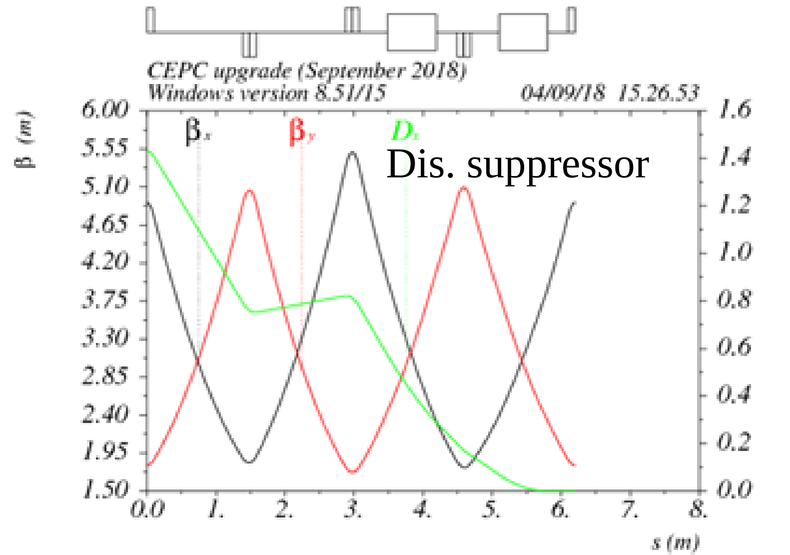
	DR V2.0
Energy (Gev)	1.1
Circumference (m)	75.4
Bending radius (m)	3.6
Dipole strength B_0 (T)	1.03
U_0 (kev/turn)	36.3
Damping time x/y/z (ms)	15.2/15.2/7.6
δ_0 (%)	0.05
ε_0 (mm.mrad)	376.7
injection σ_z (mm)	5
Extract σ_z (mm)	7.5
ε_{inj} (mm.mrad)	2500
$\varepsilon_{ext\ x/y}$ (mm.mrad)	530/180
δ_{inj} /δ_{ext} (%)	0.18 /0.05
Energy acceptance by RF(%)	1.0
f_{RF} (MHz)	650
V_{RF} (MV)	2.0

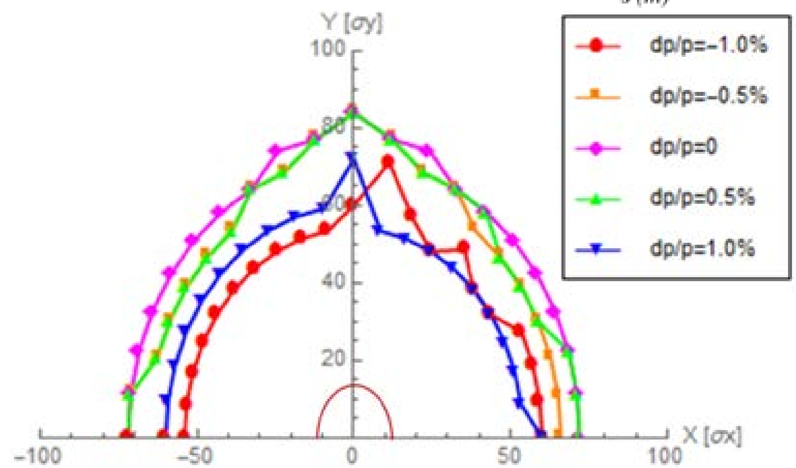
DR optics

- 60°/60° FODO
- interleave sextupole scheme
- 2 sextupole families
- DA > 5×injection beam size







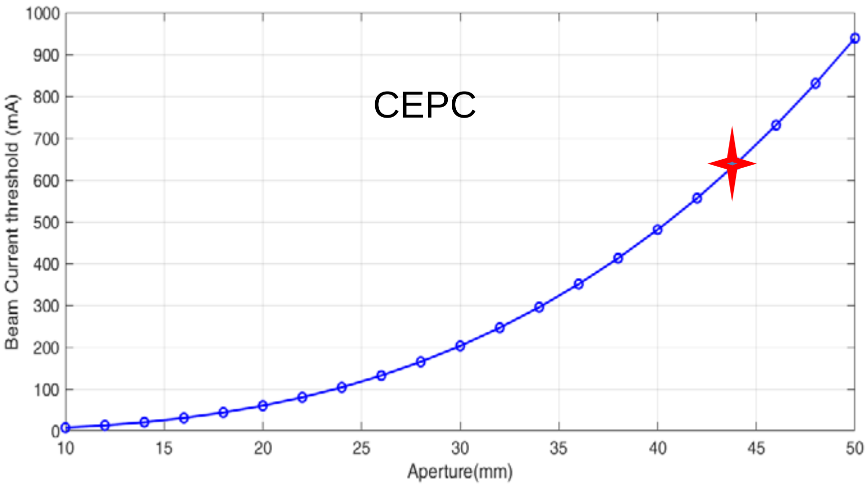


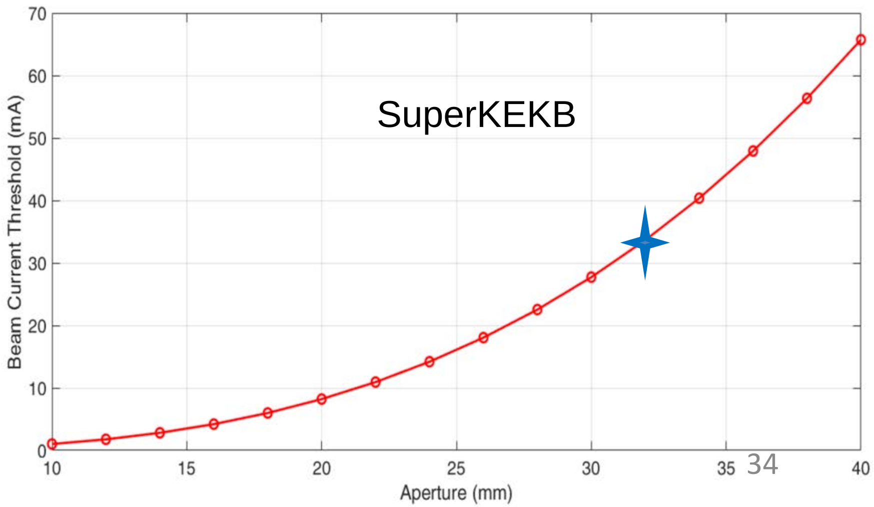
Impedance threshold

Y. D. Liu

- BSC: 4σ+5mm → d= 33mm (including dispersion effect)
- Size of beam pipe: 44mm, Al, 2mm thickness
- Circular beam pipe (SR power density=5W/m)

parameters	damping ring for SuperKEKB	damping ring for CEPC
Energy	1.1Gev	1.1Gev
circumference	135.5	75.4
Beta tune	8.24/7.265	3.84/4.81
Bunch lenght	11.12mm	5mm
Bunch number	4	2
synchtron tune	0.0153	0.062
Beam current	70 mA	10 mA





CSR threshold

- The beam is assumed to be moving in a circle of radius ρ between two parallel plates at locations $y=\pm h$

- The threshold of bunch population for CSR is given by

$$S^{\mathrm{th}} = 0.50 + 0.12\Pi \qquad S = \frac{r_e N_b \rho^{1/3}}{2\pi \nu_s \gamma \sigma_\delta \sigma_z^{4/3}}, \qquad \Pi = \frac{\sigma_z \rho^{1/2}}{h^{3/2}}$$

- For CEPC DR, $\sigma_z \rho^{1/2}/h^{3/2}=4.4$ (=> CSR shielded)

  - Inner diameter of beam pipe: 44 mm

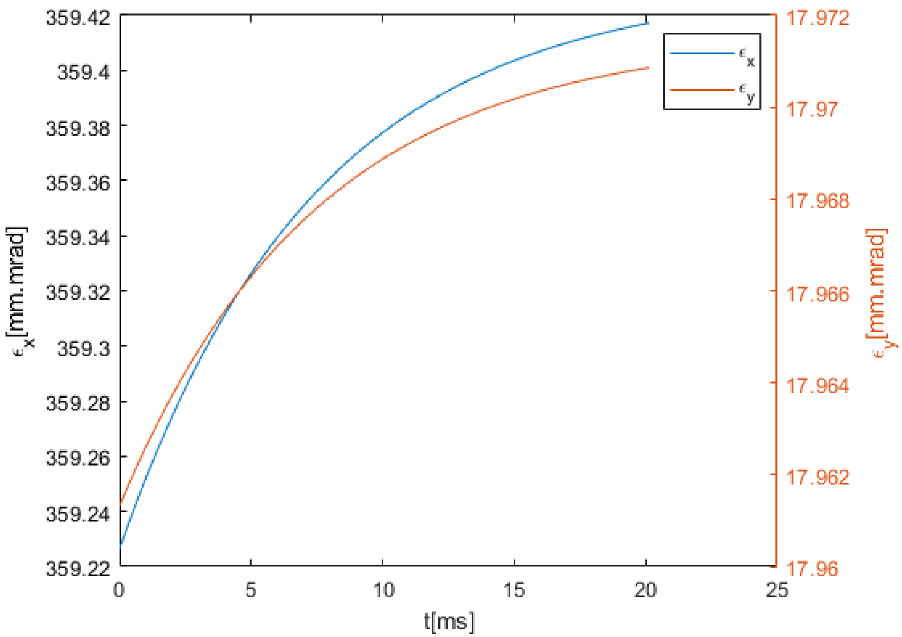
- The CSR threshold in CEPC DR is

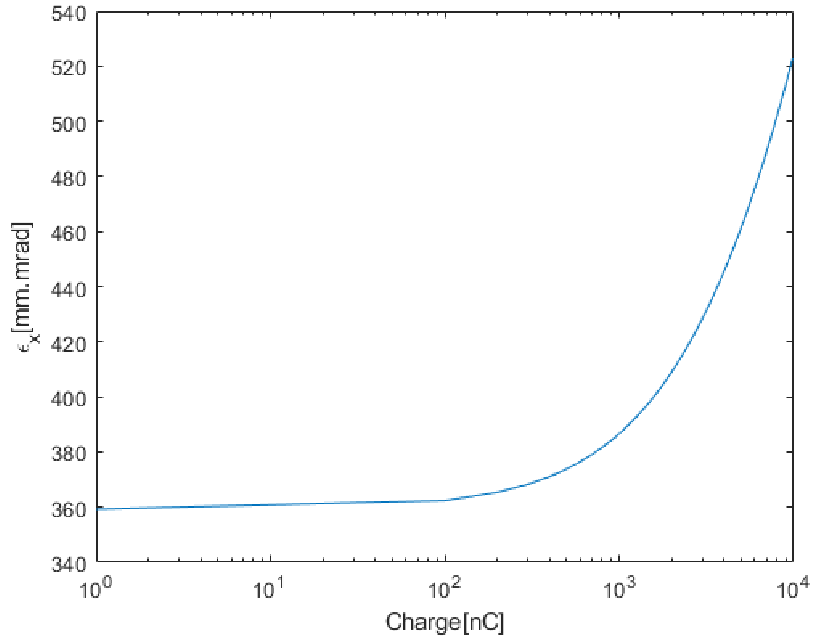
  $N_{\mathrm{b,Th}} = 1.46\times10^{11} >> N_{\mathrm{b}} = 9.36\times10^{9}$.

IBS effect

S. K. Tian

- Equilibrium emittance (H/V): 359/18 mm·mrad
- No emittance growth at design bunch current (1.5nC/bunch)
- IBS threshold: ~100nC/bunch
- IBS is not a concern in CEPC DR.





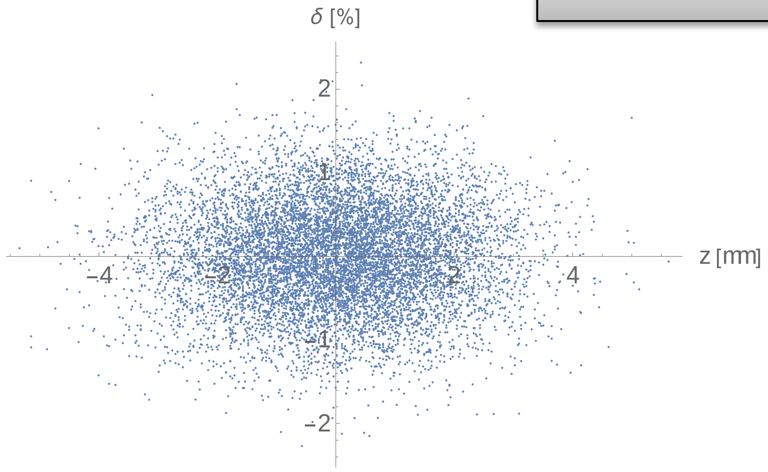
EC/BC parameters

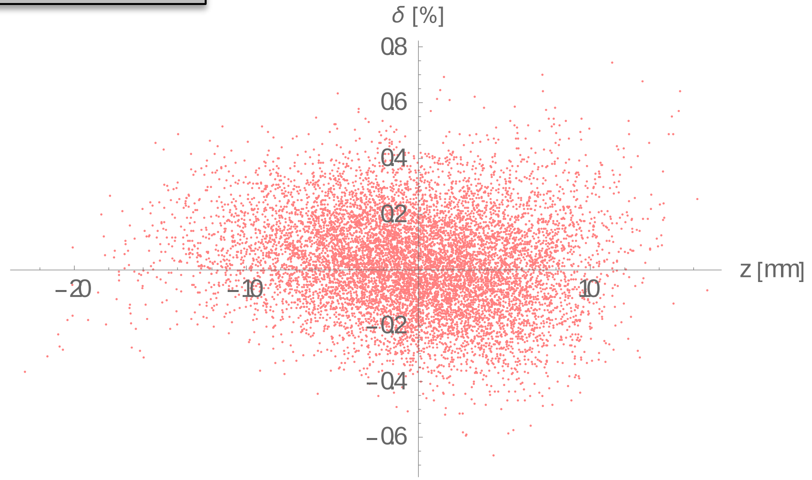
	EC
E_0 (Gev)	1.1
δ_0 (%)	0.6
σ_{z0} (mm)	1.5
f_{RF} (MHz)	2860
V_{RF} (MV)	22.0
Length of acc. Structure (m)	0.82
ϕ_{RF} (degree)	89.7
R_{56} (m)	-0.833
E_f (Gev)	1.1
δ_f (%)	0.18
σ_{zf} (mm)	5

	BC
E_0 (Gev)	1.1
δ_0 (%)	0.05
σ_{z0} (mm)	7.5
f_{RF} (MHz)	2860/1300
V_{RF} (MV)	13.1/29
Length of acc. Structure (m)	0.48/2.5
ϕ_{RF} (degree)	89.6
R_{56} (m)	-1.4
E_f (Gev)	1.1
δ_f (%)	0.54
σ_{zf} (mm)	0.7

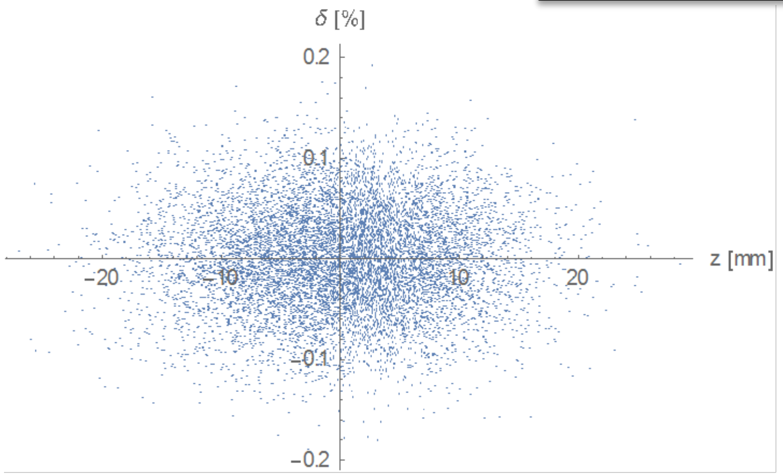
Beam simulation on transport lines

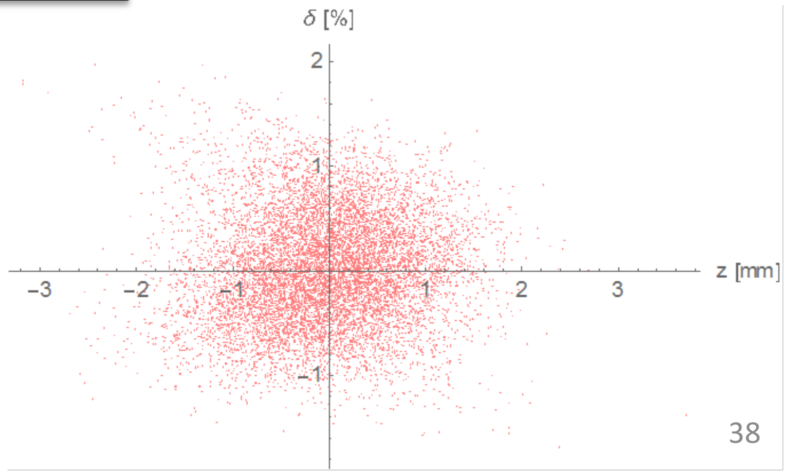
Linac → DR (2.86GHz)





DR → Linac (1.3GHz)



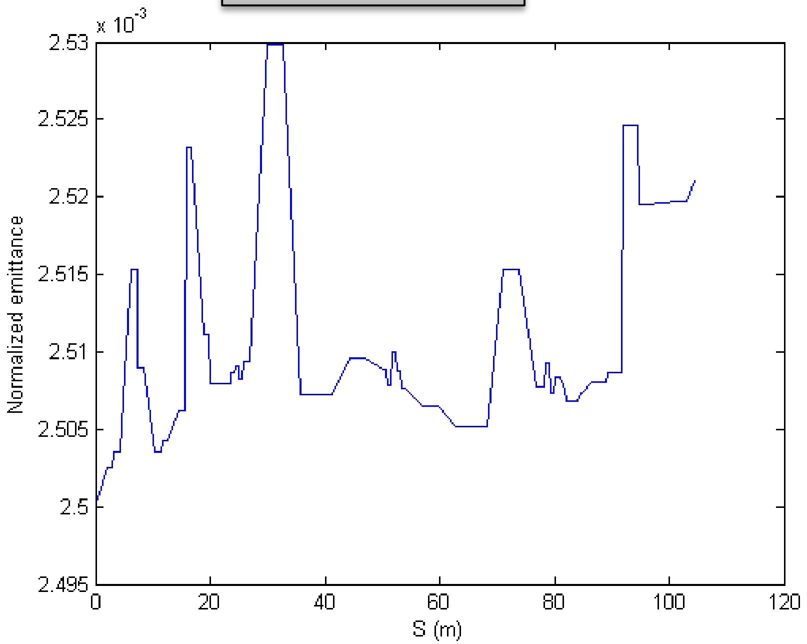


Emittance evolution on transport lines

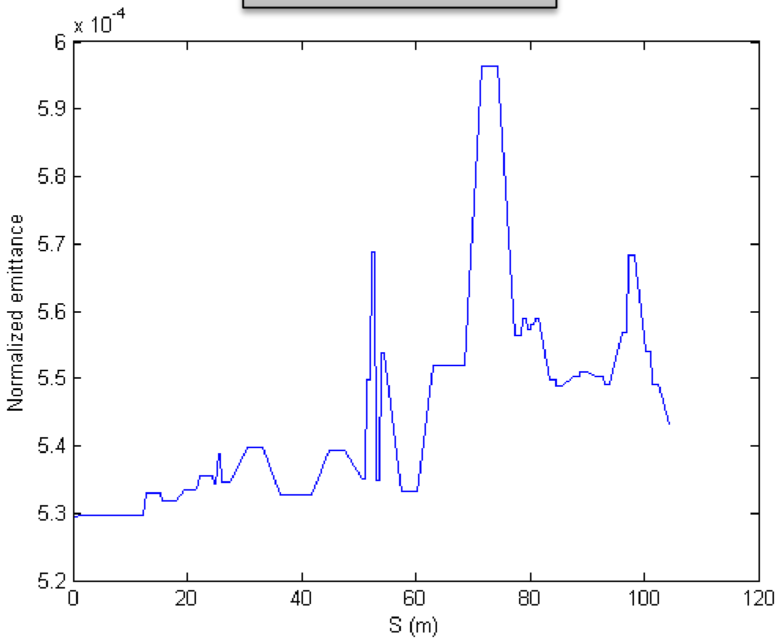
X. H. Cui

- Dipole strength for the chicane: 0.49T
- No error included
- No emittance growth due to radiation effect

Linac → DR



DR → Linac



Summary

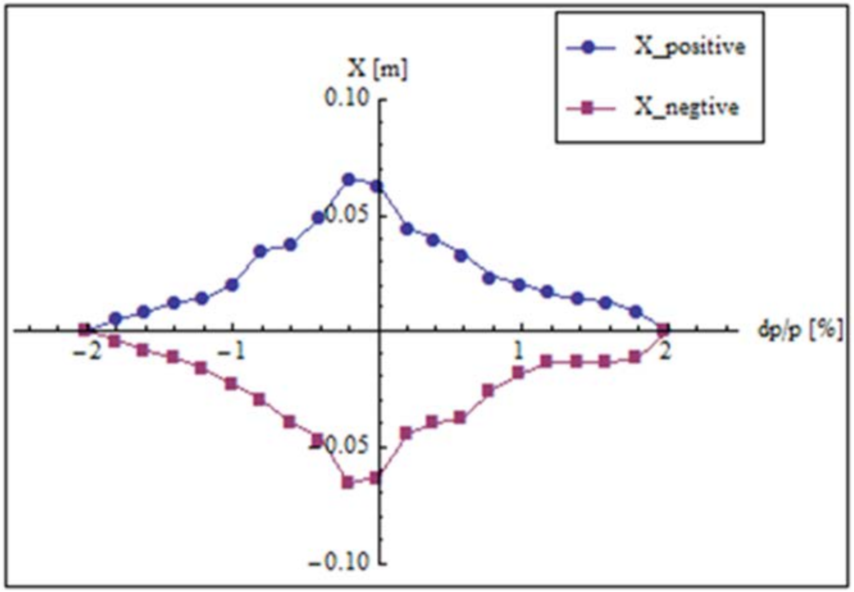
- Propose new parameters with higher luminosity after CDR.
- Booster design in CDR was refined. Become more solid.
- A lot of effort to find a new design for booster with lower emittance
  - *Higgs off-axis injection in CDR*
  - *Higgs on-axis injection in high lumi. mode*
- No principle difficulties to use the new booster. Still comprehensive assessment of error effect is necessary.
- Both transverse and longitudinal feedback system has substantive progress.
- DR system was specified. Key beam parameters can be realized. Error studies on the way.

Thanks for your attention!

Back up

Off-momentum DA of booster (CDR)

SAD



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