Collective effects in SuperKEKB

Demin Zhou

Division VI, Acc. Lab, KEK

with contributions from

KEK: **T. Abe, T. Ishibashi, Y. Morita, K. Ohmi, N. Ohuchi, K. Shibata, Y. Suetsugu, H. Sugimoto, M. Tobiyama, M. Yoshida**

SLAC: **Y. Cai, G. Stupakov, R. Warnock**

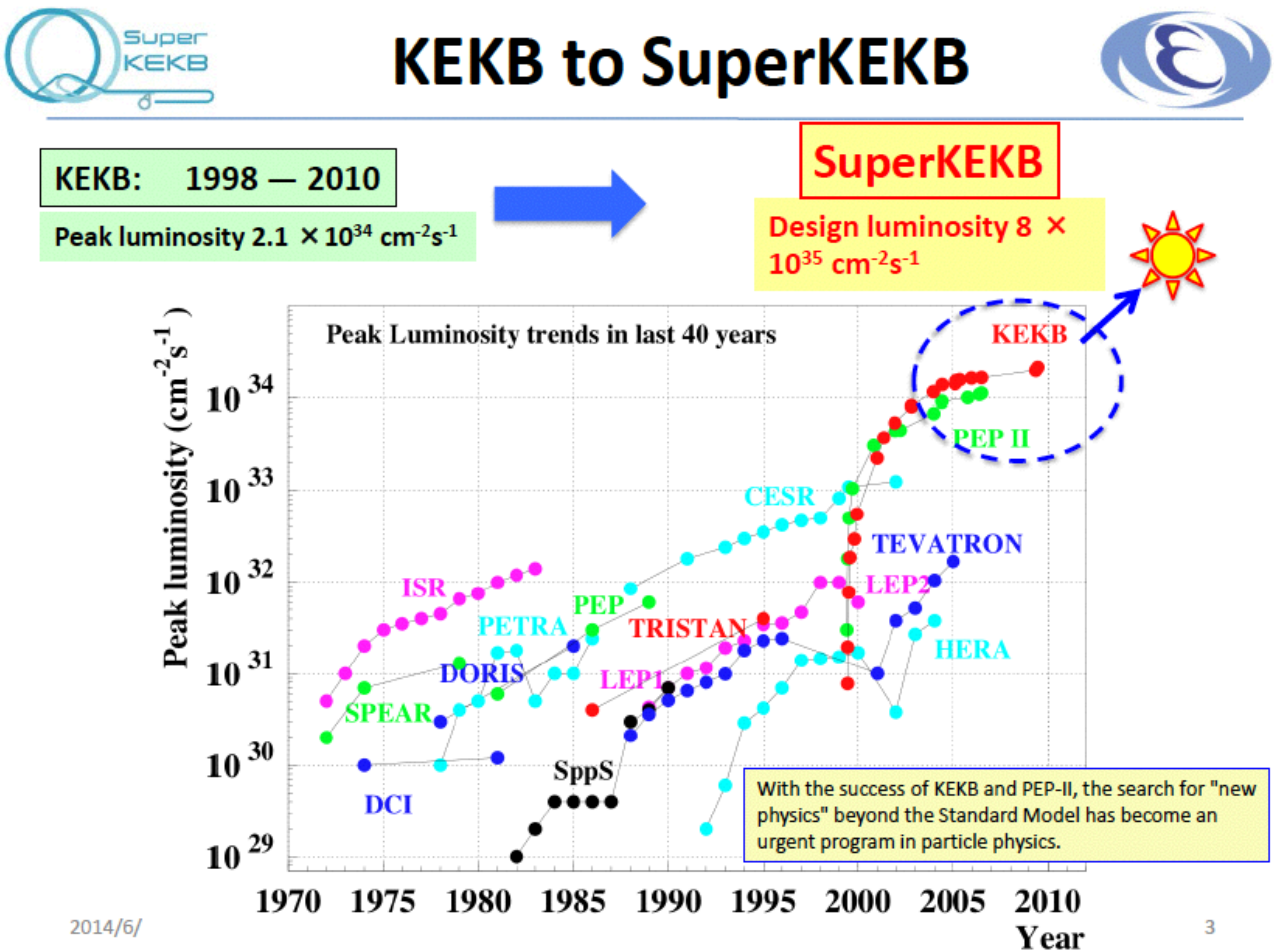
CLASSE Seminar, Cornell University, Ithaca, NY

Aug. 06, 2014

Outline

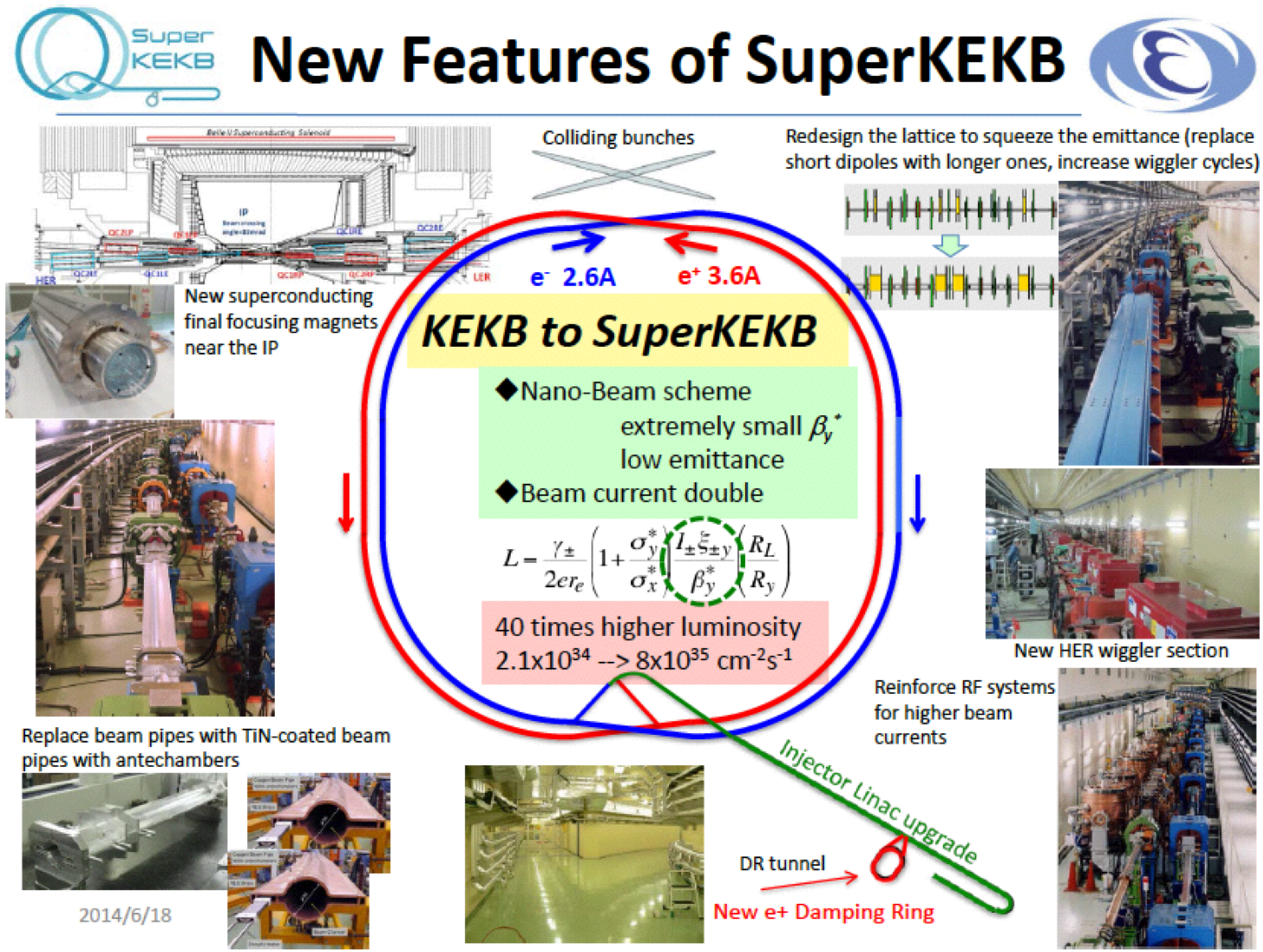
- **Introduction**
  - **Design target, features of SuperKEKB, “Nano-beam”, …**
- **Beam-beam and luminosity**
  - **BB simulations, luminosity calculations, …**
  - **Interplay of beam-beam and lattice nonlinearity**
- **Impedance and Single-bunch effects**
  - **Impedance calculations, impedance budget, …**
  - **Bunch lengthening, MWI, beam tilt, TMCI, …**
- **Electron cloud**
  - **Ecloud density estimation, instability simulations, …**
- **Space charge**
  - **Linear tune shift, effect on luminosity, …**
- **Intra-beam scattering**
  - **Emittance growth, …**
- **Summary**

1. Introduction: Lum. trends



From N. Ohuchi, IPAC14, WEOCA01

1. Introduction: Features of SuperKEKB



From N. Ohuchi, IPAC14, WEOCA01

1. Introduction: Expected lum. gain

SuperKEKB

- Increase the luminosity by 40 times based on "Nano-Beam" scheme

$$L = \frac{\gamma_{\pm}}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\left(\frac{I_{\pm}\xi_{\pm y}}{\beta_y^*}\right)\left(\frac{R_L}{R_y}\right) = 8 \times 10^{35}\ \mathrm{cm^{-2}s^{-1}}$$

- Vertical β function at IP : 5.9 → 0.27/0.30 mm (× 20)

  KEKB SuperKEKB Luminosity Gain
- Beam current : 1.7/1.4 → 3.6/2.6 A (× 2)
- Vertical beam-beam parameter : 0.09 → 0.09 (× 1)
- Beam energy: 3.5/8.0 → 4.0/7.0 GeV

LER : Longer Touschek lifetime and mitigation of emittance growth due to the intra-beam scattering
HER : Lower emittance and lower SR power

From N. Ohuchi, IPAC14, WEOCA01

1. Introduction: Scaling SuperKEKB/KEKB

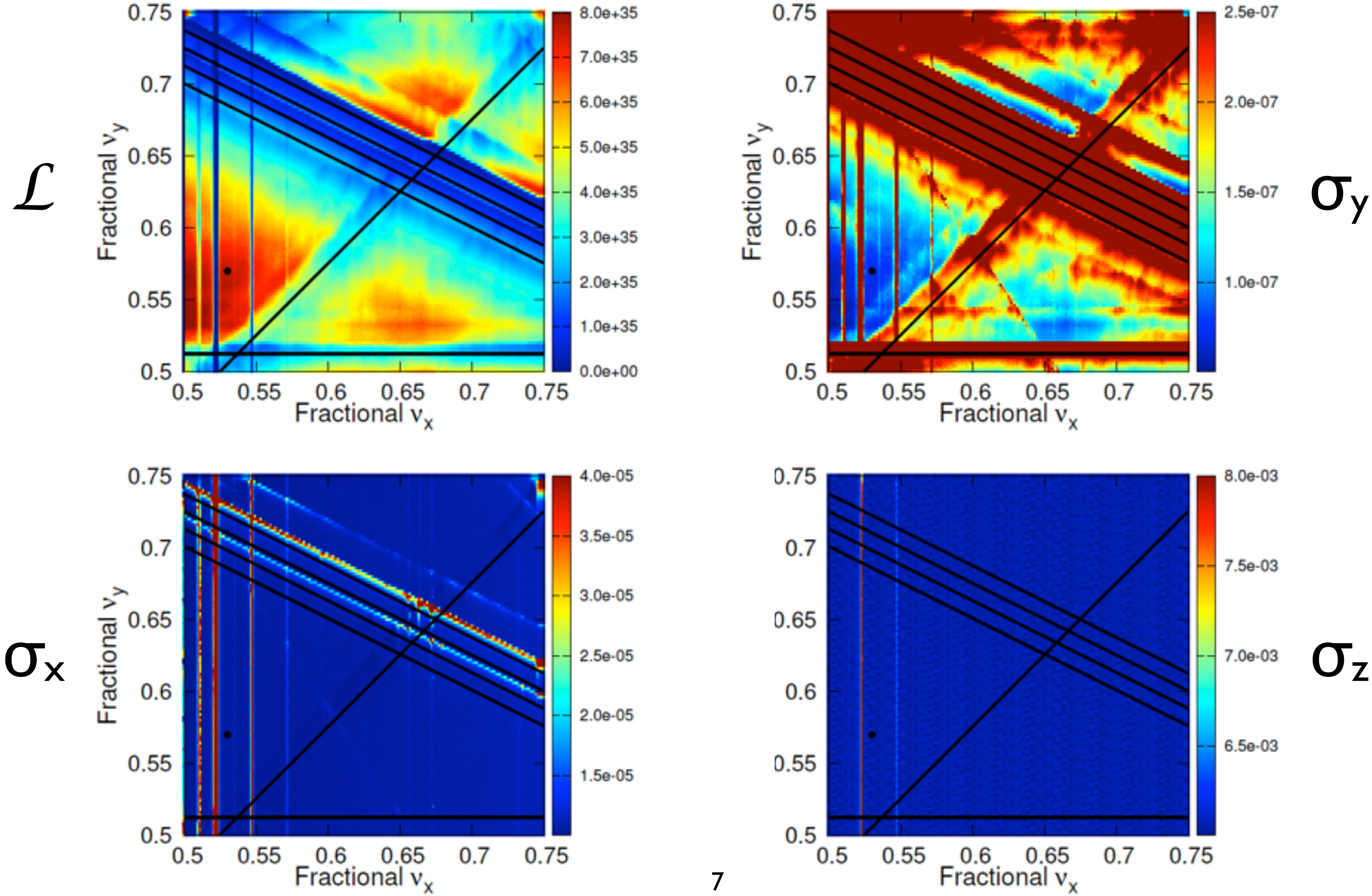
	LER			HER		
	SKEKB	KEKB	Factor	SKEKB	KEKB	Factor
E(GeV)	4	3.5	1.14	7.007	8	0.876
I	1.44	1.03	1.4	1.04	0.75	1.4
ε	3.2	18	0.18	4.6	24	0.19
ε	8.64	180	0.048	11.5	240	0.048
β	0.032	1.2	0.027	0.025	1.2	0.021
β	0.27	5.9	0.046	0.3	5.9	0.051
α	3.25	3.31	0.98	4.55	3.43	1.33
σ	8.08	7.73	1.11	6.37	6.3	0.96
σ	5	4.6		4.9	5.2	

*Machine parameters on Jun.17, 2009

See http://www-superkekb.kek.jp/index.html for details

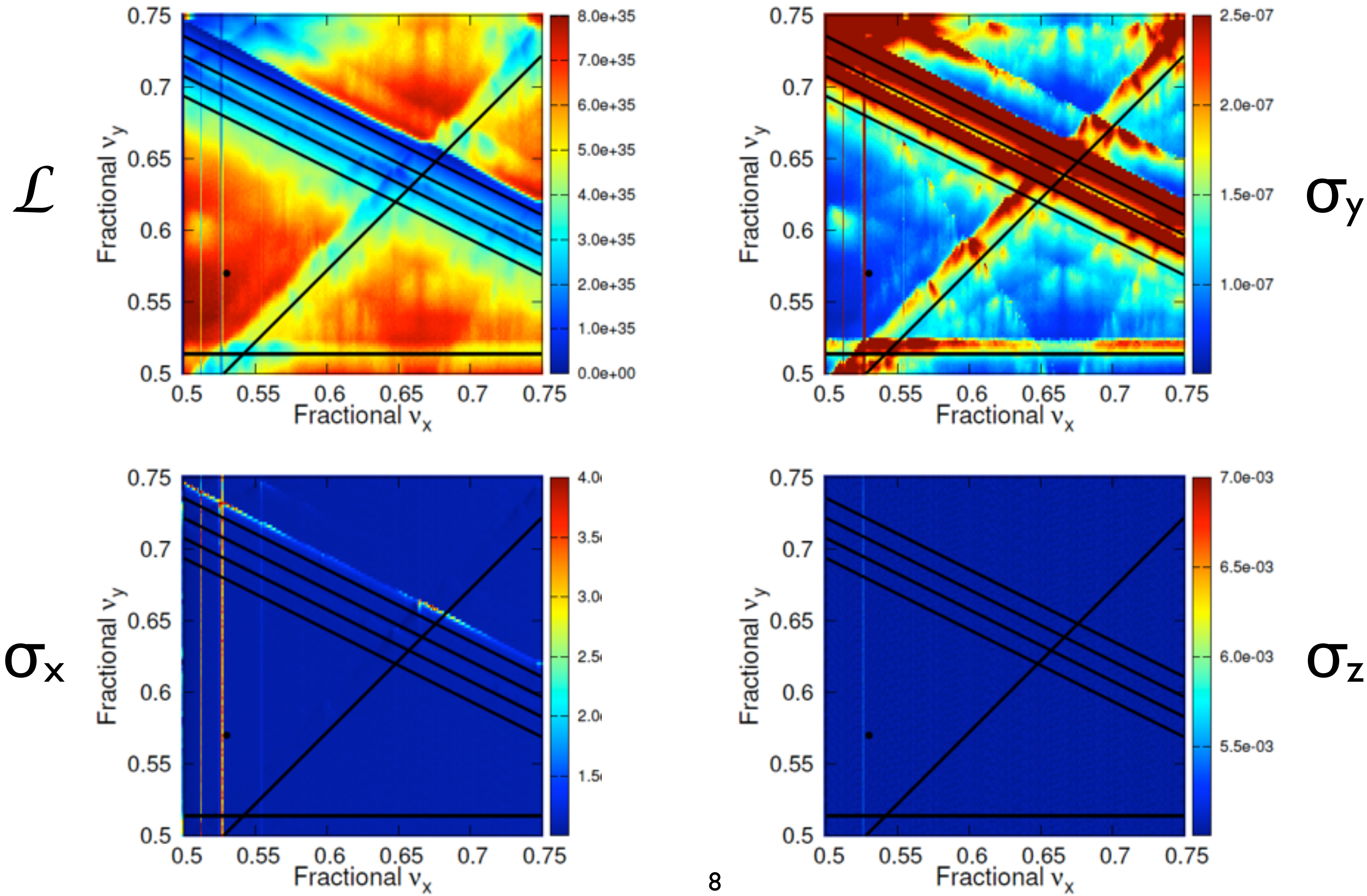
2. Beam-beam and luminosity: LER

➤ **Lum. tune scan for LER (by BBWS)**



2. Beam-beam and luminosity: HER

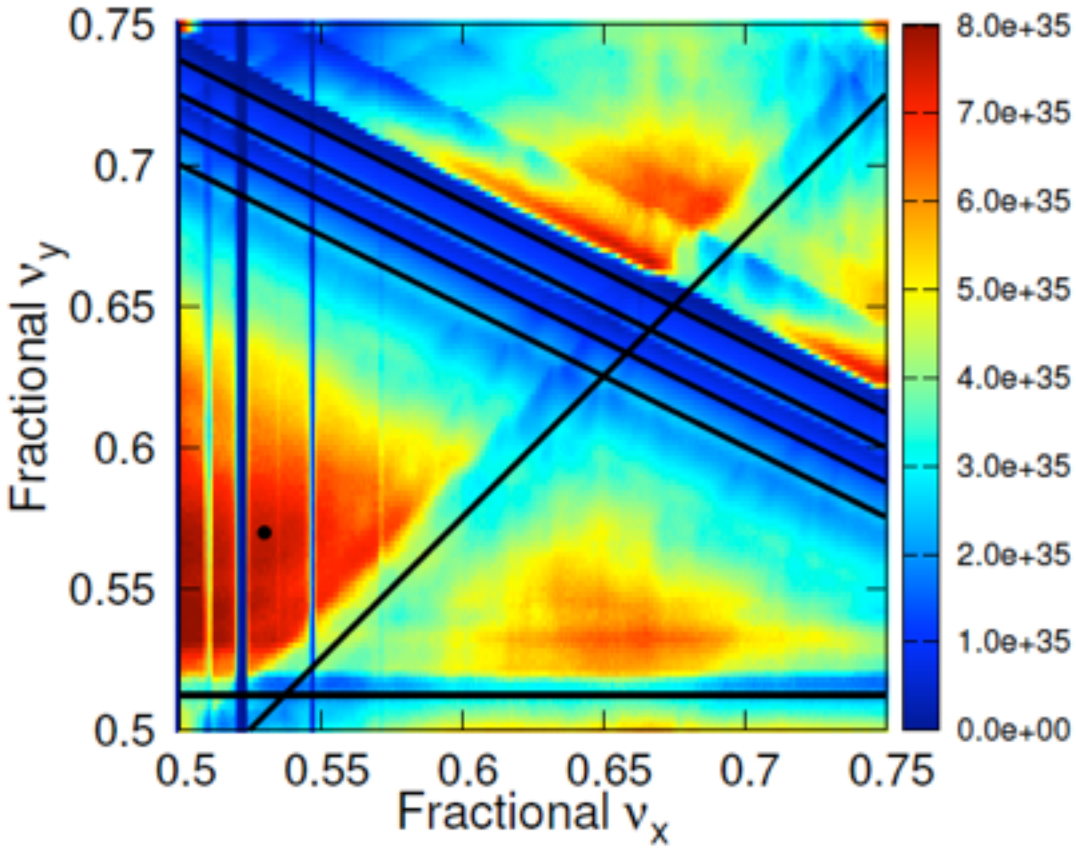
➤ **Lum. tune scan for HER (by BBWS)**



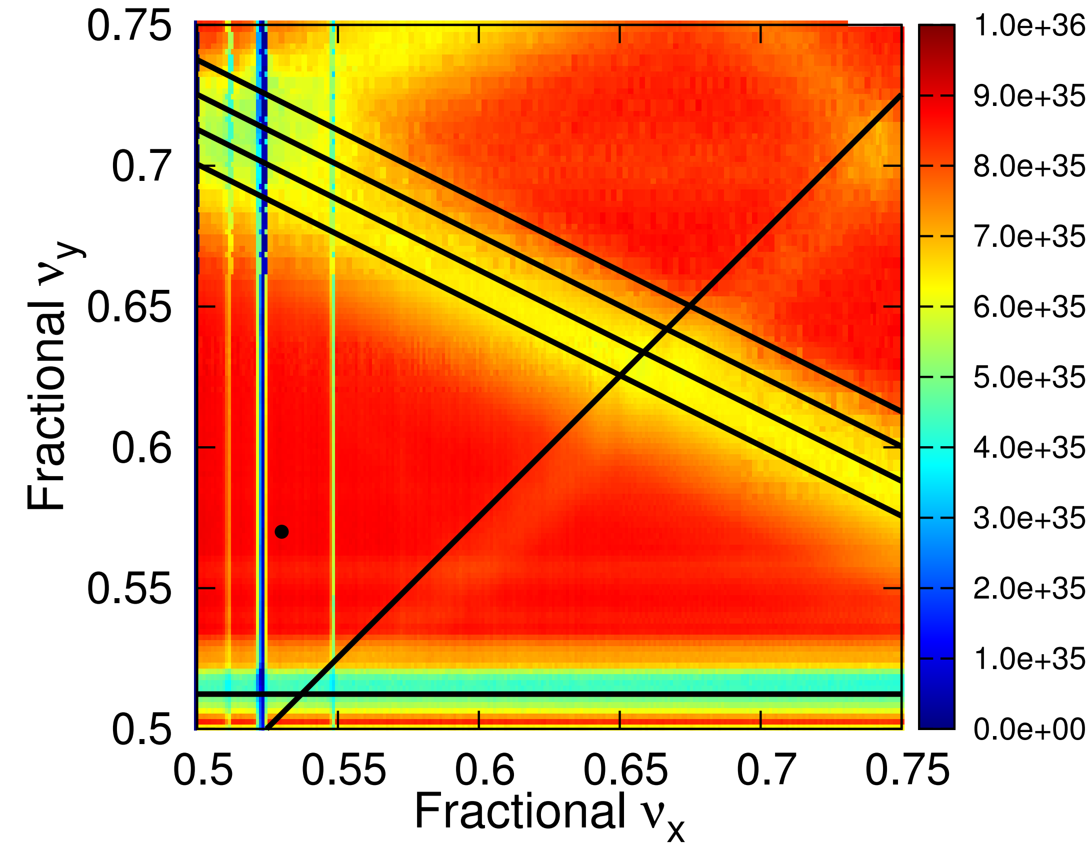
2. Beam-beam and luminosity: LER

➤ Lum. scan w/o and w/ crab waist for LER (by BBWS)

- **Crab waist creates freedom of choice. This is attractive …**
- **But optics design is a challenging issue …**



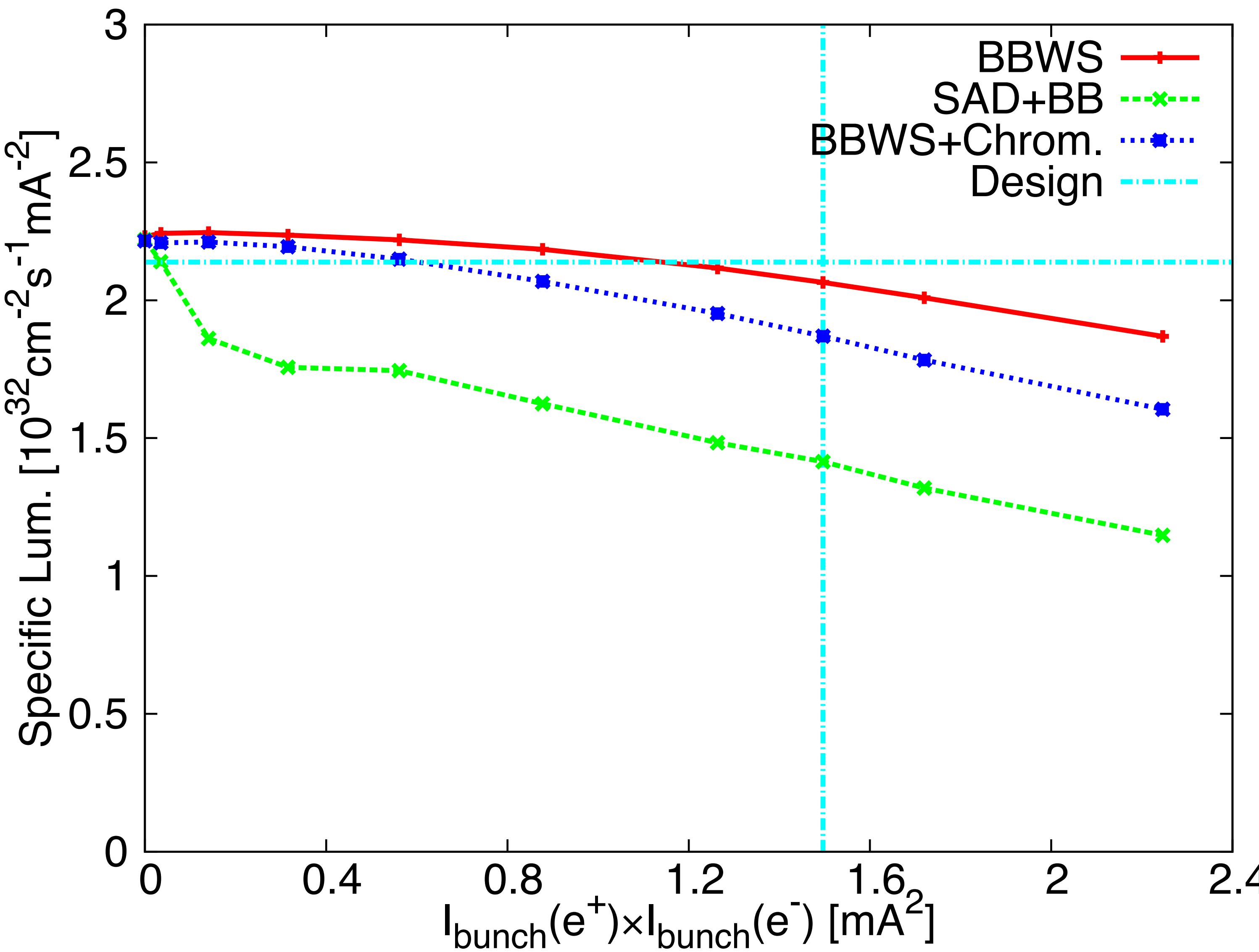
w/o crab waist



w/ crab waist

2. Beam-beam: Lattice nonlinearity: LER

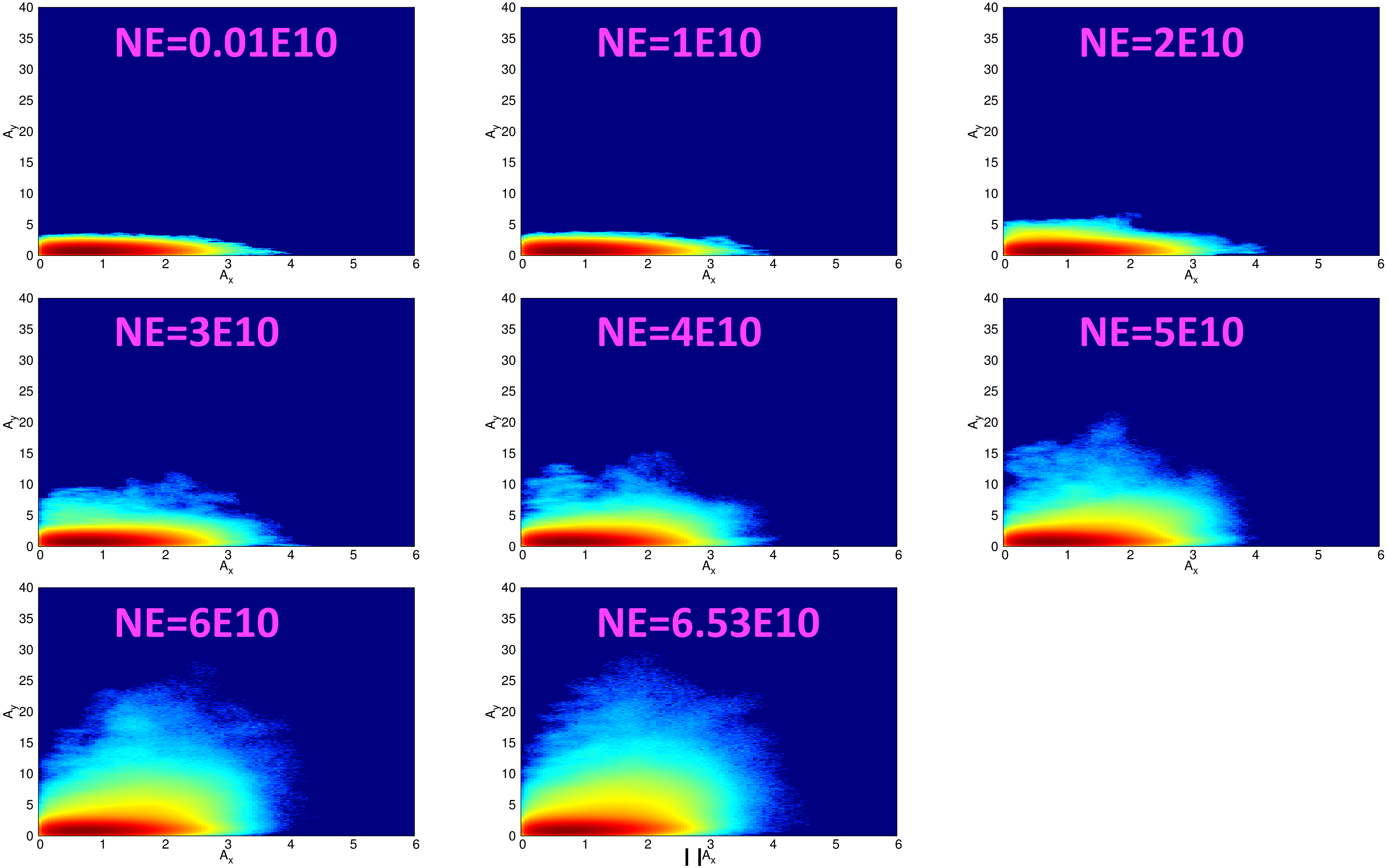
- ➤ **Chromatic effect: KEKB experiences**
- ➤ **Mom.-dependent nonlin. controlled in lattice design**
- ➤ **Chromatic effect can not explain the lum. loss**
- ➤ **Amplitude-dependent nonlin. more important?**



sler_1684

2. Beam-beam: Lattice nonlinearity: LER

➤ Beam tail w/ BB by BBWS



2. Beam-beam: Lattice nonlinearity: LER

➤ Beam tail w/ BB+LN by SAD

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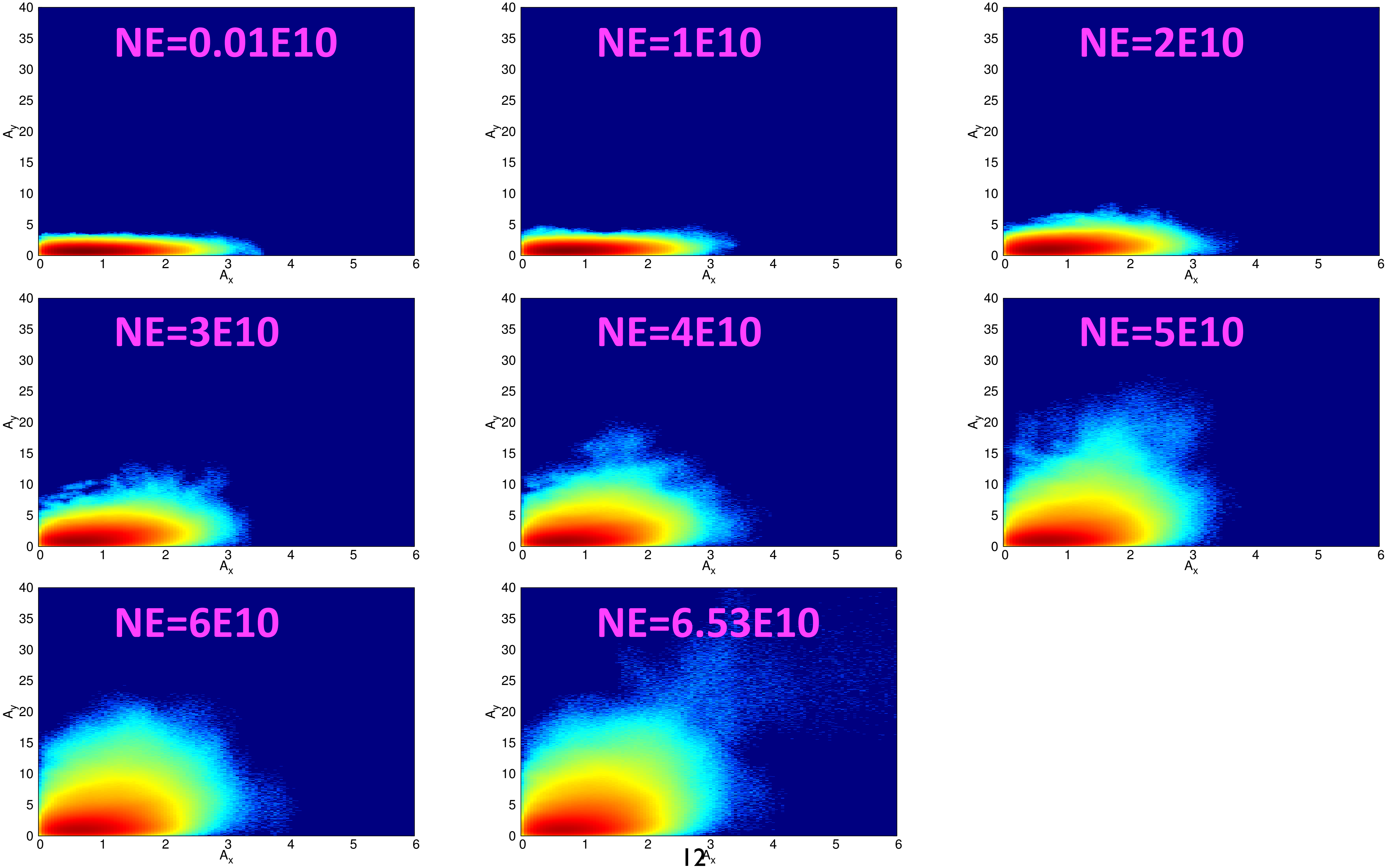
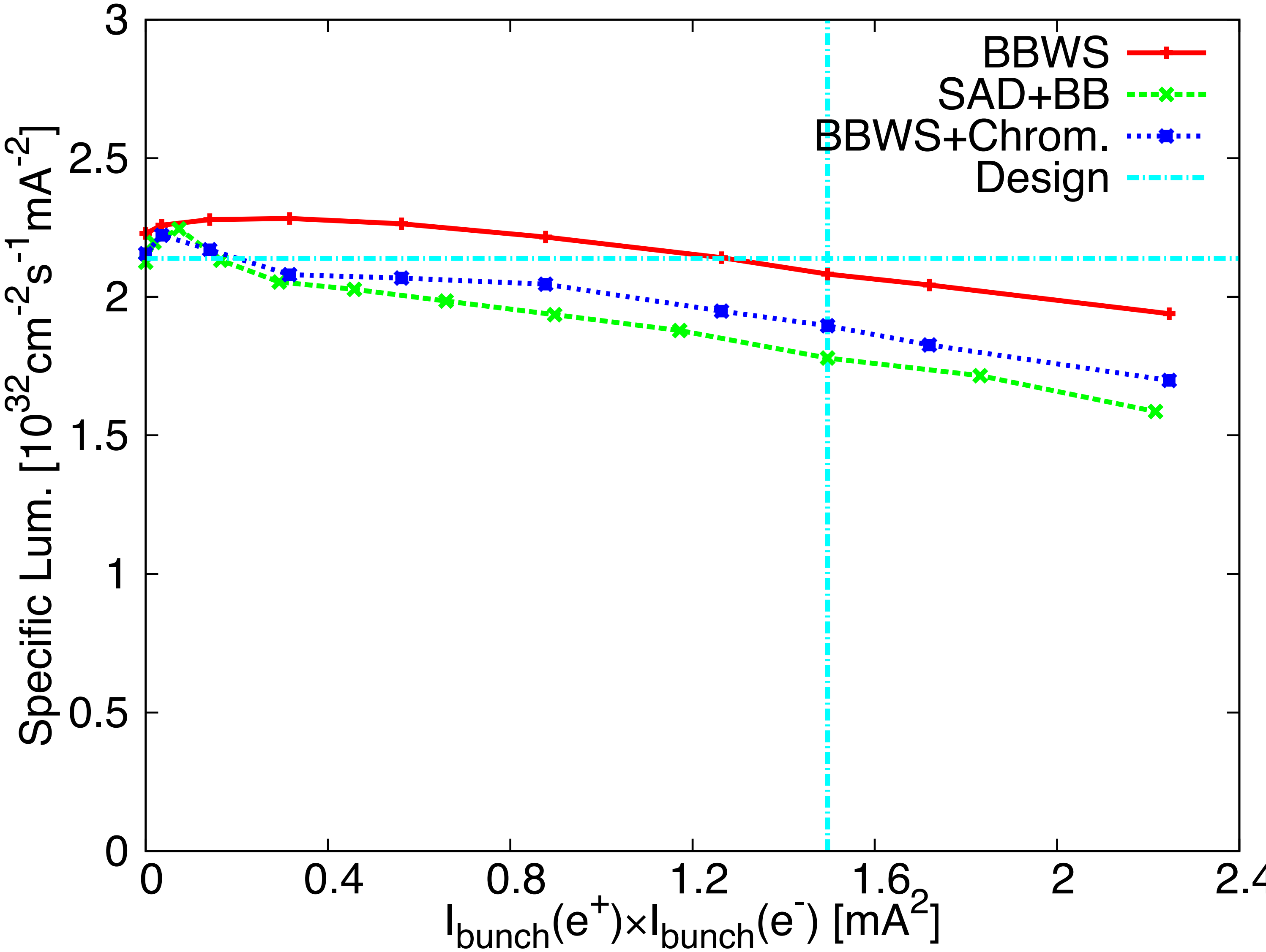


2. Beam-beam: Lattice nonlinearity: HER

- ➤ Chromatic effect: KEKB experiences
- ➤ Mom. nonlin. not controlled in lattice design
- ➤ The lum. loss is mainly due to chromatic effect



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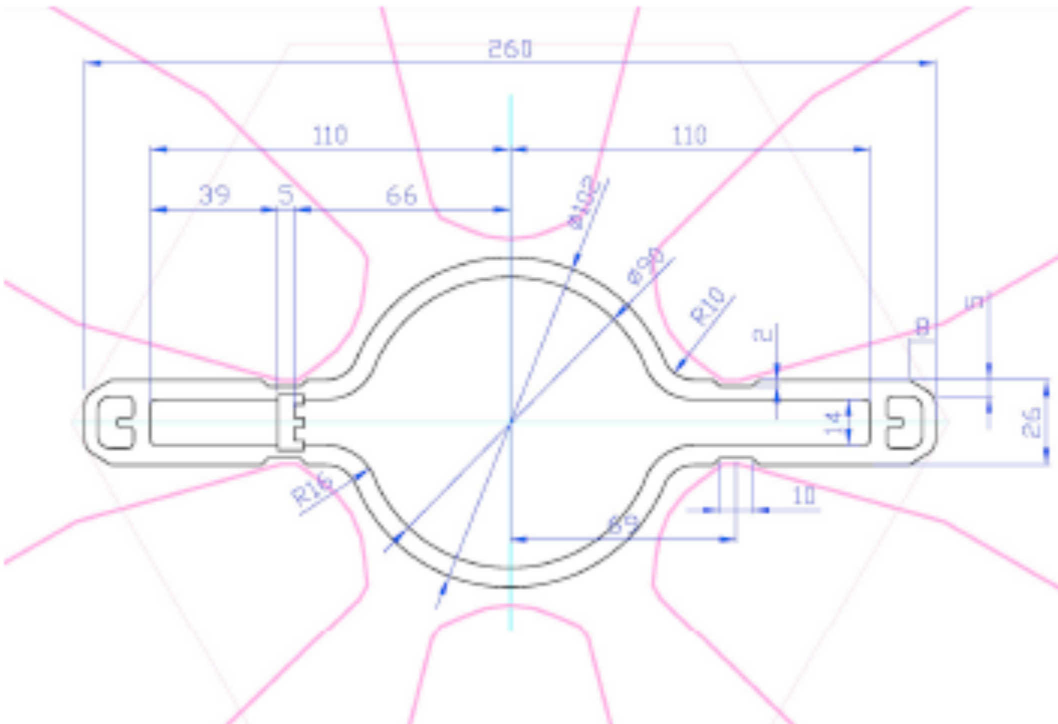
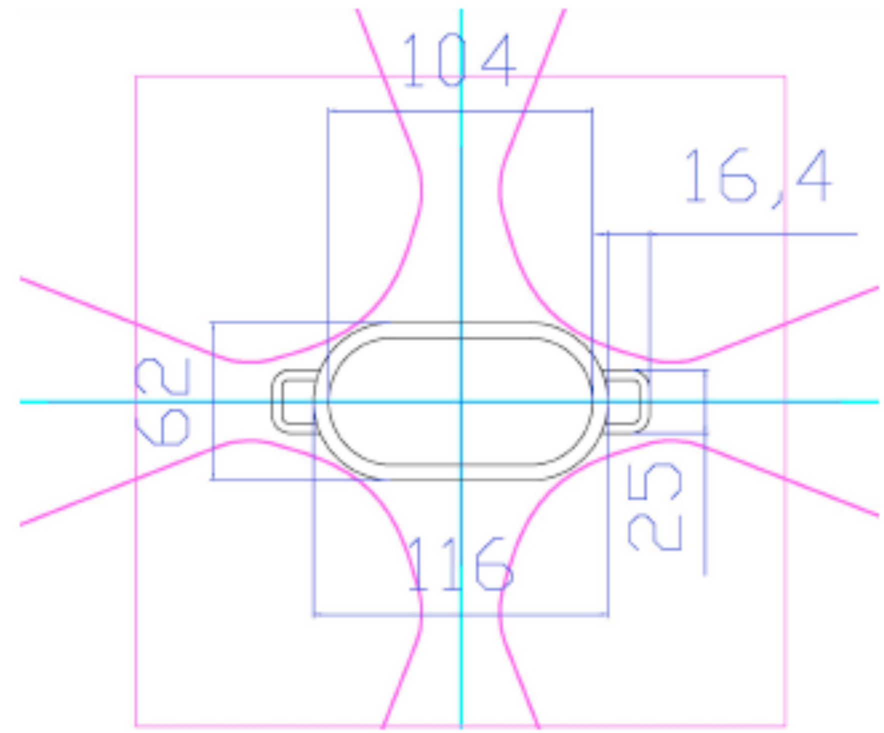
3. Impedance: Modelling

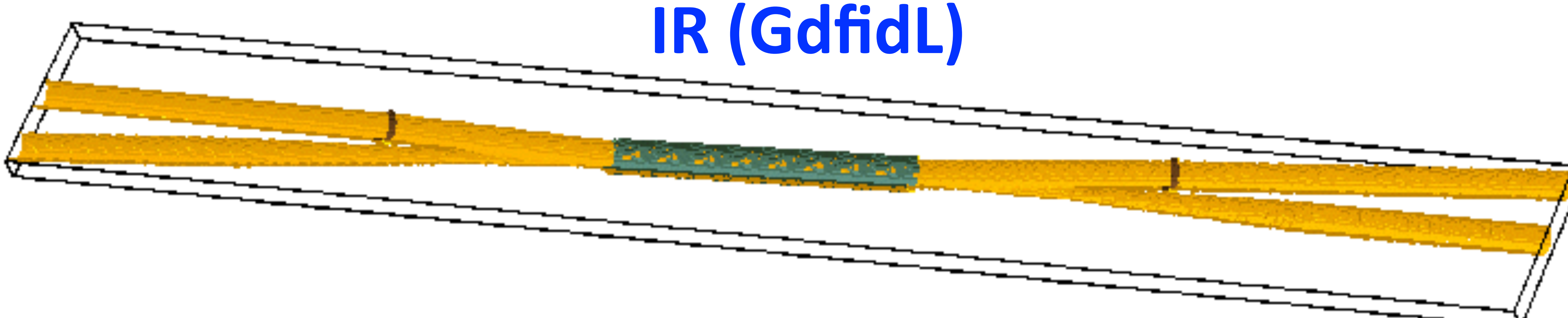
LER typical (~90%)
Aluminum w/ antechamber



HER typical (~70%)
Copper w/o antechamber



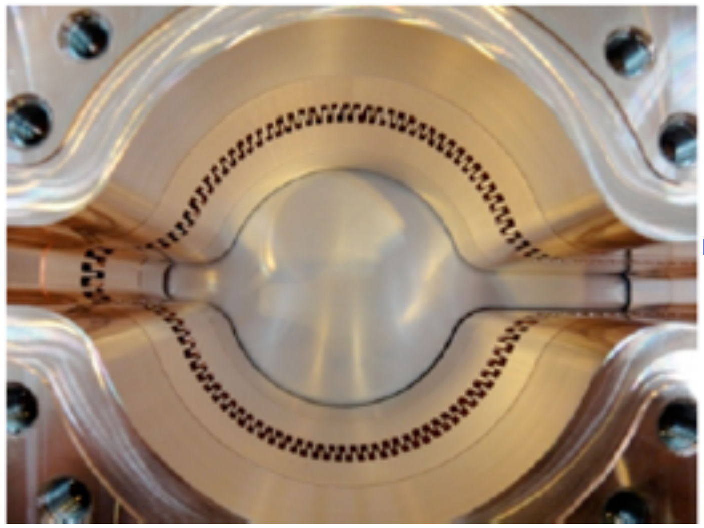
IR (GdfidL)

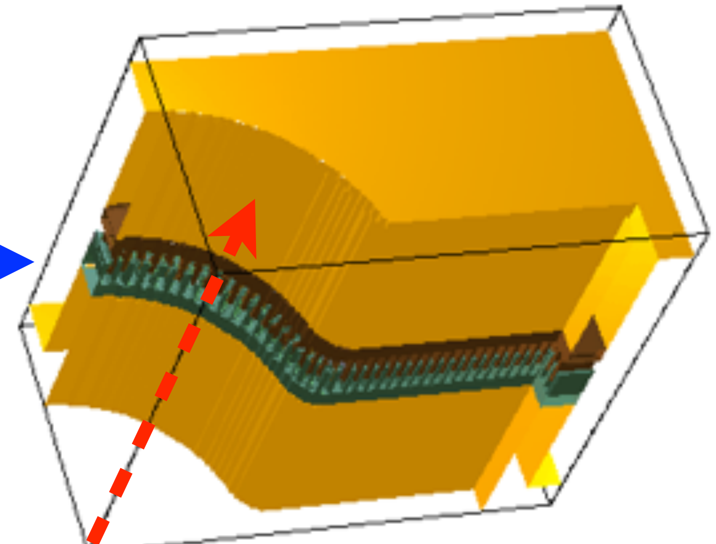


From Y. Suetsugu and K. Shibata

3. Impedance: Modelling: LER

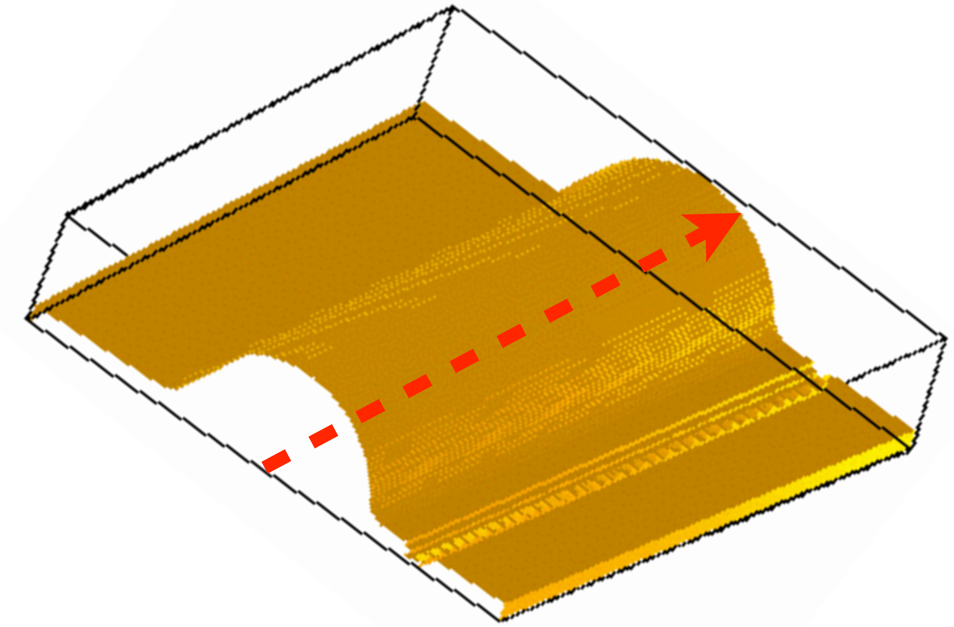
Bellows



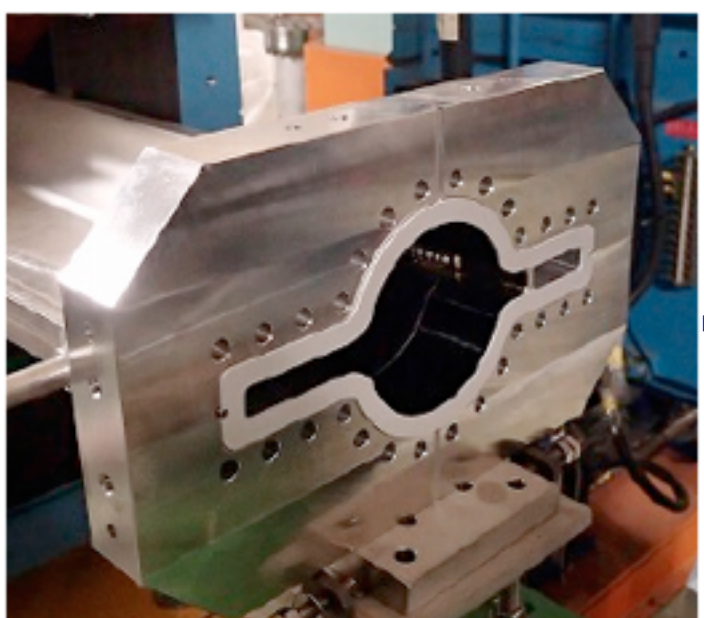


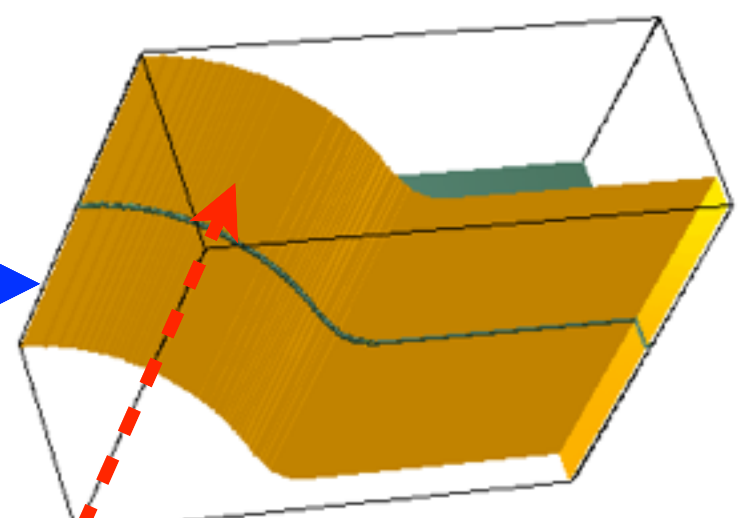
Comb-type: Unique for SuperKEKB

Pumping port



MO-type flange



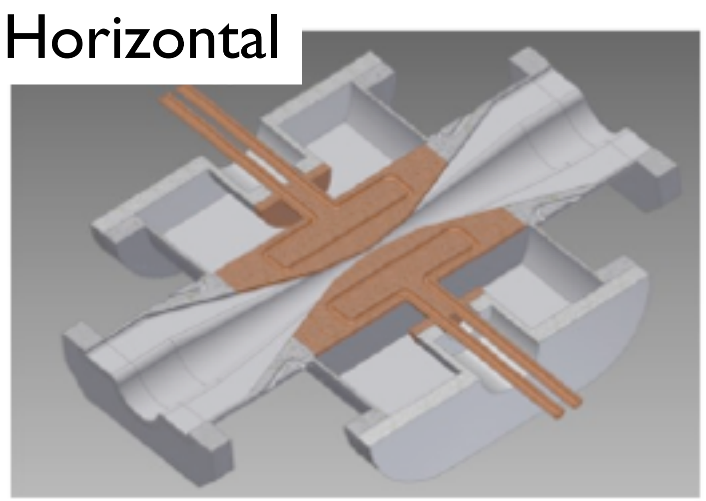


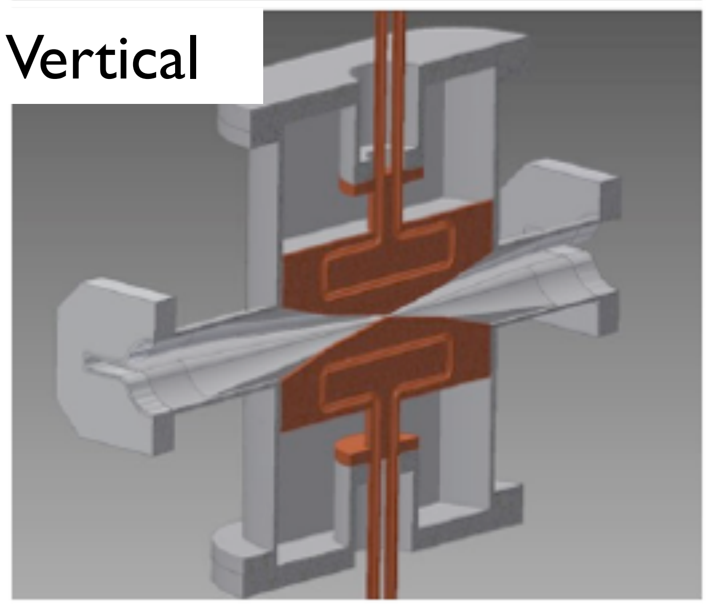
ARES RF cavity

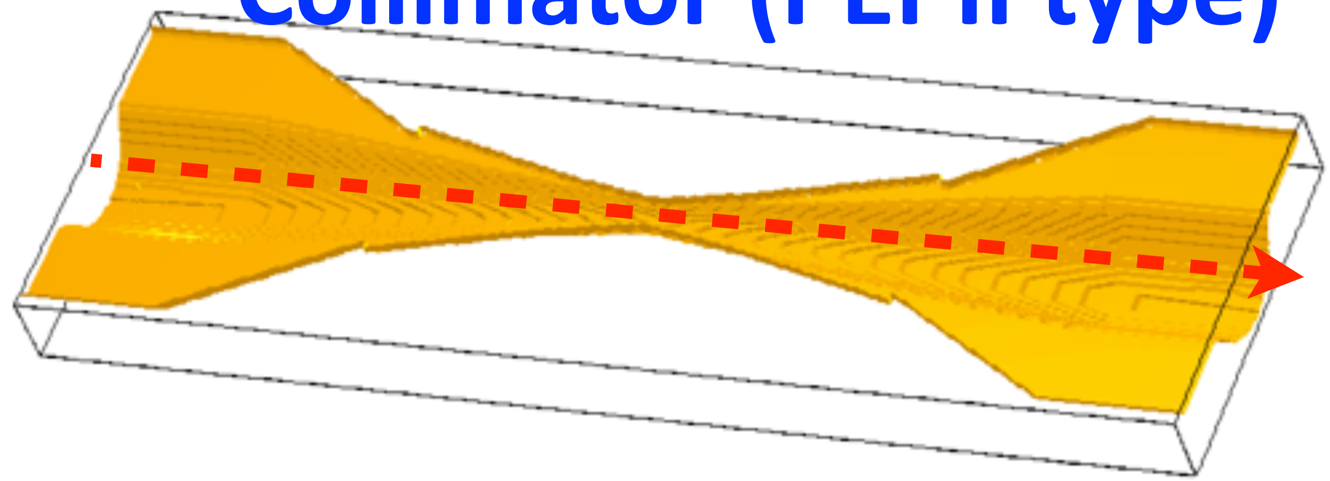
From T. Abe and K. Shibata

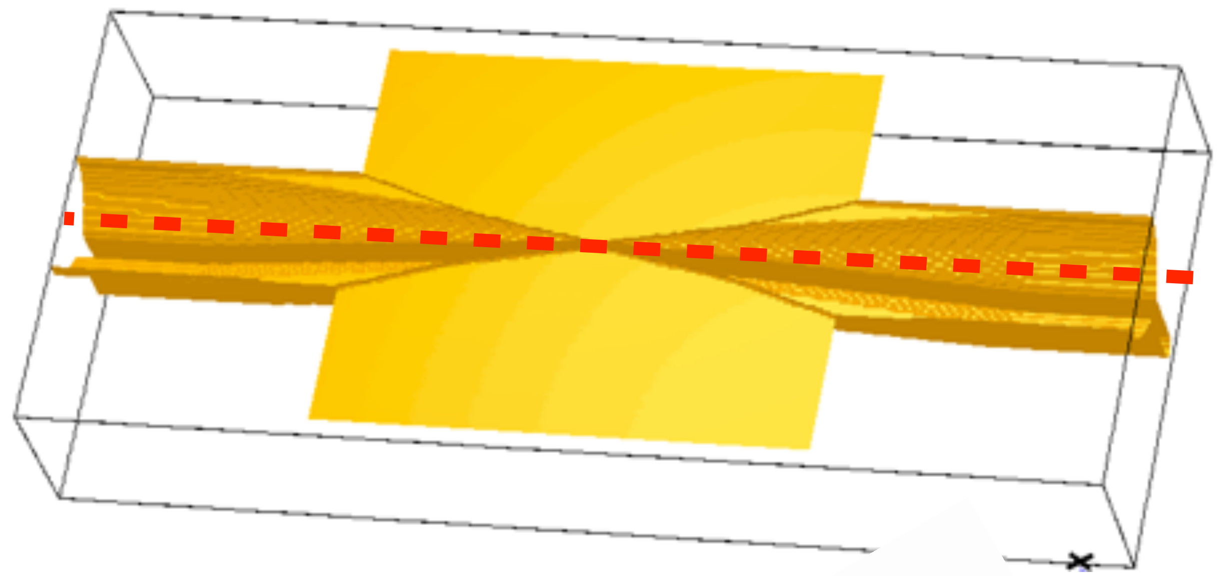
3. Impedance: Modelling: LER

Collimator (PEPII type)

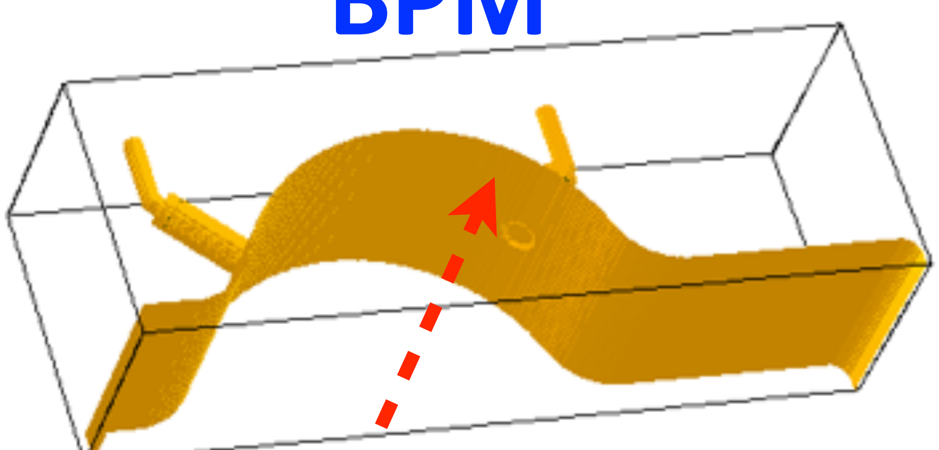




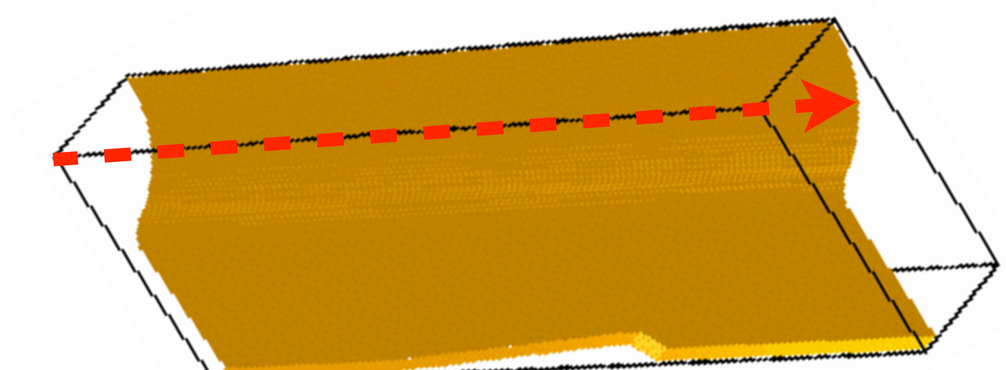




BPM



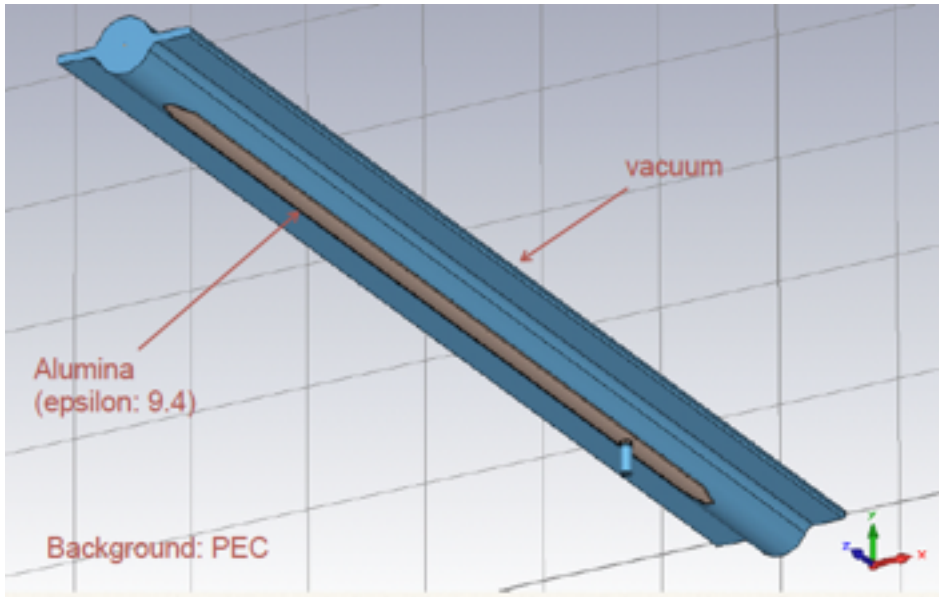
SR mask



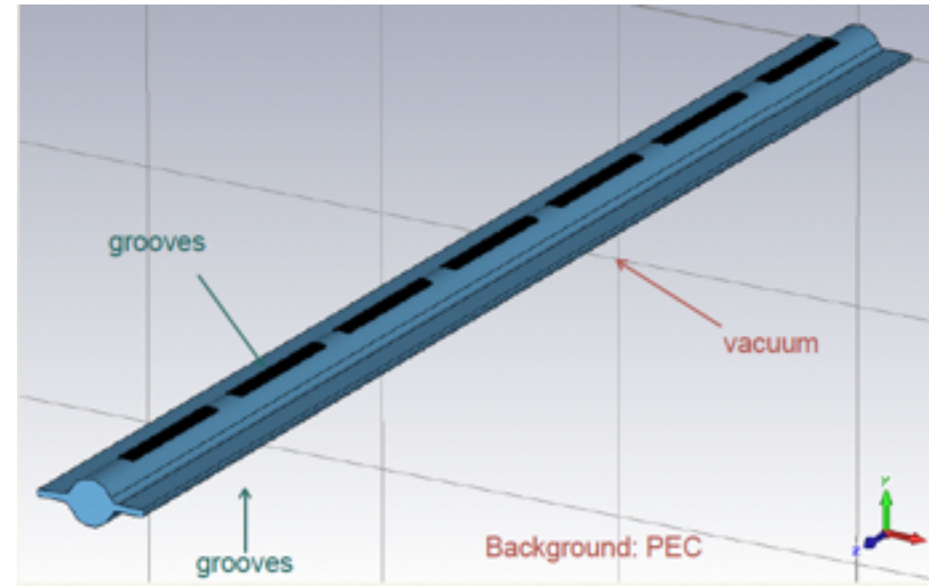
From T. Ishibashi, M. Tobiyama, and K. Shibata

3. Impedance: Modelling: LER

Clearing electrode



Grooved surfaces



From T. Ishibashi

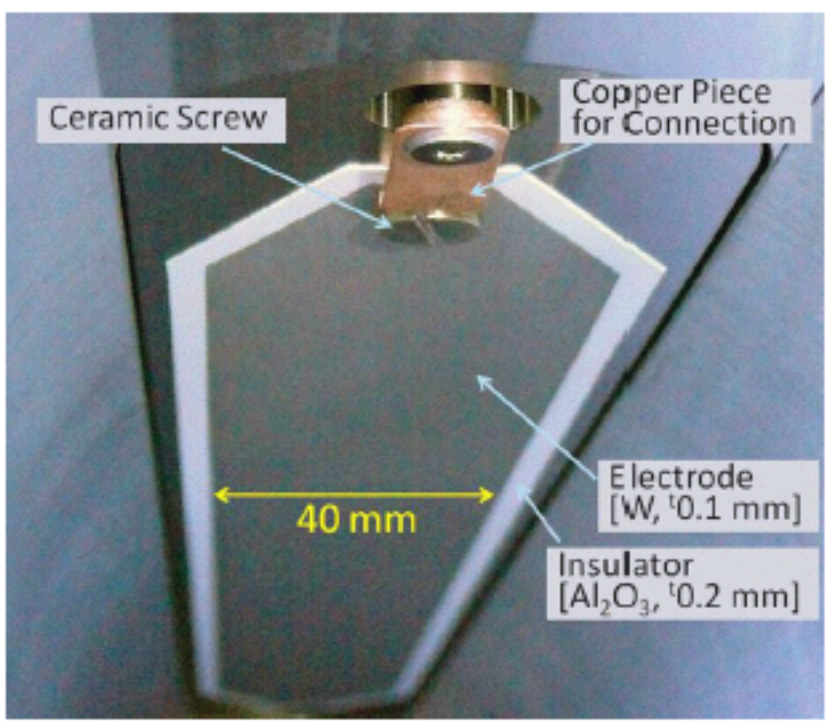


Fig. 2. Clearing electrode installed in test chamber. The electrode and the feed-through are connected by small piece of copper.

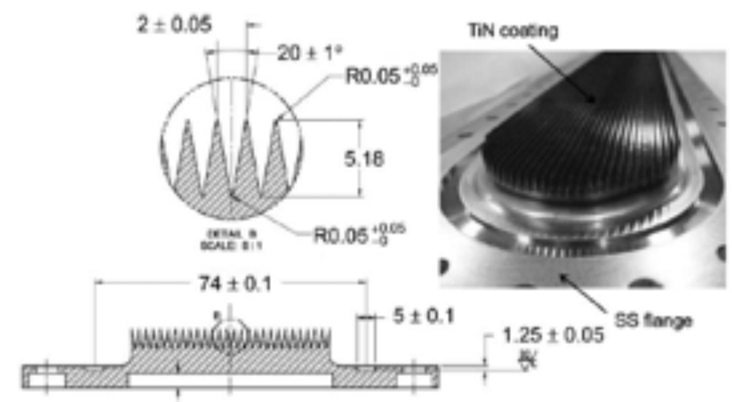


Fig. 1. Insertion with TiN-coated groove surface.

Tested in KEKB

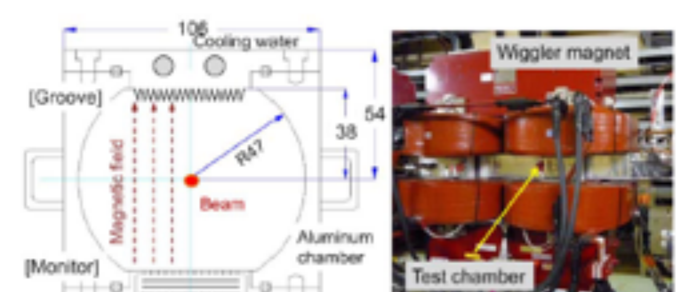


Fig. 2. Cross-section of the test chamber and the experimental setup in a wiggler magnet section in the KEKB positron ring.

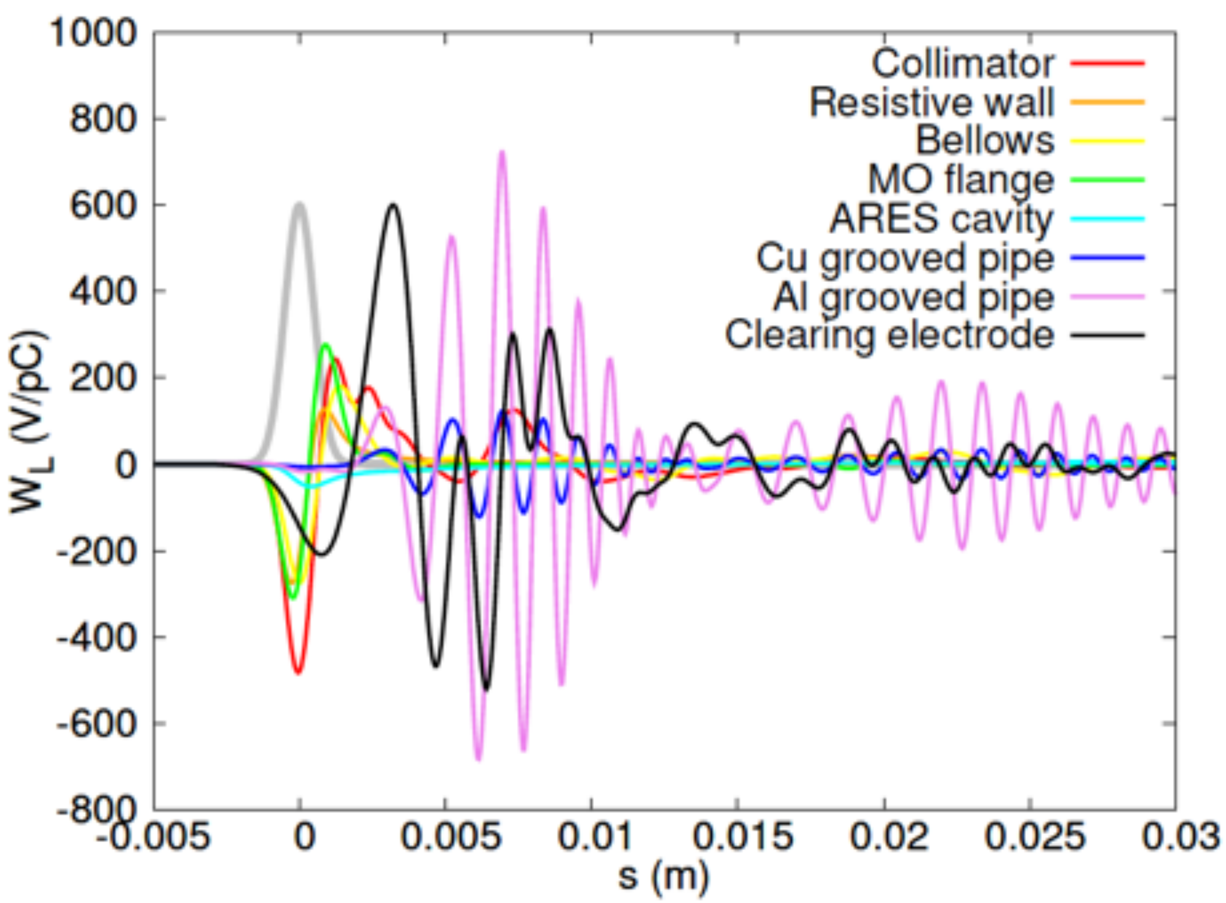
Ref. Y. Suetsugu et al., NIMA 598 (2009)

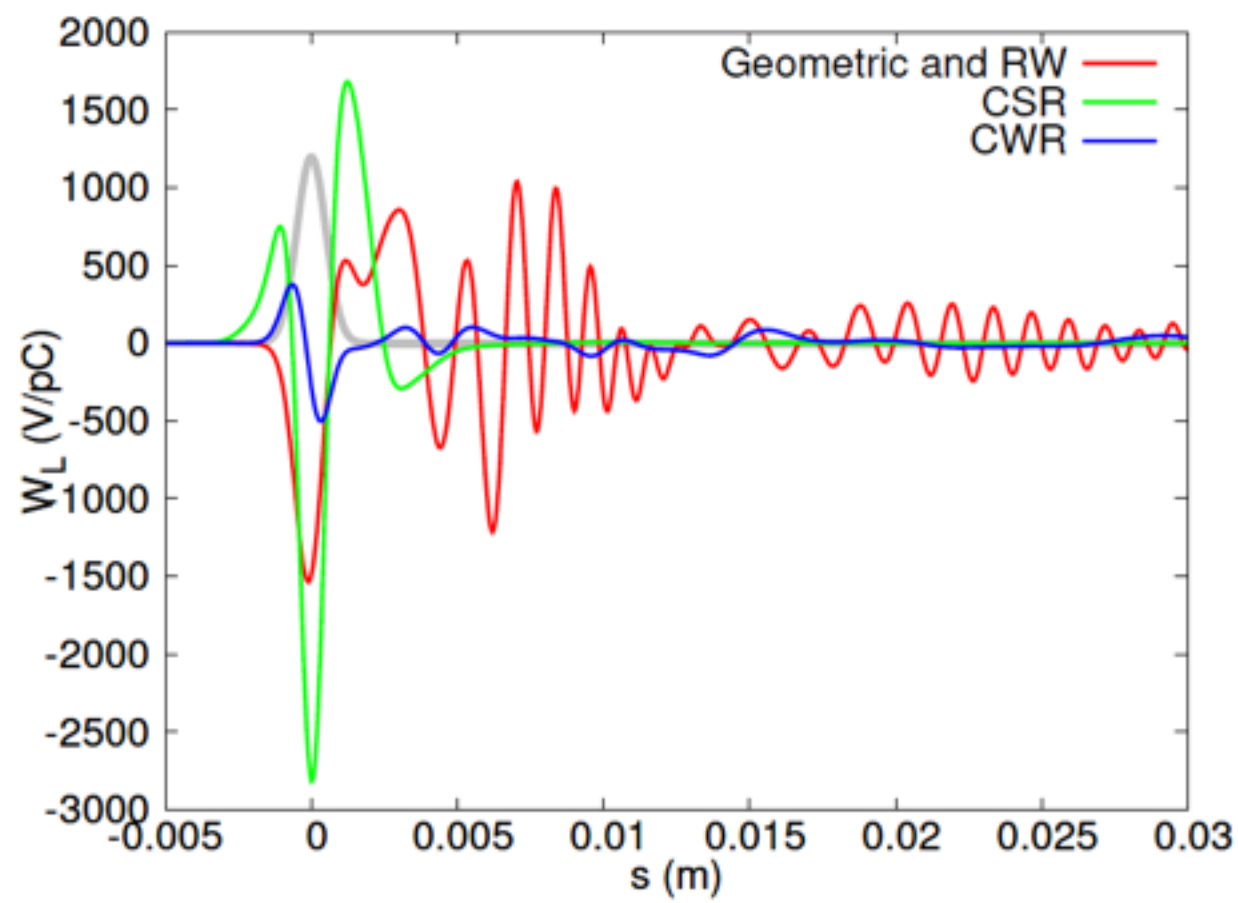
Ref. Y. Suetsugu et al., NIMA 604 (2009)

3. Impedance: Results: LER

➤ Pseudo-Green wake function

- σ_z=0.5mm
- Pumping ports and SR masks are negligible sources because of antechamber
- CSR and CWR (Wiggler radiation): CSRZ code with rectangular chamber

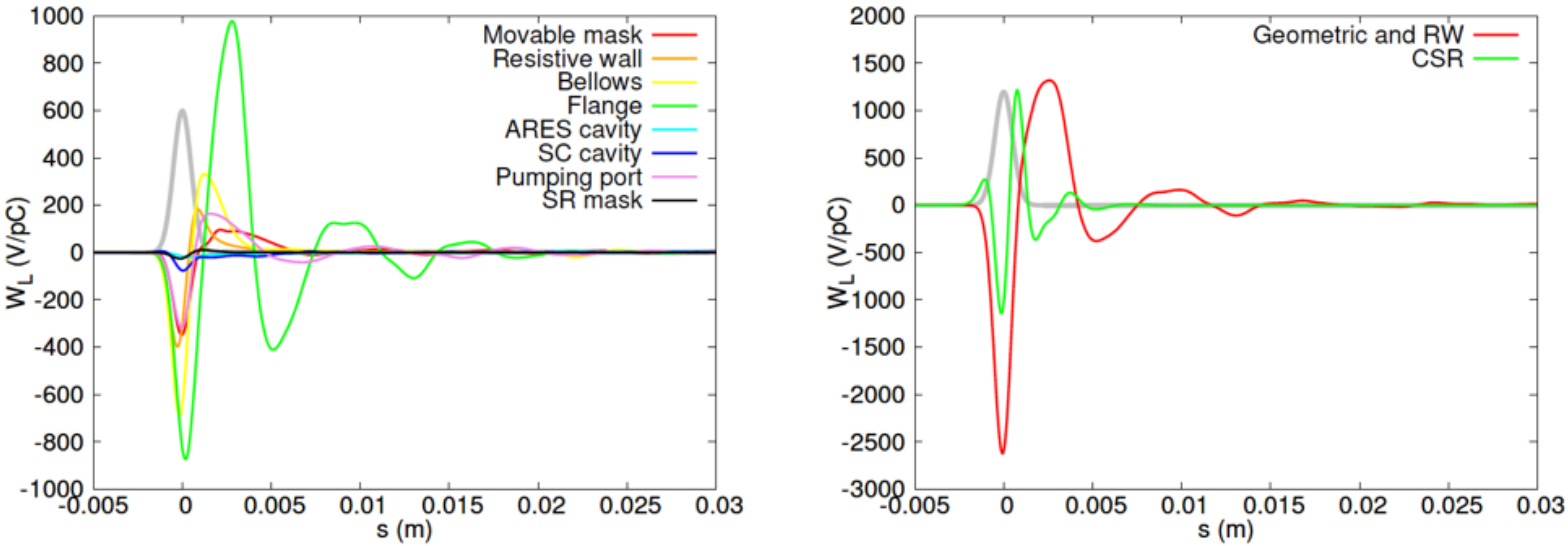




3. Impedance: Results: HER

➤ Pseudo-Green wake function

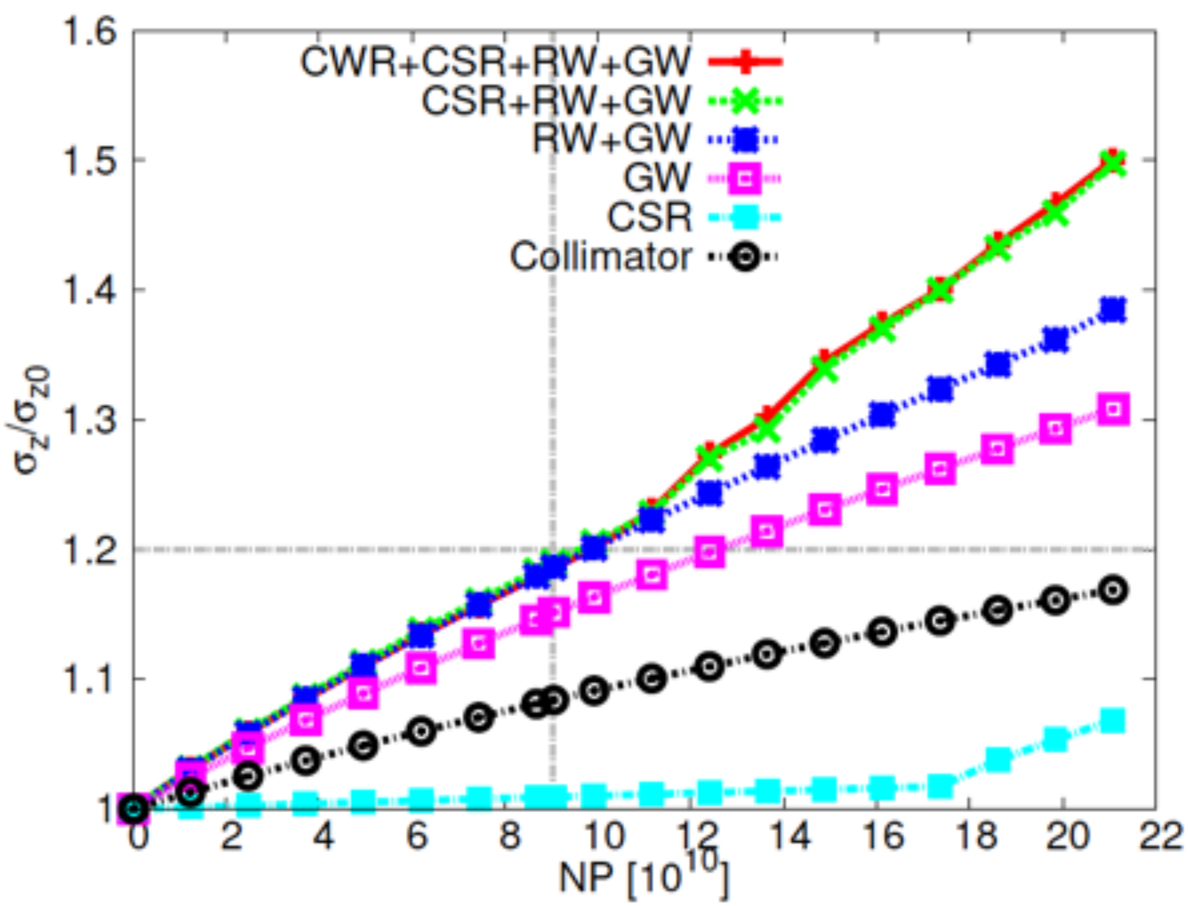
- σ_z=0.5mm
- CSR: CSRZ code with rectangular chamber
- CWR (Wiggler radiation) not considered yet

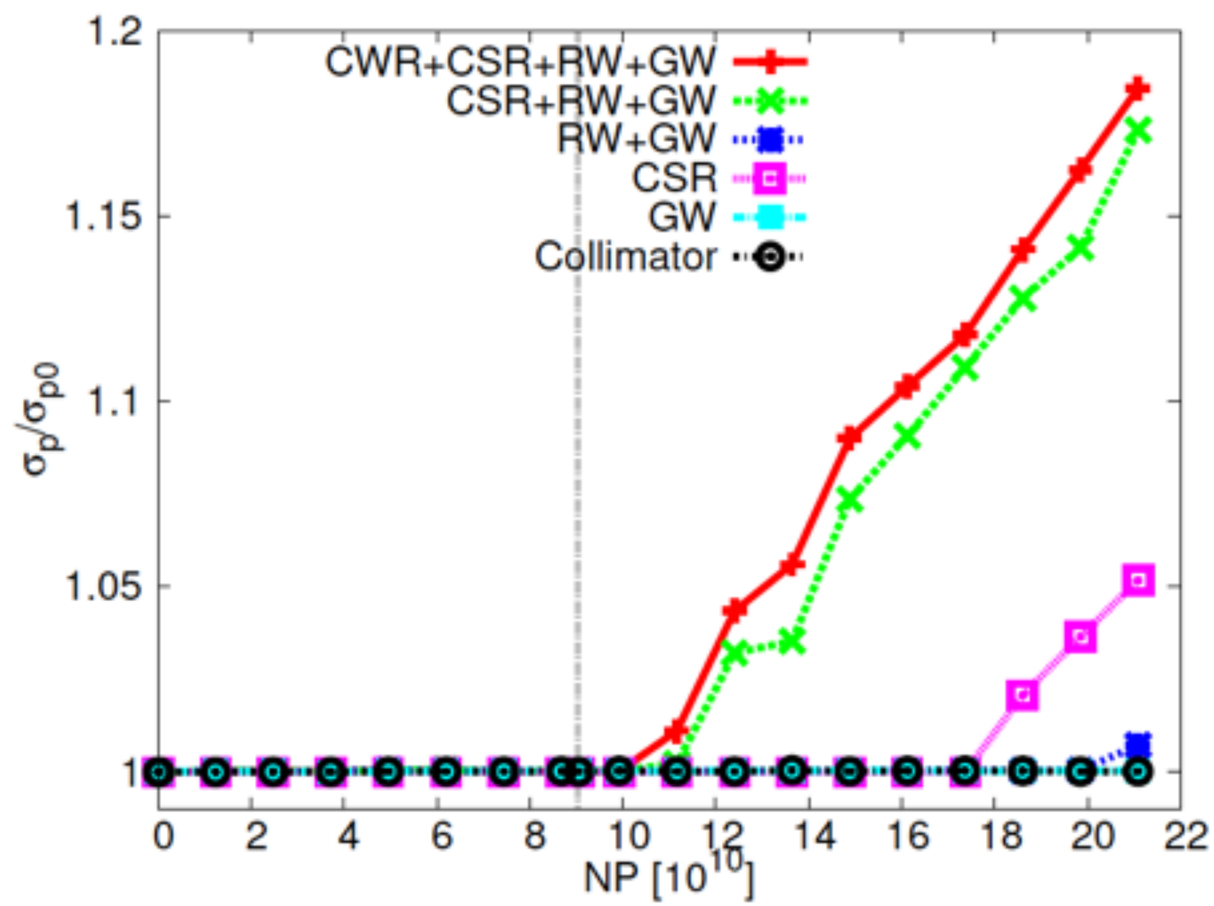


3. Single-bunch effects: Longitudinal: LER

➤ **Simulations with input of Pseudo-Green wake:**

- **Use Warnock-Cai's VFP solver**
- **Collimators are important sources in bunch lengthening**
- **Simulated $\sigma_z \approx 5.9$mm @Design bunch current**
- **Simulated MWI threshold is around NP_{th}=1.05E11**
- **Interplay between CSR and conventional wakes?**

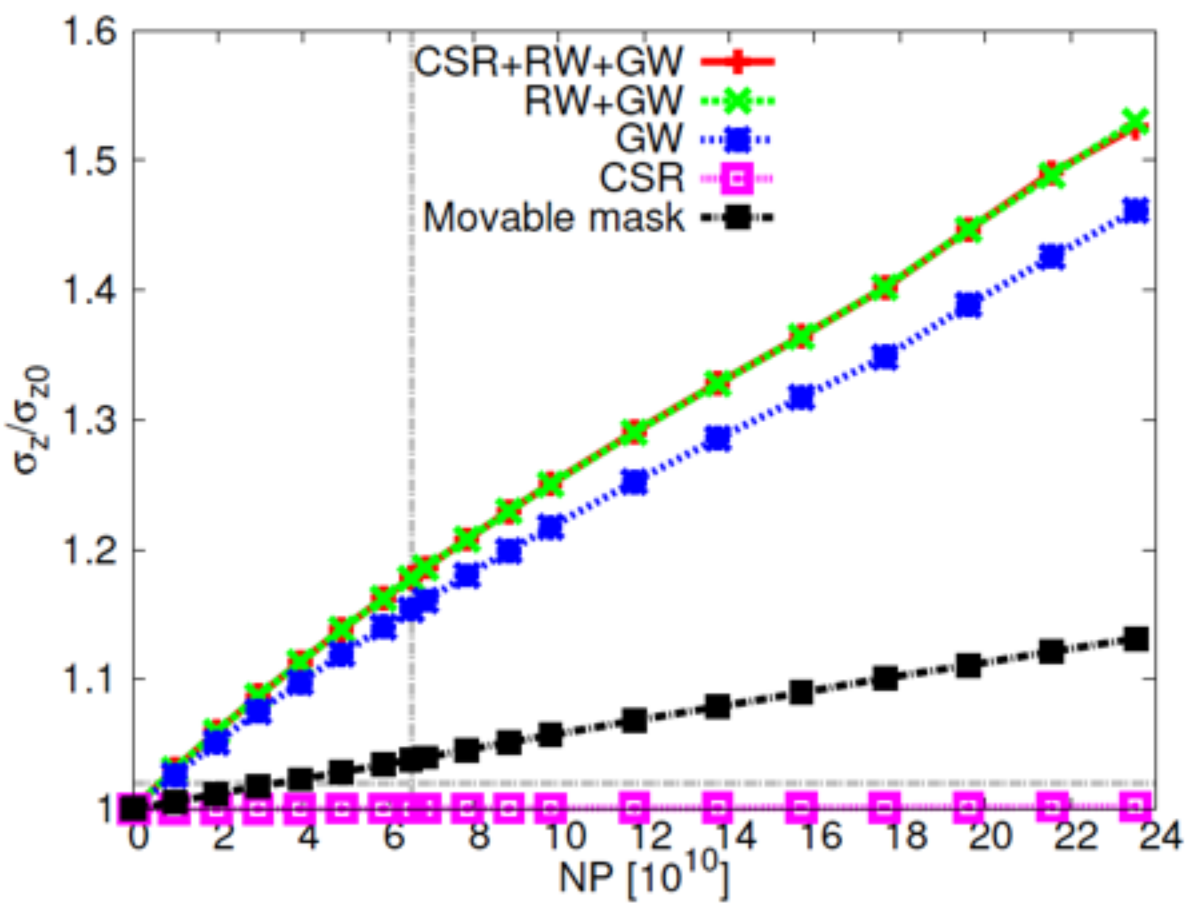


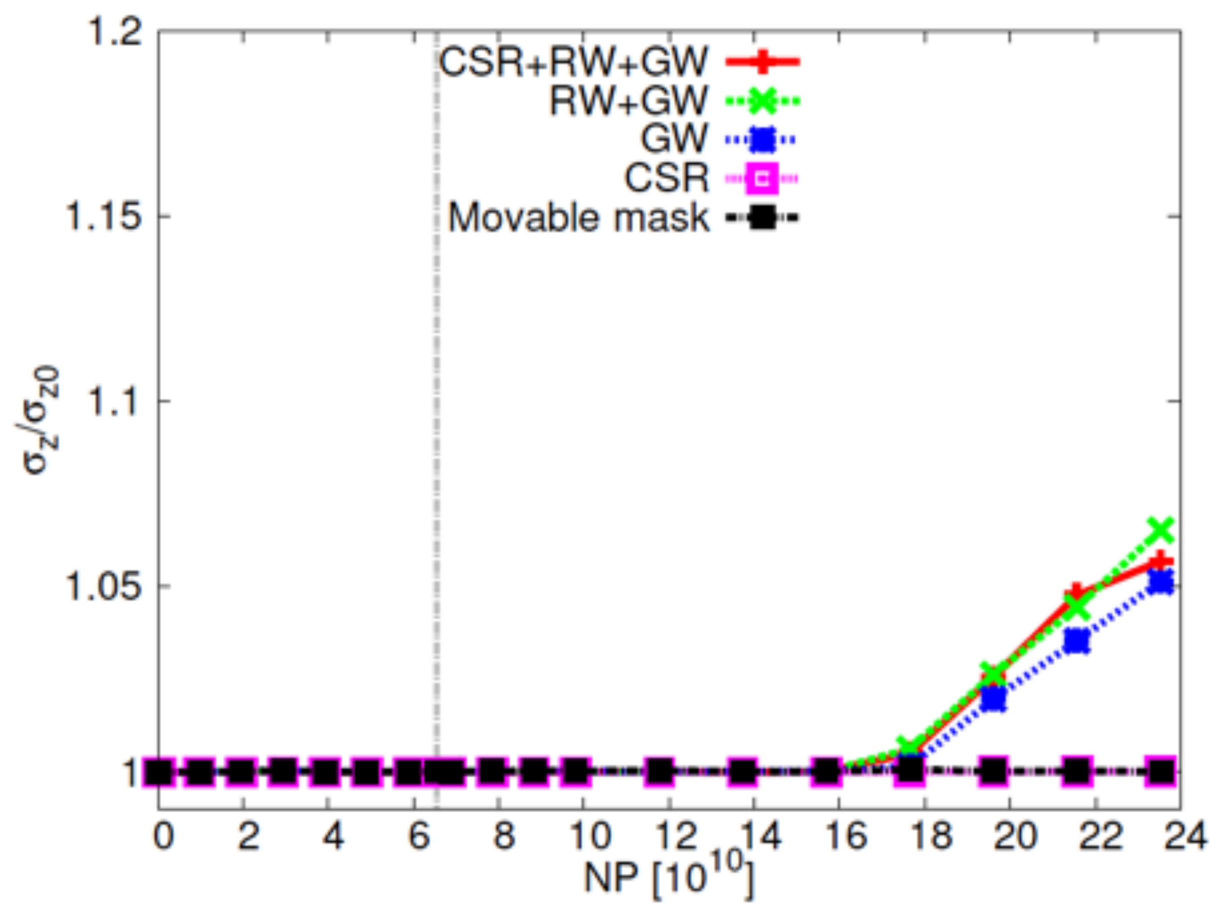


3. Single-bunch effects: Longitudinal: HER

➤ Simulations with input of Pseudo-Green wake:

- Use Warnock-Cai's VFP solver
- Simulated $\sigma_z \approx 5.8$mm @Design bunch current
- Simulated MWI threshold is around NP_{th}=1.7E11
- CSR and CWR are likely to be not important.





3. Single-bunch effects: Transverse: Beam tilt

➤ **G. Stupakov's theory on transverse beam tilt:**

- **To be a concern in low emittance rings**
- **Asymmetric protrusion (if exists)**

$$\Delta\epsilon_y = \frac{1}{4\sin^2(\pi\nu_y)}\beta_y\theta_{\rm rms}^2$$

$$\theta_{\rm rms} = \frac{Ne^2}{\gamma m_0 c^2}\sqrt{\langle(W_y - \langle W_y\rangle)^2\rangle}$$

$$\langle W_y\rangle = \int_{-\infty}^{\infty} W_y(s)\lambda(s)ds$$

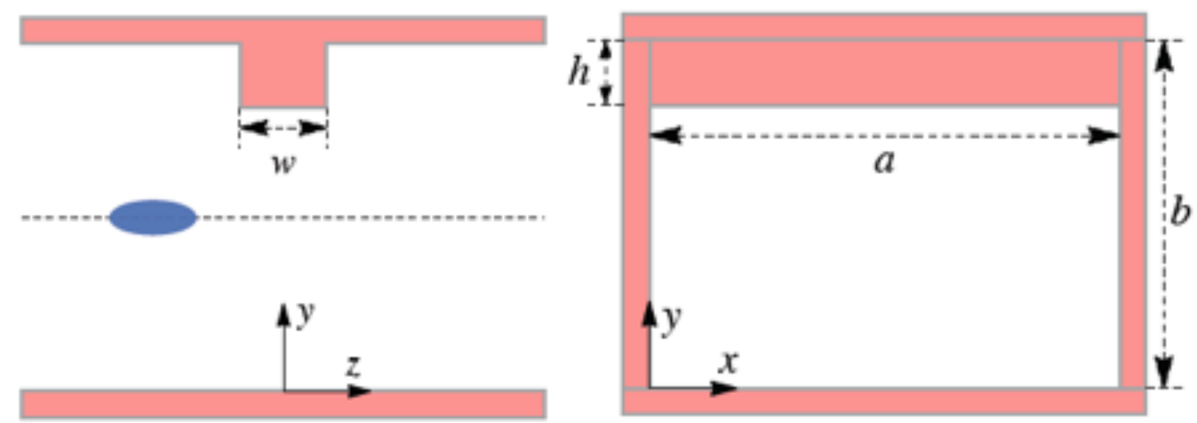
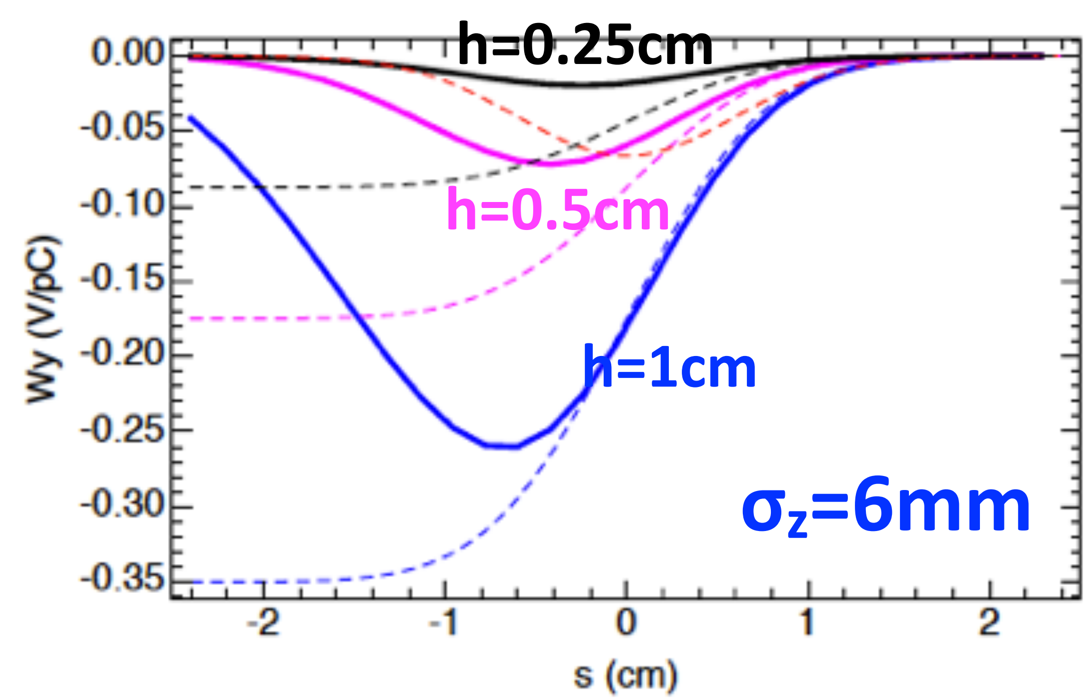


TABLE II. Emittance increase in LER of SUPERKEKB

Corrugation depth h (cm)	1	0.5	0.25
$\theta_{\rm rms}$ (nrad)	290	77	20
$\Delta\epsilon$ (pm)	0.45	0.03	0.002

Submitted to NIMA

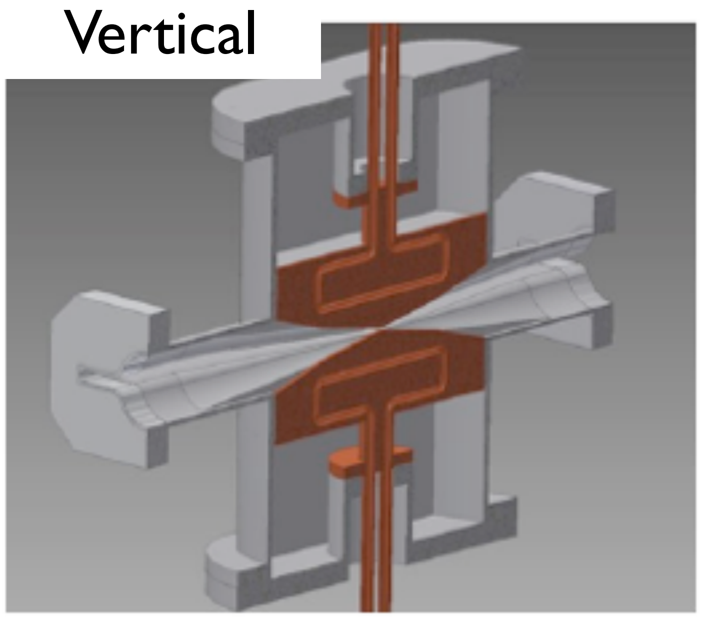


From G. Stupakov

3. Single-bunch effects: Transverse: Beam tilt

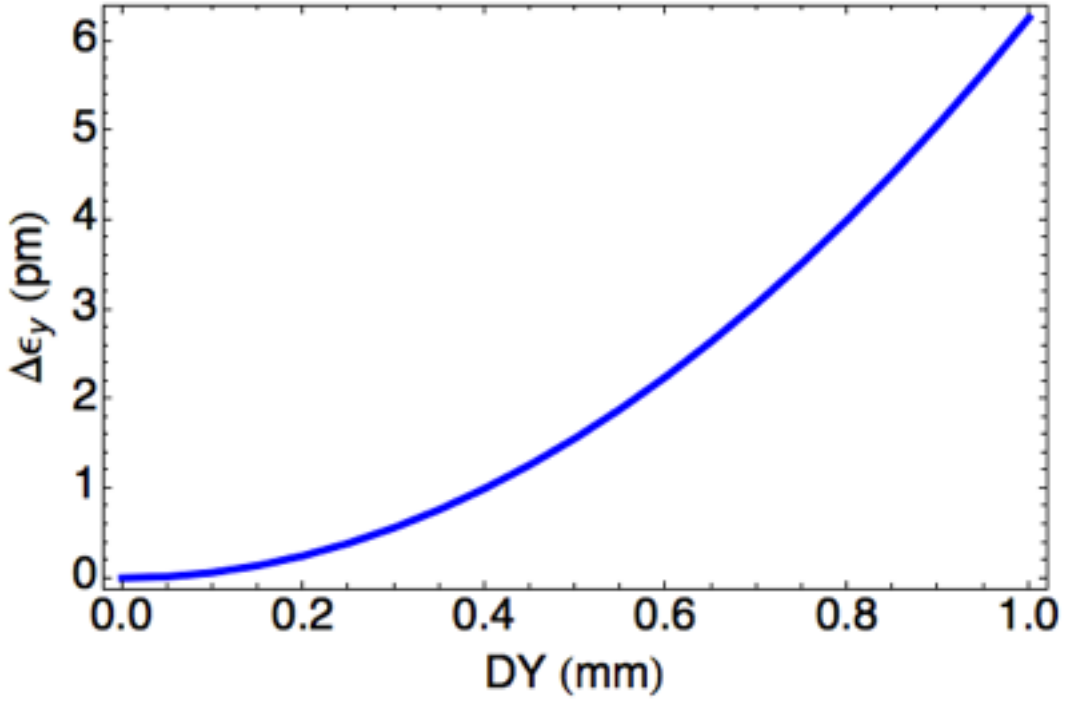
➤ G. Stupakov's theory on transverse beam tilt:

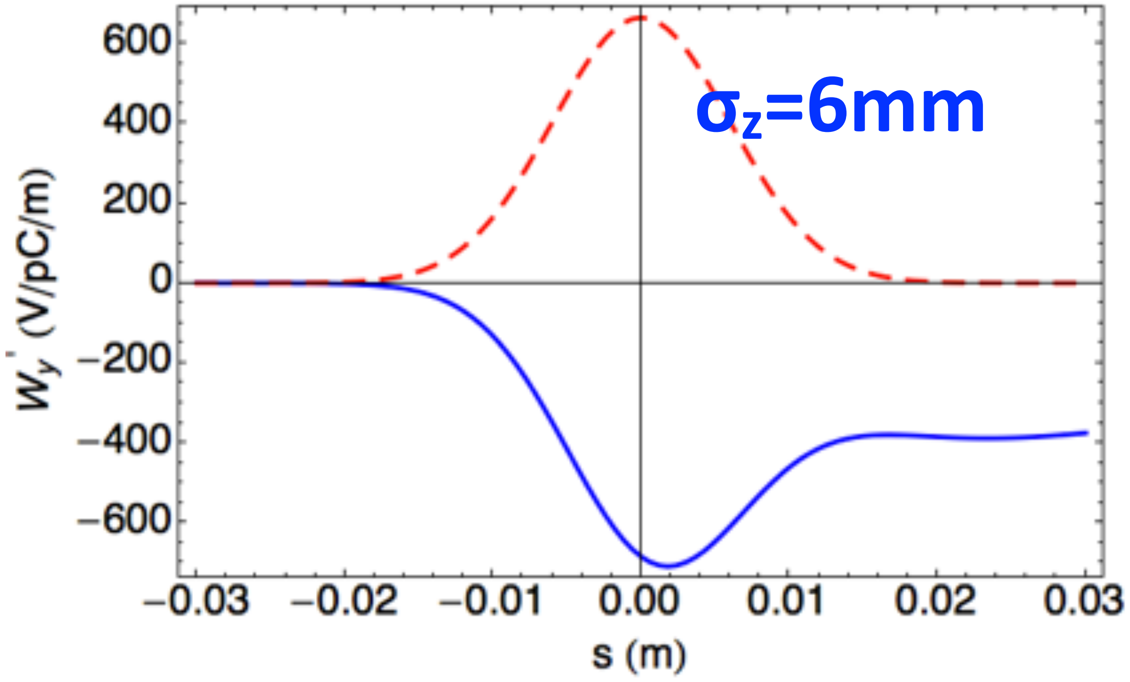
- Symmetric 3D structure (like collimator) with orbit offset
- D02V1 in LER as an example: d=-2/2mm, βy=104.6m
- COD DY < 0.2 mm required?



$$\Delta\epsilon_y = \frac{1}{4\sin^2(\pi\nu_y)}\beta_y\theta^2_{\rm rms}$$

$$\theta_{\rm rms} = \frac{Ne^2\Delta y}{\gamma m_0 c^2}\sqrt{\langle(W_y' - \langle W_y'\rangle)^2\rangle}$$





3. Single-bunch effects: TMCI: LER

- We estimated the threshold of the Transverse Mode Coupling Instability using actual β value at each collimator with σ_z = 6 mm.
- The bunch current of the design value in LER is 1.44 mA/bunch.
- A kick factor in D02V1 is quite large because of the narrow aperture (±2 mm), and it limits the bunch current.
- We may need an another structure, such as long heads with gradual slope, for D02V1.

	TMC Threshold (mA/bunch)	
	All Closed	Actual Apertures
Horizontal	1.41	13.15
Vertical	0.96	1.25

$$I_{thresh} = \frac{C_1 f_s E/e}{\sum_i \beta_i \kappa_{\perp i}(\sigma_z)}$$

Collimator No.	d [mm]	k [V pC^{-1}]	$k_\perp$ [V pC^{-1}m^{-1}]	β_x [m]	β_y [m]
D06 H1	-16.0 / +17.0	0.036	8	24.28	5.5043
D06 H2	-16.0 / +16.0	0.036	8	24.28	5.5042
D06 H3	-16.0 / +15.0	0.036	9	24.28	5.5043
D06 H4	-13.0 / +13.0	0.037	15	24.28	5.5042
D03 H1	-21.0 / +20.0	0.036	6	28.97	3.021
D03 H2	-18.0 / +20.0	0.036	7	28.97	3.021
D03 V1	-9.0 / +9.0	0.058	40	10.38	17.05
D03 V2	-9.0 / +9.0	0.058	40	10.38	17.05
D02 H1	-10.6 / + 12.0	0.038	25	33.20	19.06
D02 H2	-16.0 / +20.0	0.036	8	81.01	22.01
D02 H3	-18.0 / +21.0	0.036	7	31.09	173.3
D02 H4	-13.0 / +9.0	0.04	40	45.63	6.236
D02 V1	-2.0 / 2.0	0.098	600	21.79	104.6

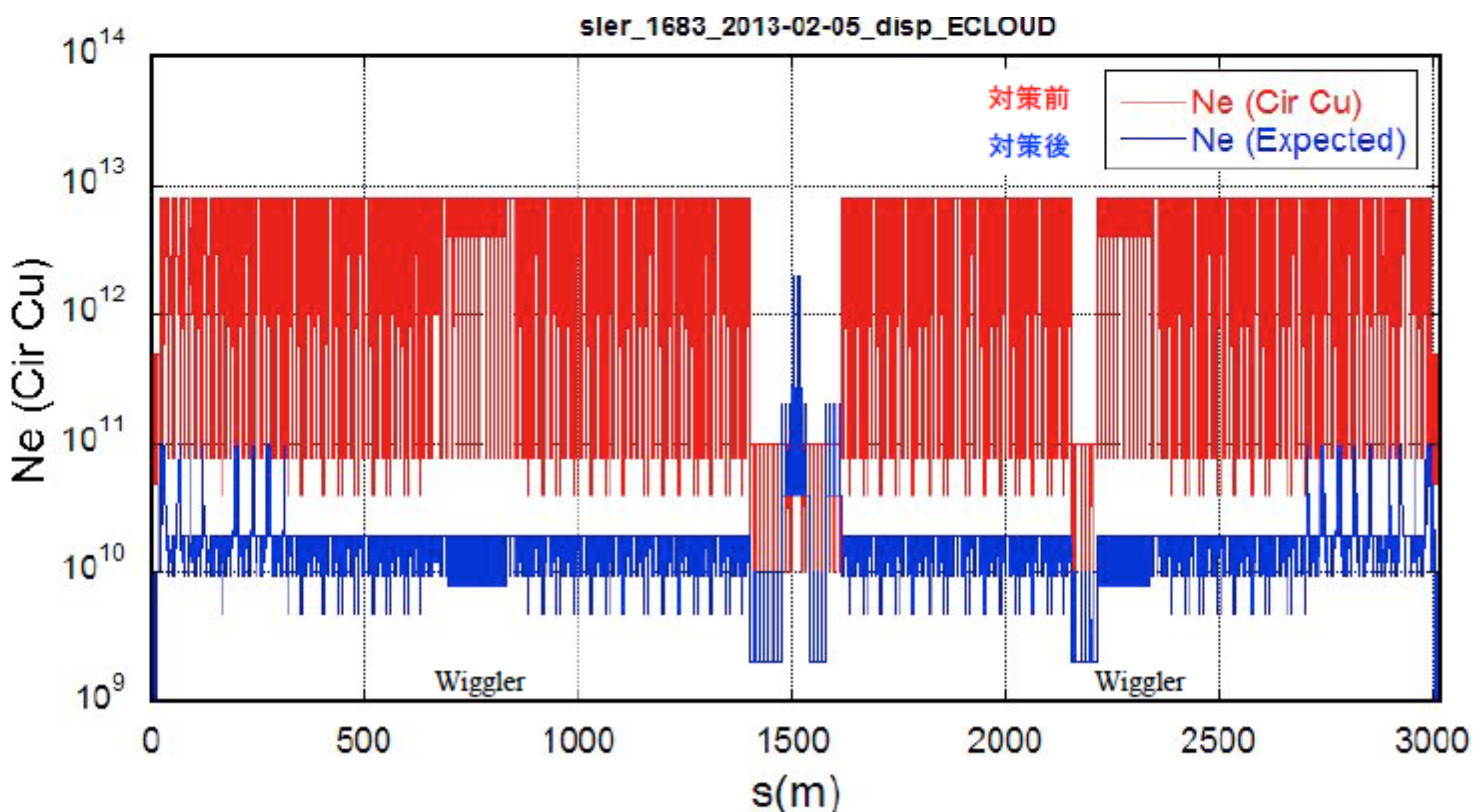
Lattice version: sler_1689

From T. Ishibashi and Y. Suetsugu

4. Electron cloud: Density estimation

➤ SuperKEKB: Improvements in vacuum chambers

- Antechamber, Solenoid winding, TiN coating, Grooved surfaces, Clearing electrodes, … => Expected low ecloud density (data extracted from KEKB experiments)
- J. Crittenden is helping simulate cloud density in the IR …



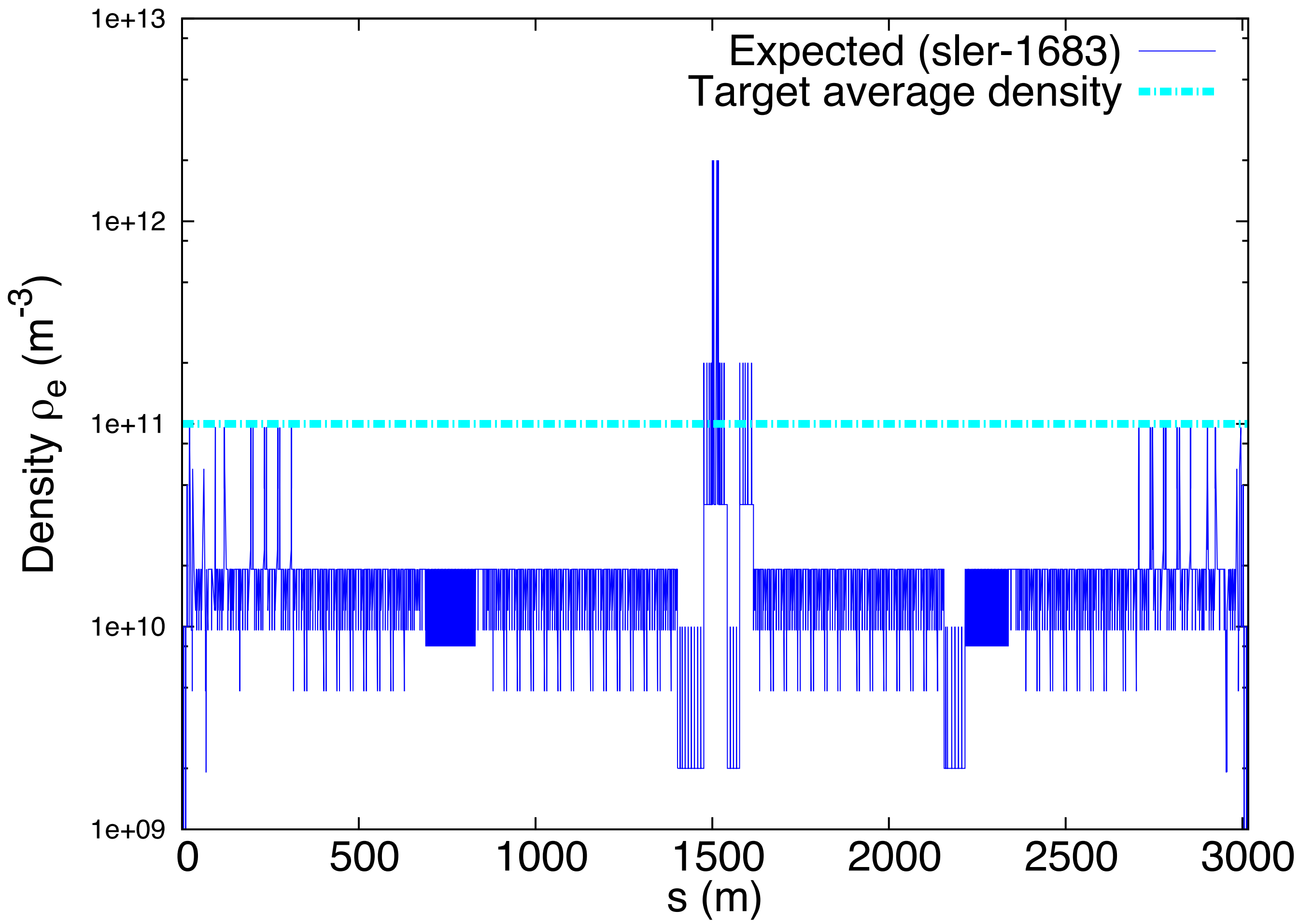
Courtesy of Y. Suetsugu

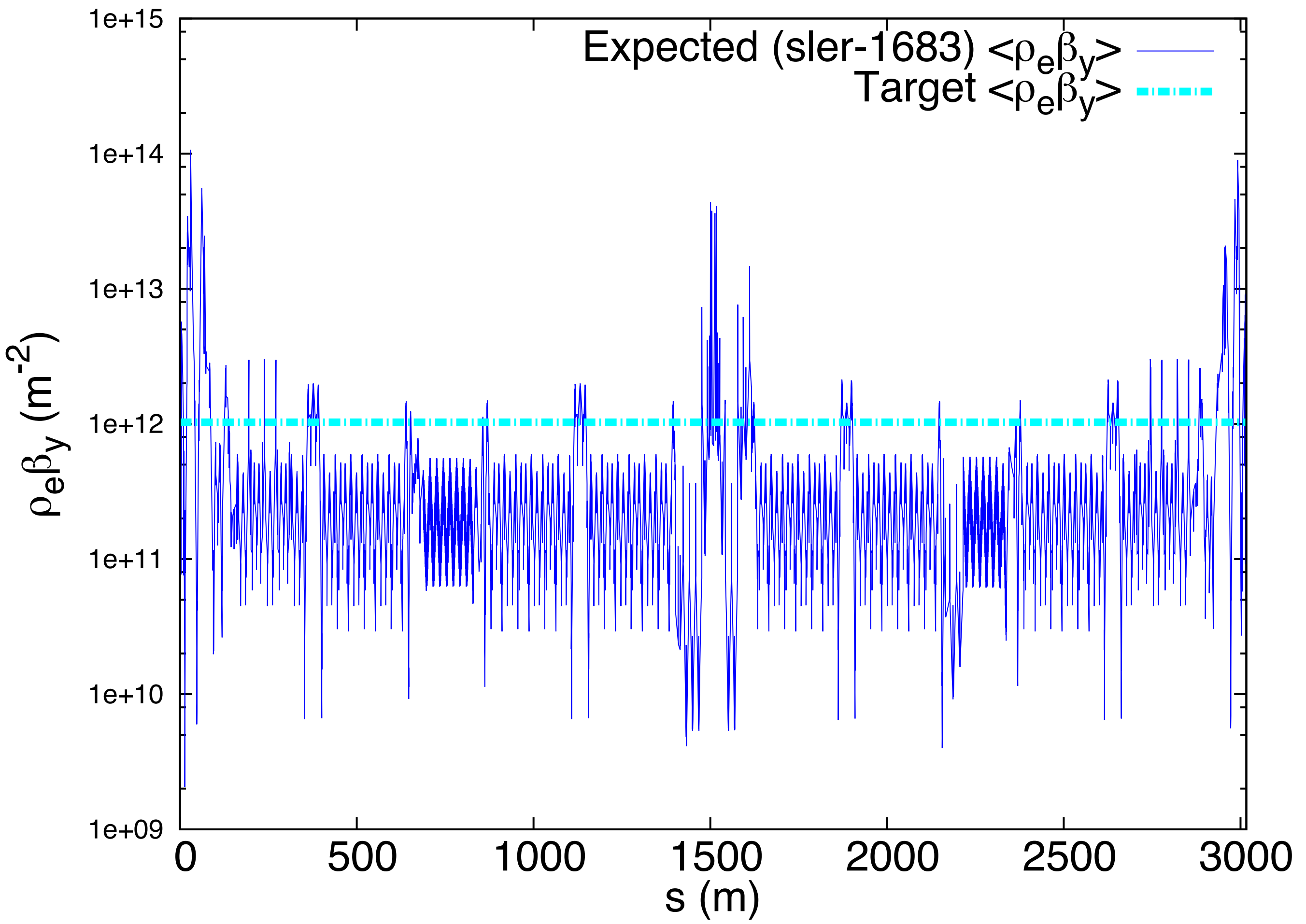
4. Electron cloud: Instability threshold

- **Ecloud instability theory:**
  - $\rho_{e,th} \propto \nu_s$
  - $\rho_{e,th} \propto 1/\beta$
  - $\rho_{e,th}$=**2.2E11** m^{-3} for SuperKEKB LER

$$\rho_{e,th} = \frac{2\gamma\nu_s\omega_e\sigma_z/c}{\sqrt{3}KQr_e\beta_y L}$$

- **Average ecloud density:**
  - Expected: $\langle\rho_e\rangle$=**2.2E10** m^{-3}
  - Weighted by β_y: $\langle\rho_e\beta_y\rangle/\langle\beta_y\rangle$=**1.1E11** m^{-3}



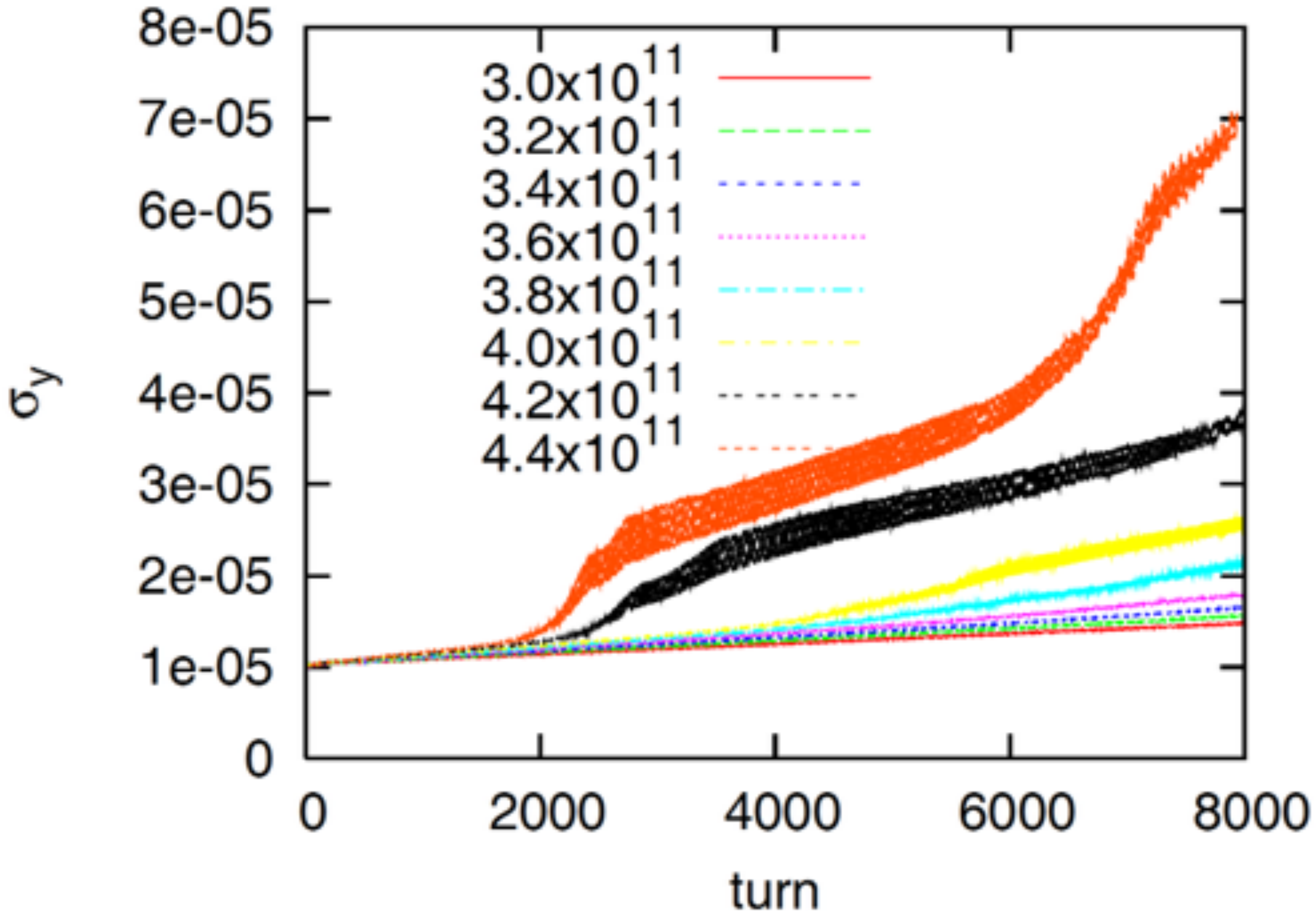


Ref. K. Ohmi and D. Zhou, IPAC14, TUPRI020

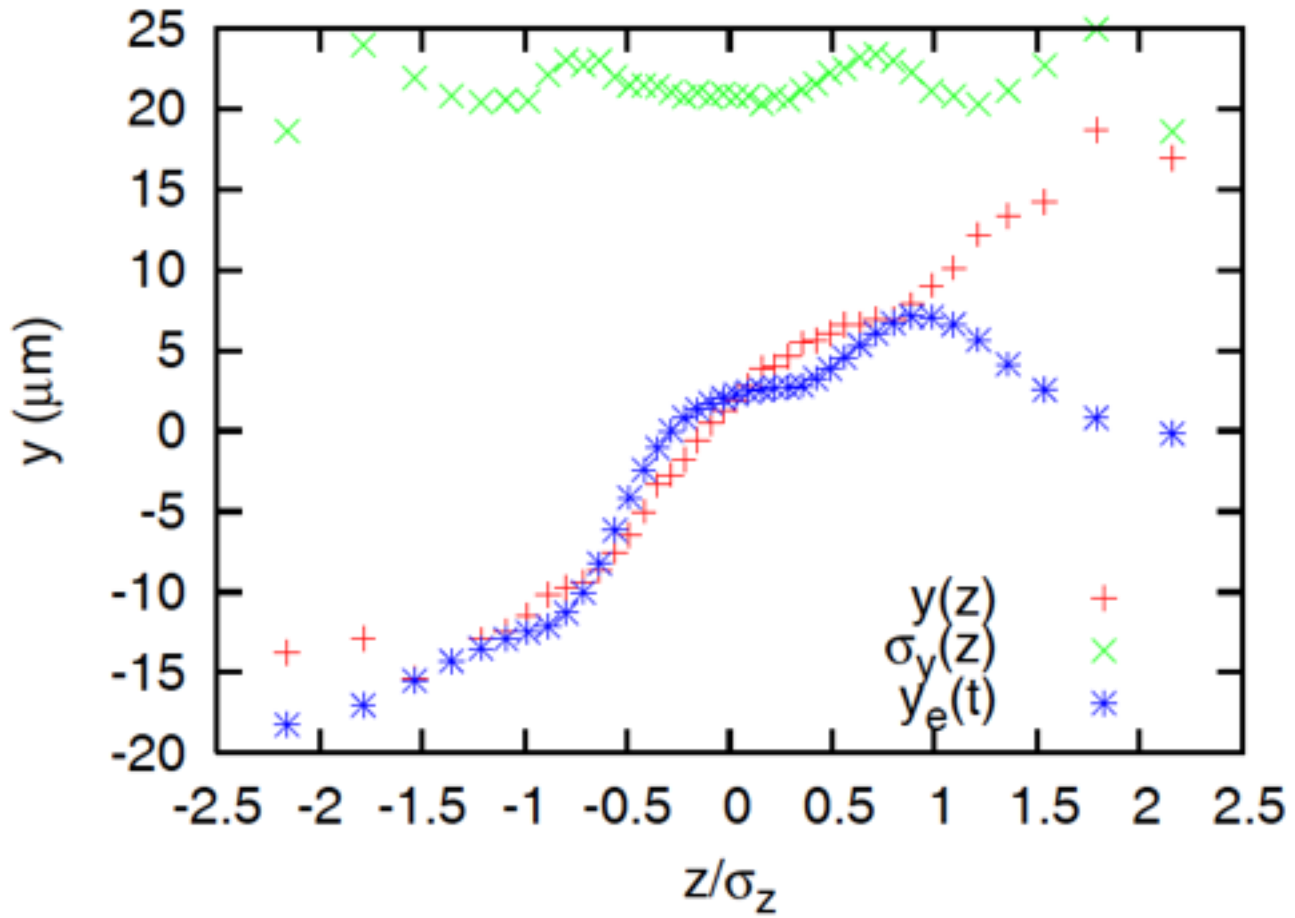
4. Electron cloud: PEHTS simulations

➤ Constant cloud density and constant beta function

- **Simulation: $\rho_{e,th}$=3.8E11 m^{-3}**
- **Coherent instability dominates the emittance growth above threshold**



Turn-by-turn beam sizes varying ecloud density w/o radiation damping



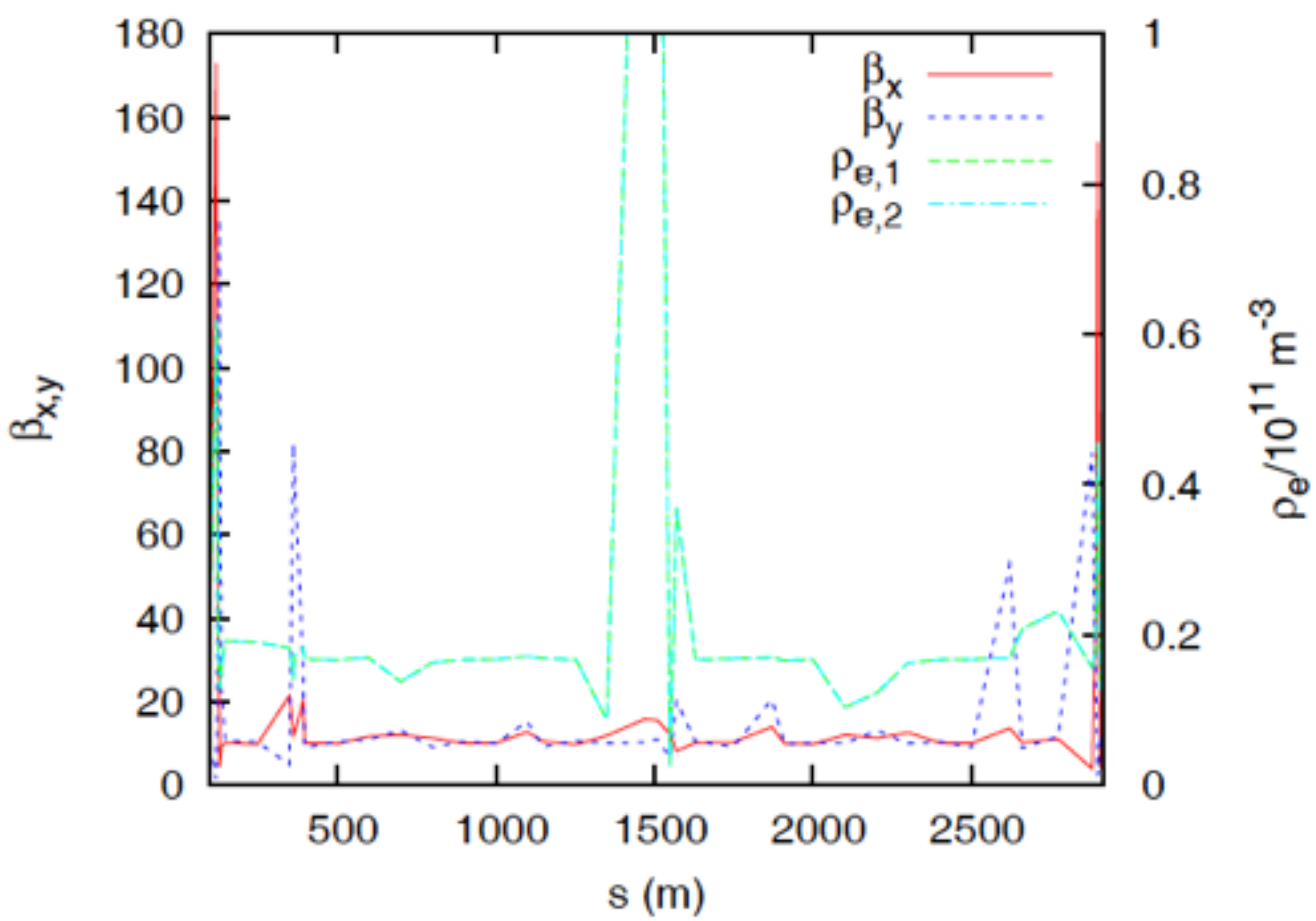
Snapshot of beam-cloud motion at 4000 turn with ρ_e=4.2E11m^{-3}

Ref. K. Ohmi and D. Zhou, IPAC14, TUPRI020

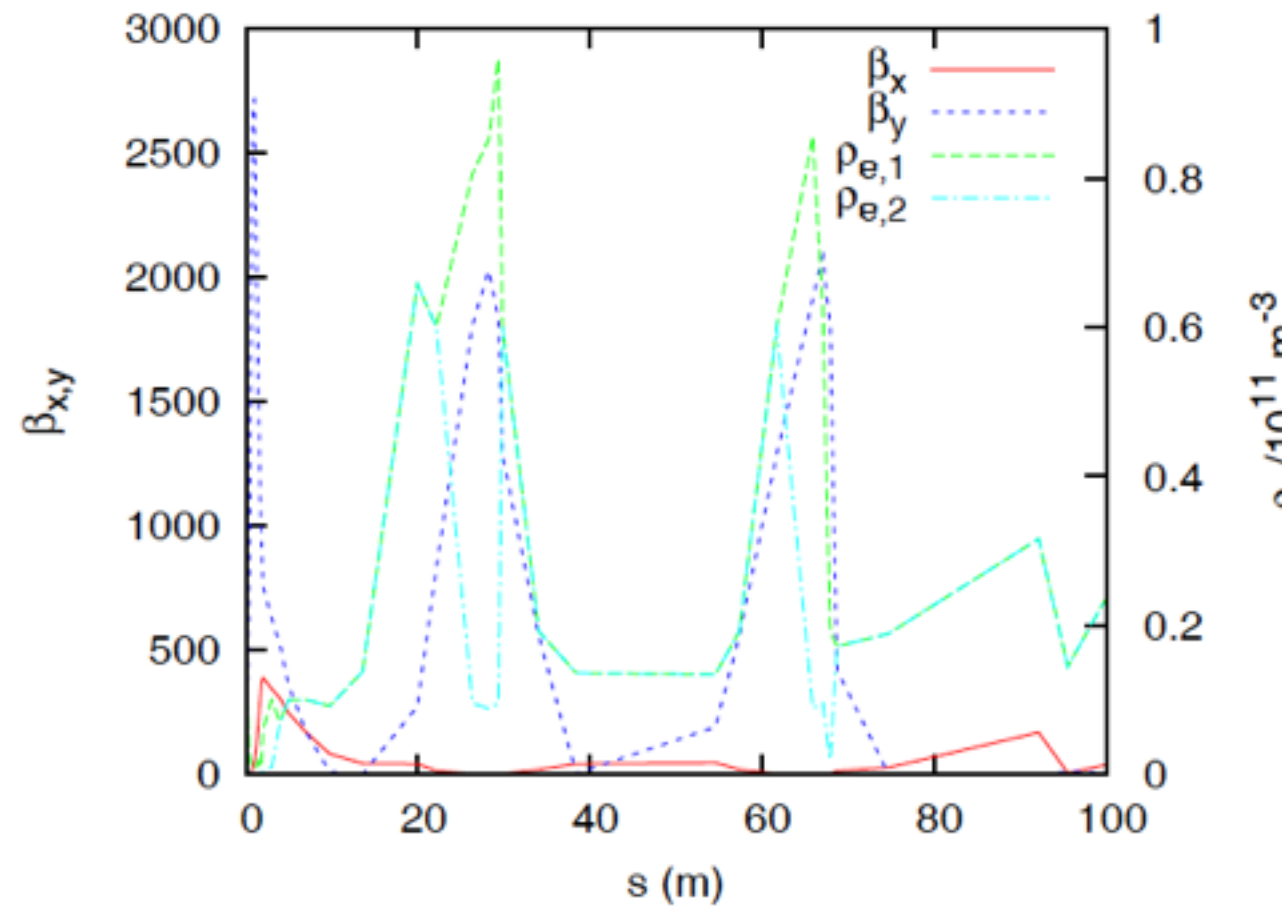
4. Electron cloud: PEHTS simulations

➤ s-dependent cloud density and beta function

- Split the ring into ~40 slices
- Two cases: high and low ecloud density at the high beta sections



s-depdent β_y and ρ_e



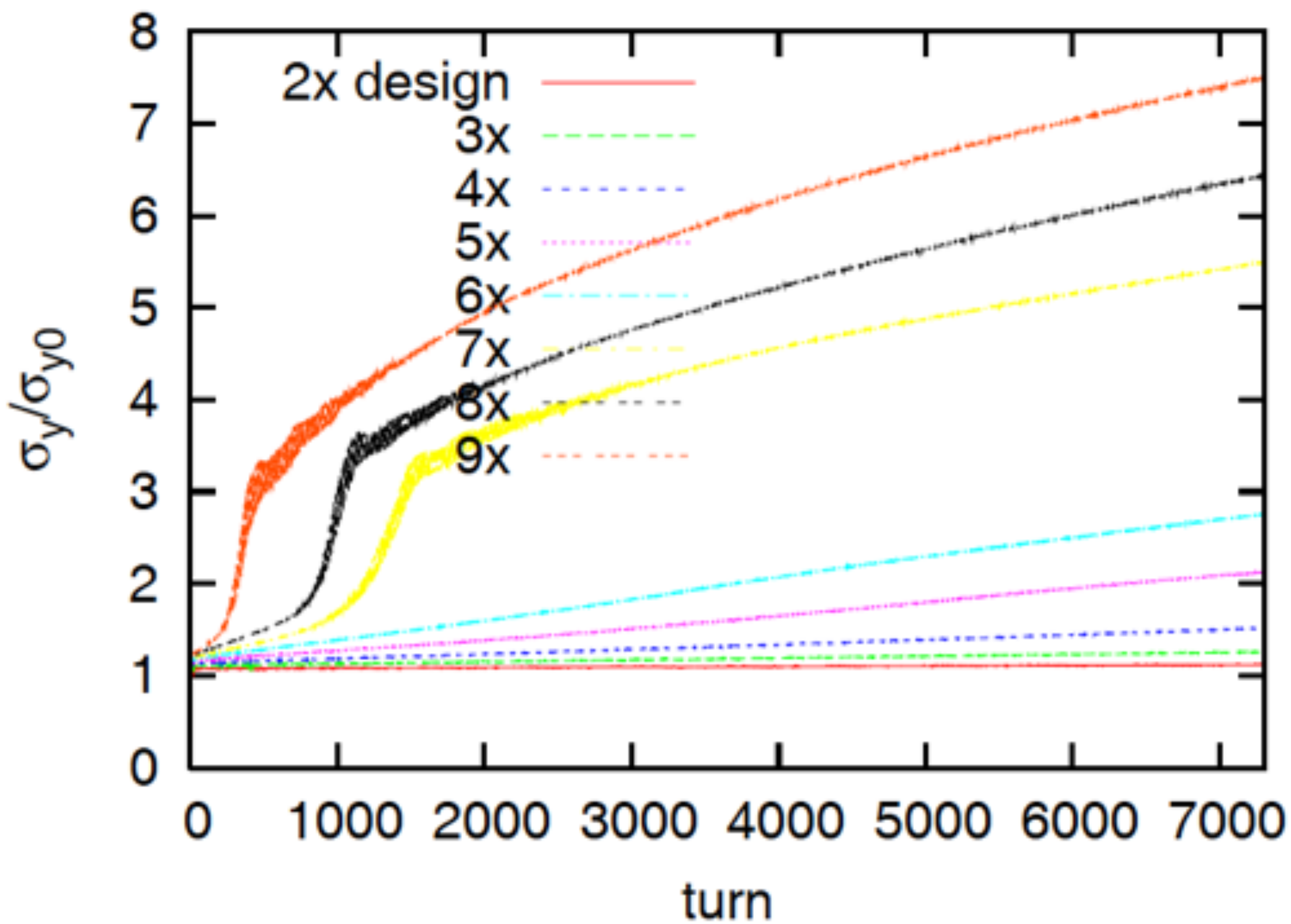
s-depdent β_y and ρ_e at the IR region

Ref. K. Ohmi and D. Zhou, IPAC14, TUPRI020

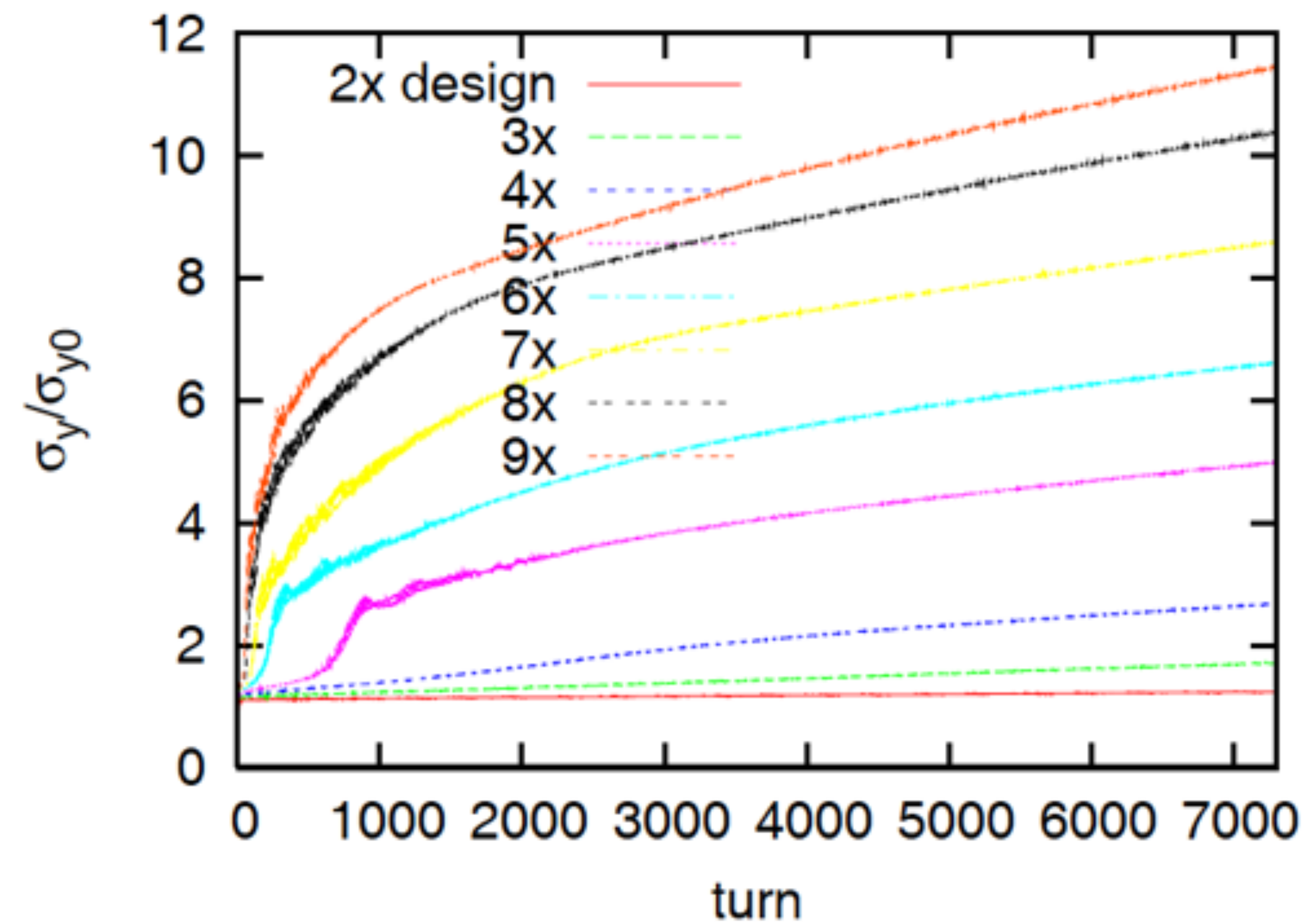
4. Electron cloud: PEHTS simulations

➤ s-dependent cloud density and beta function

- Simulation: $\rho_{e,th}$=4x and 6x of estimated cloud density for the two cases in the previous page
- Supposed that the estimated density is reasonable …
- Ecloud at high-beta section makes difference …



Turn-by-turn beam sizes varying ecloud density w/o radiation damping for low cloud density in high-beta region



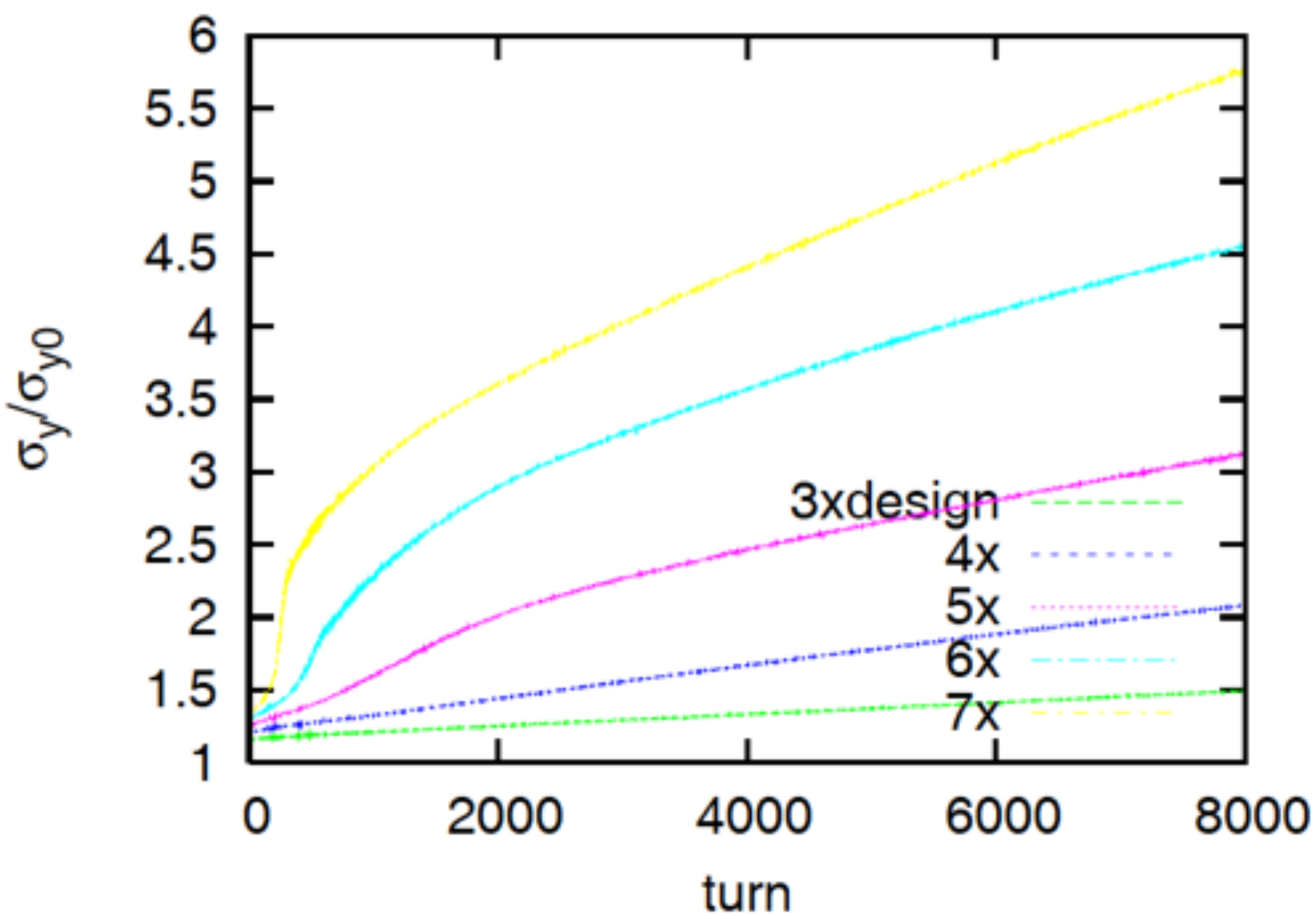
Turn-by-turn beam sizes varying ecloud density w/o radiation damping for high cloud density in high-beta region

Ref. K. Ohmi and D. Zhou, IPAC14, TUPRI020

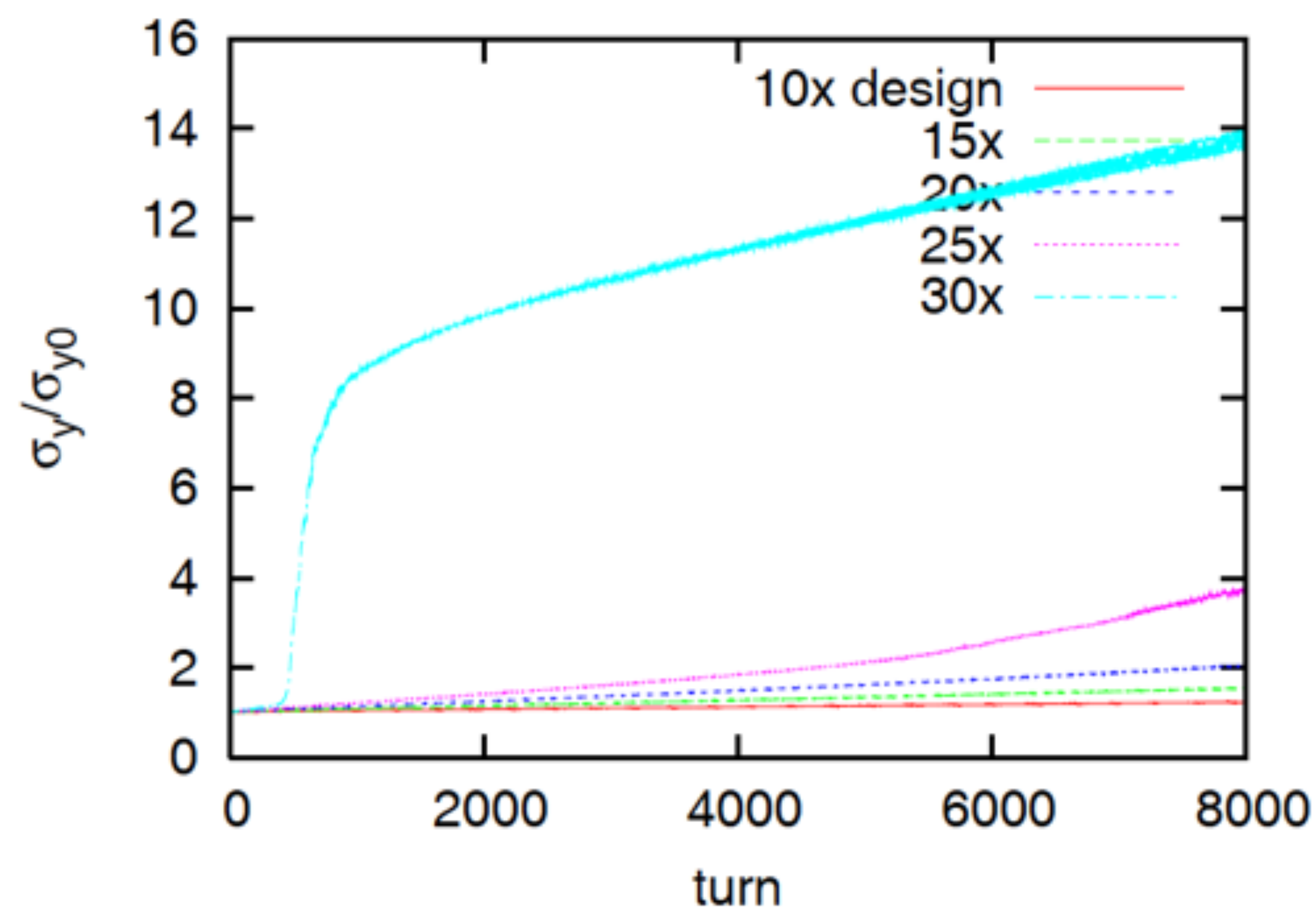
4. Electron cloud: PEHTS simulations

➤ **s-dependent cloud density and beta function**

- **Treat the ecloud in the IR and arc sections separately**
- **Look at the case of high cloud density in high-beta regions**
- **It is found that ecloud in the IR region dominates the instability**



Turn-by-turn beam sizes varying ecloud density in IR w/o radiation damping for high cloud density in high-beta regions



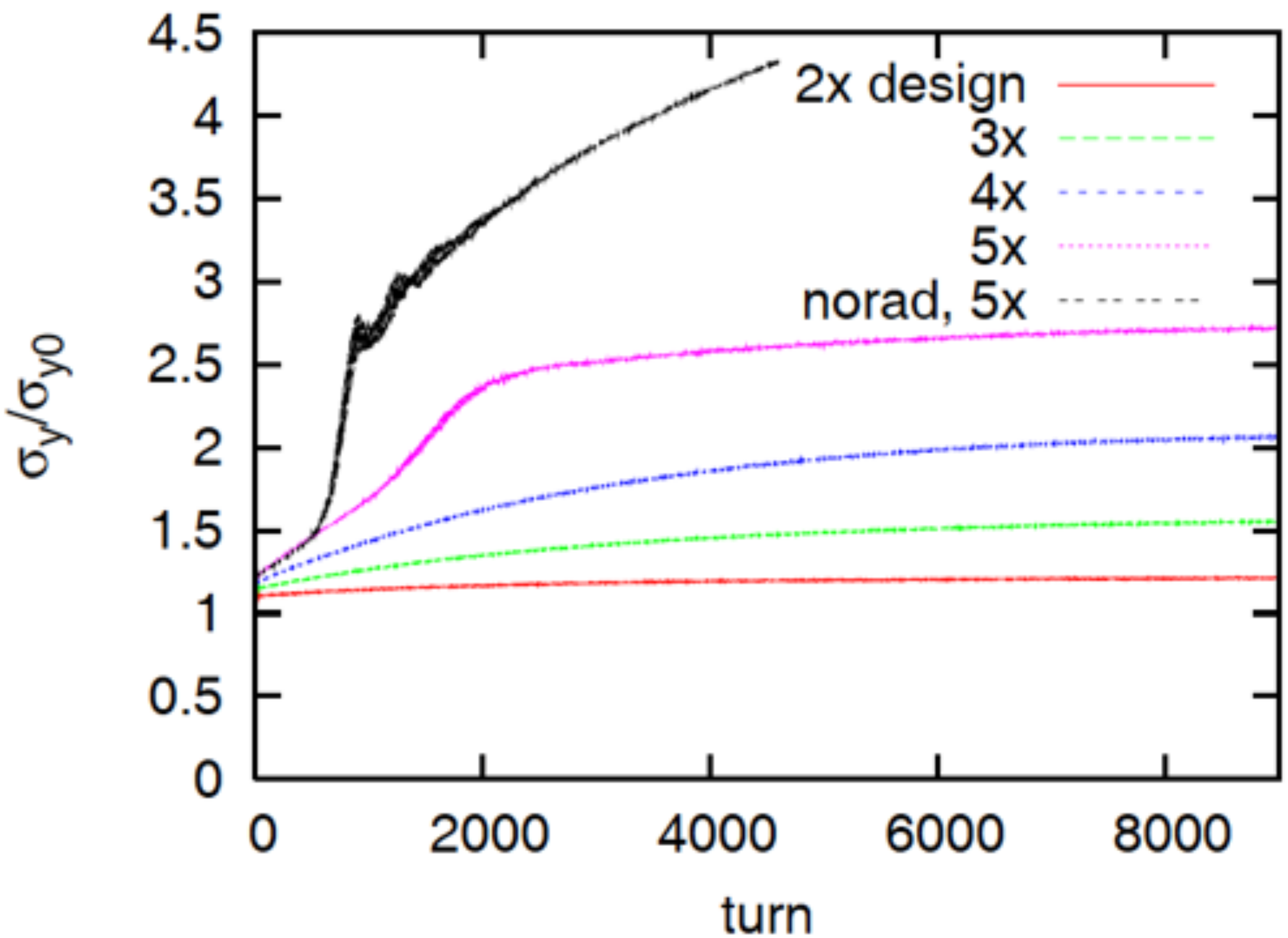
Turn-by-turn beam sizes varying ecloud density in arc w/o radiation damping for high cloud density in high-beta regions

Ref. K. Ohmi and D. Zhou, IPAC14, TUPRI020

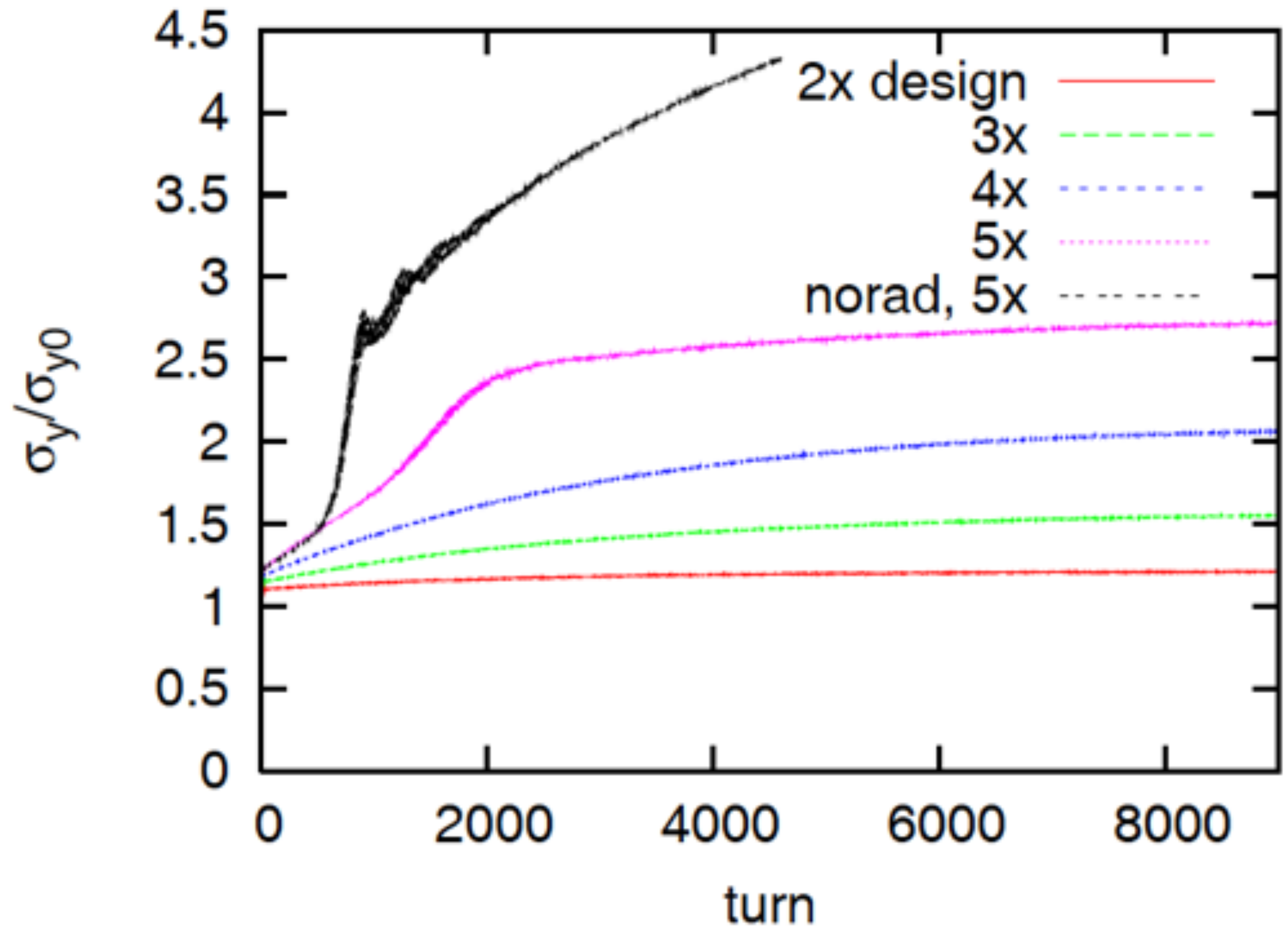
4. Electron cloud: PEHTS simulations

➤ s-dependent cloud density and beta function

- Incoherent emittance grow is observed below inst. threshold
- Turn on radiation damping and excitation
- Detect equilibrium emittance as a function of cloud density



Turn-by-turn beam sizes varying ecloud density w/o radiation damping for low cloud density in high-beta region



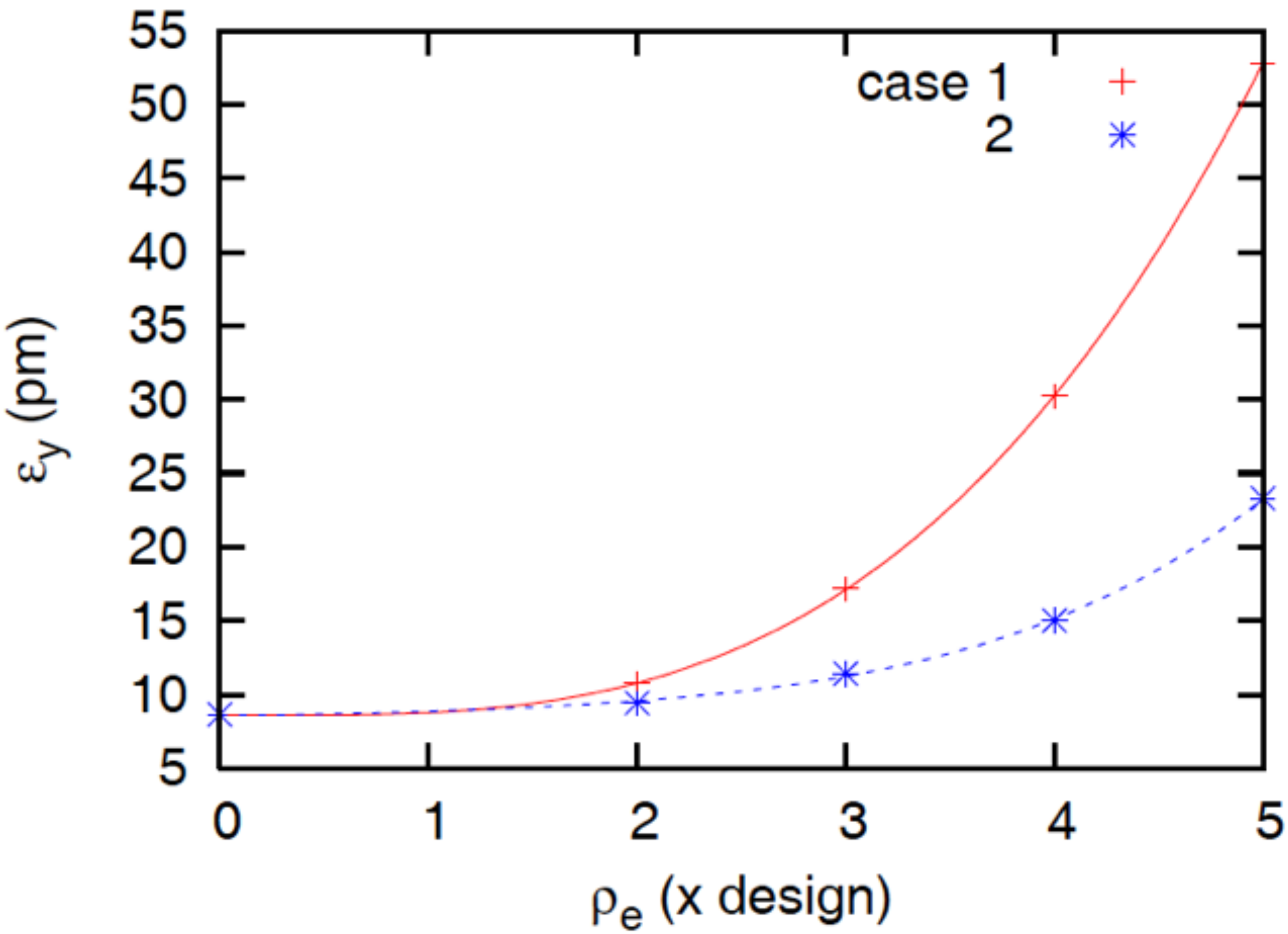
Turn-by-turn beam sizes varying ecloud density w/o radiation damping for high cloud density in high-beta region

Ref. K. Ohmi and D. Zhou, IPAC14, TUPRI020

4. Electron cloud: PEHTS simulations

➤ s-dependent cloud density and beta function

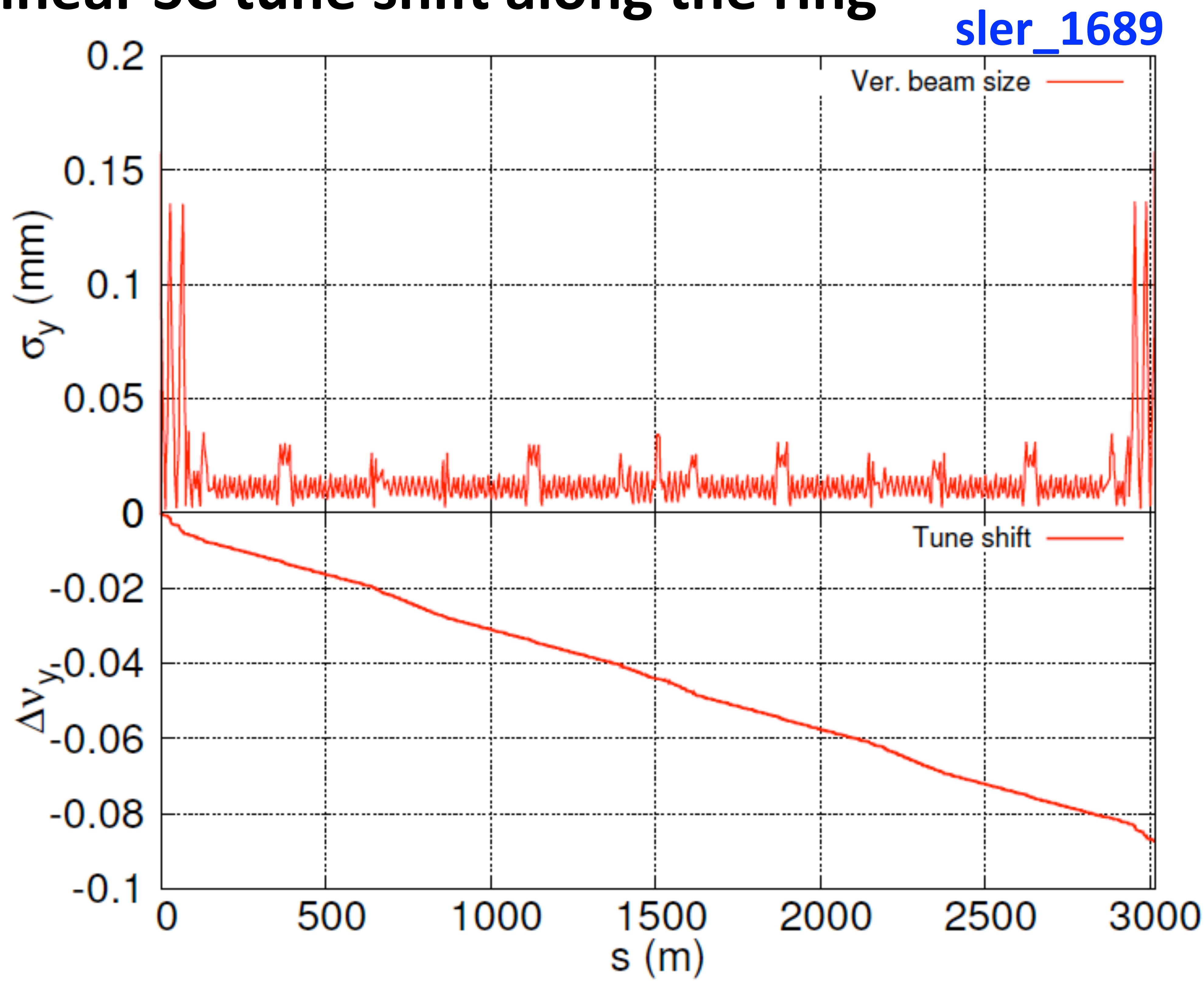
- Incoherent emittance growth is also important
- Ecloud density should be lower than 3x of estimated density, especially in the IR region



Ref. K. Ohmi and D. Zhou, IPAC14, TUPRI020

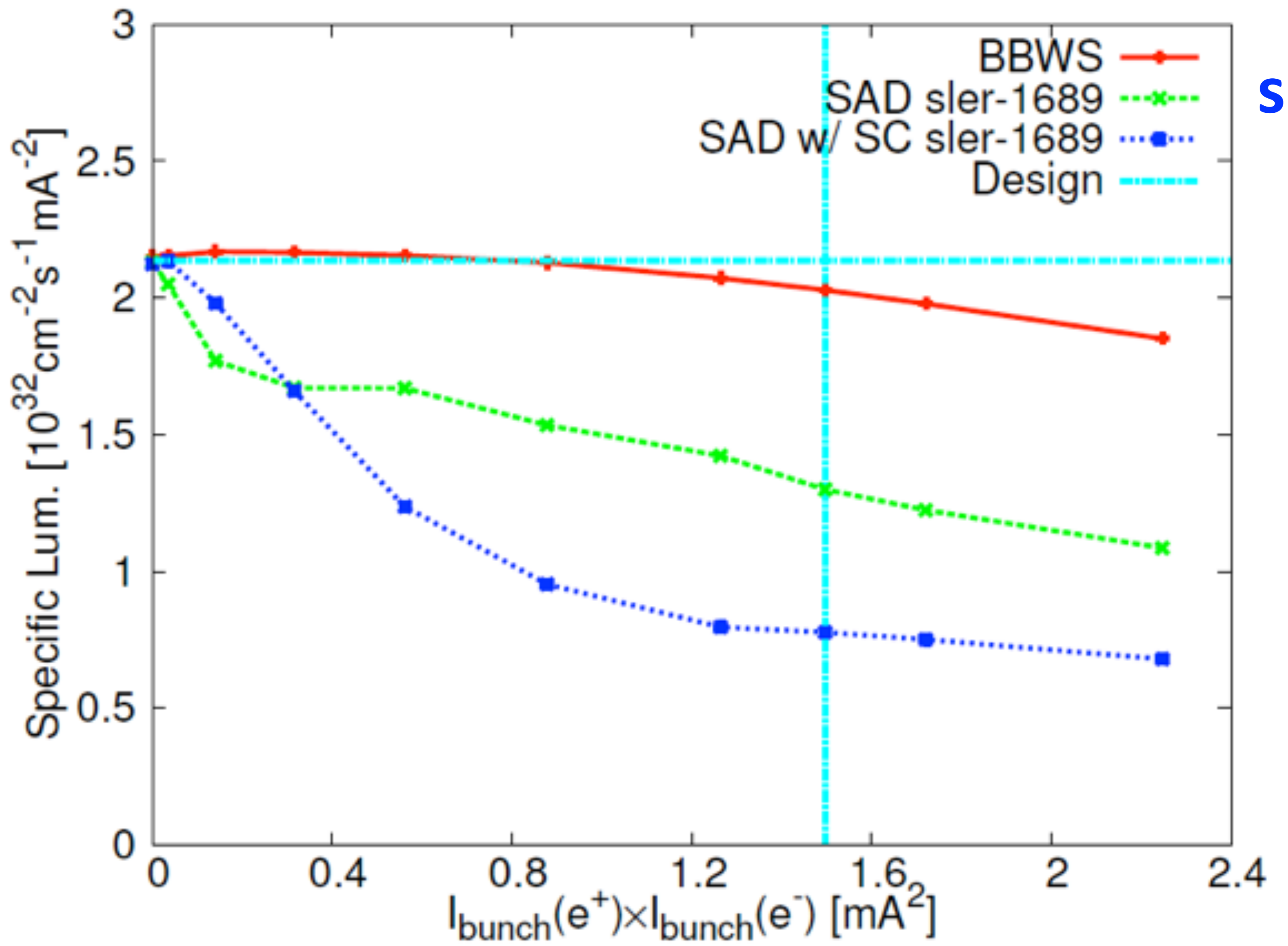
5. Space charge: LER: Tune shift

➤ **Linear SC tune shift along the ring**



5. Space charge: LER: Luminosity

- ➤ **Weak-strong model for space charge**
- ➤ **“Strong” beam: Emittance growth due to IBS included**

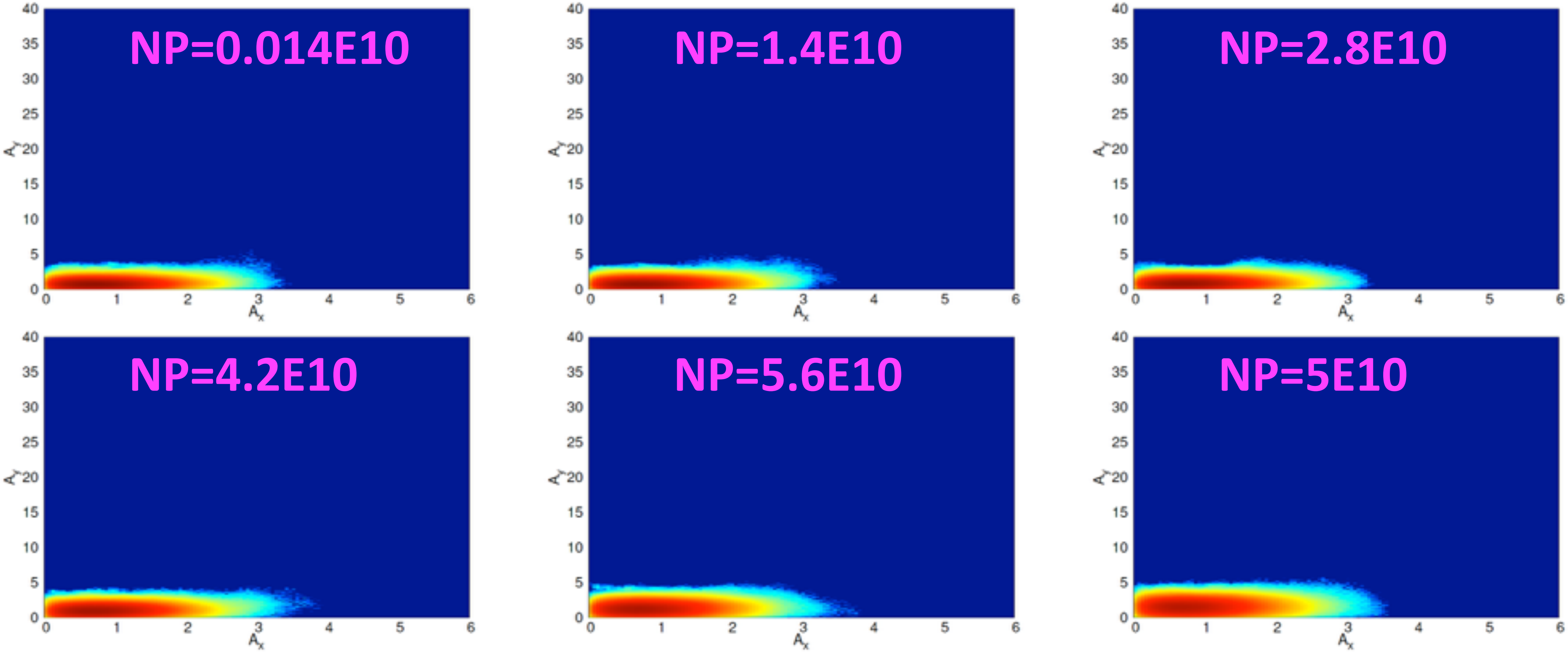


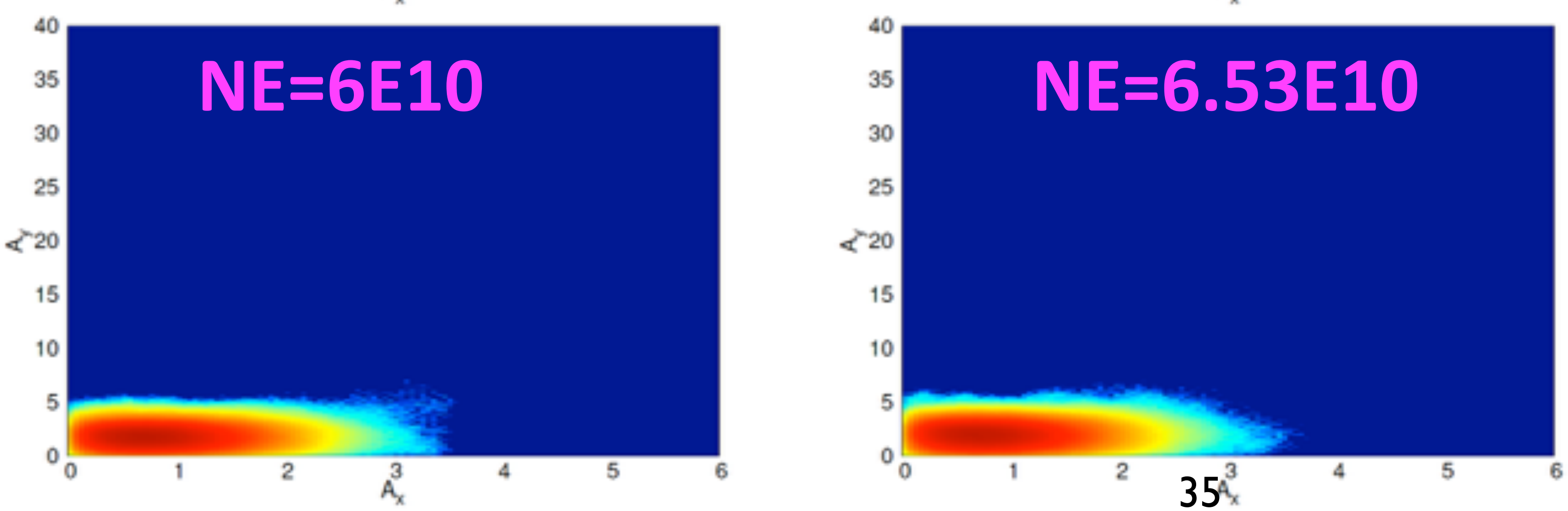
sler_1689

5. Space charge: LER: Beam tail

➤ Beam tail w/ LN+SC by SAD

sler_1689



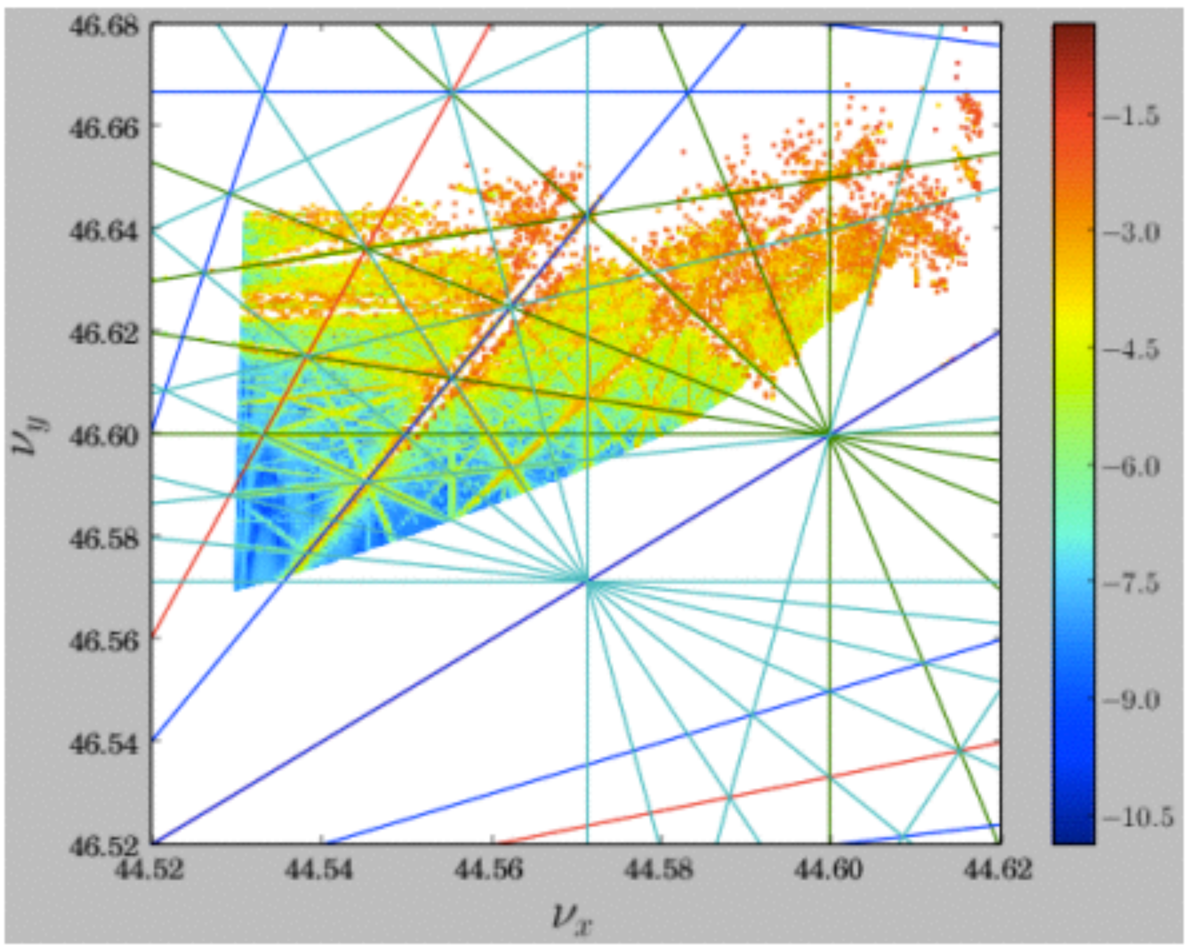


Note: No optics correct with space charge

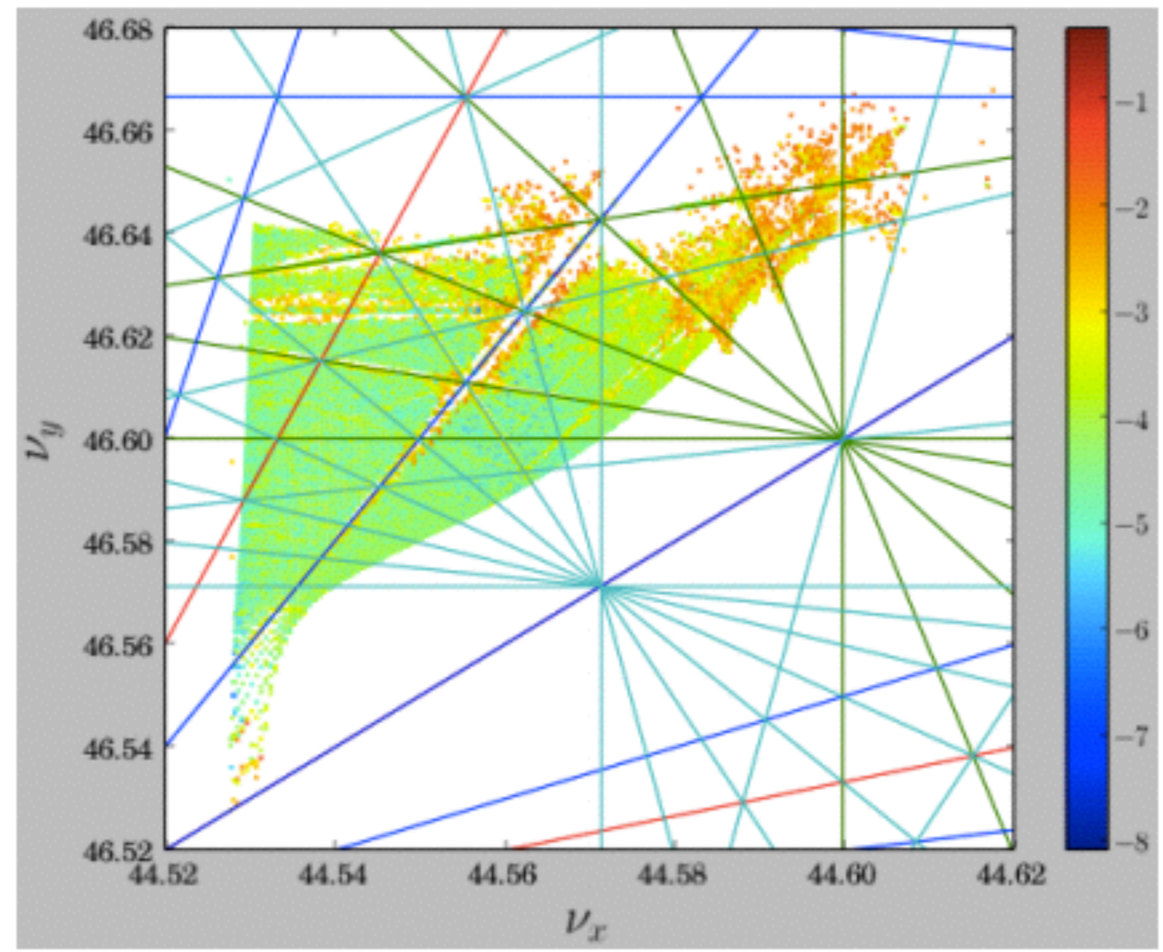
5. Space charge: LER: FMA

➤ **FMA shows betatron tunes of particles at the beam core are close to half-integer with only SC considered.**

W/O SCE



W/ SCE



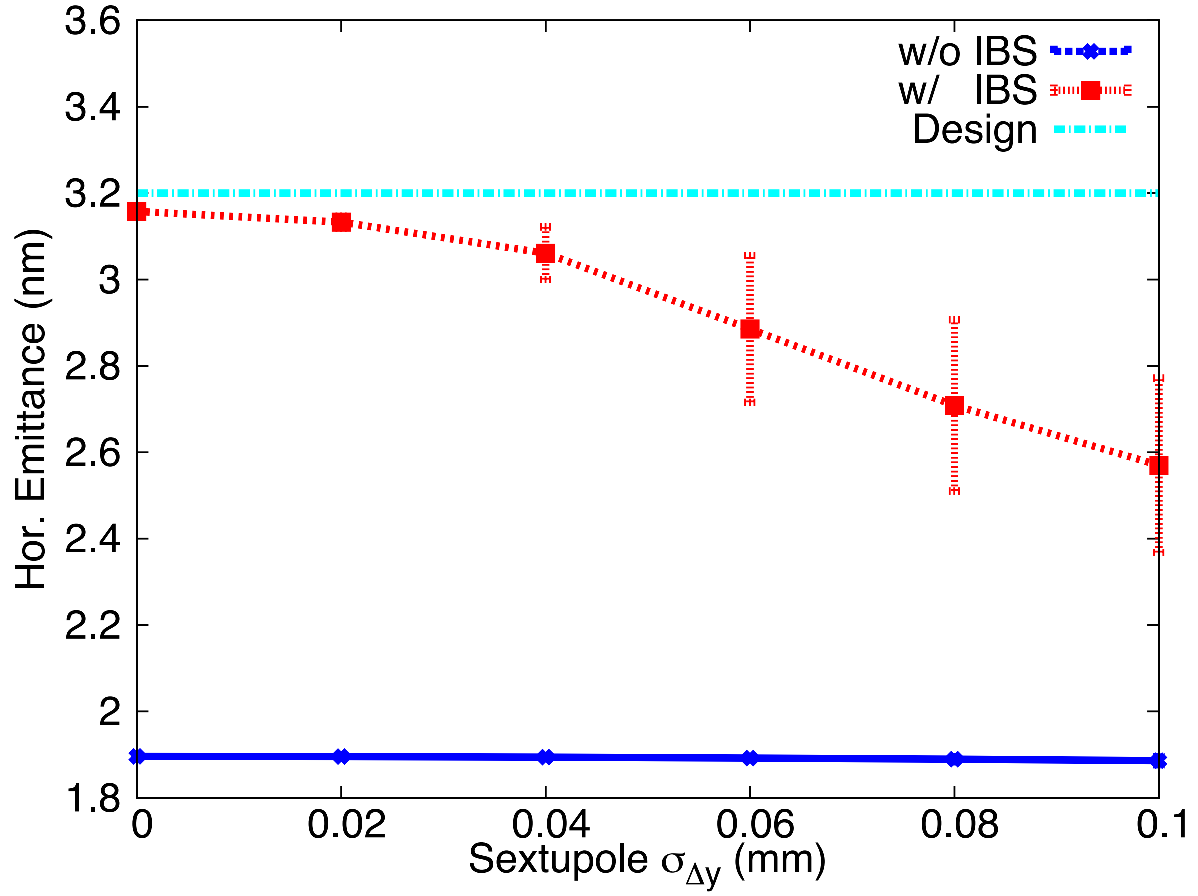
4th order
5th order
6th order
7th order

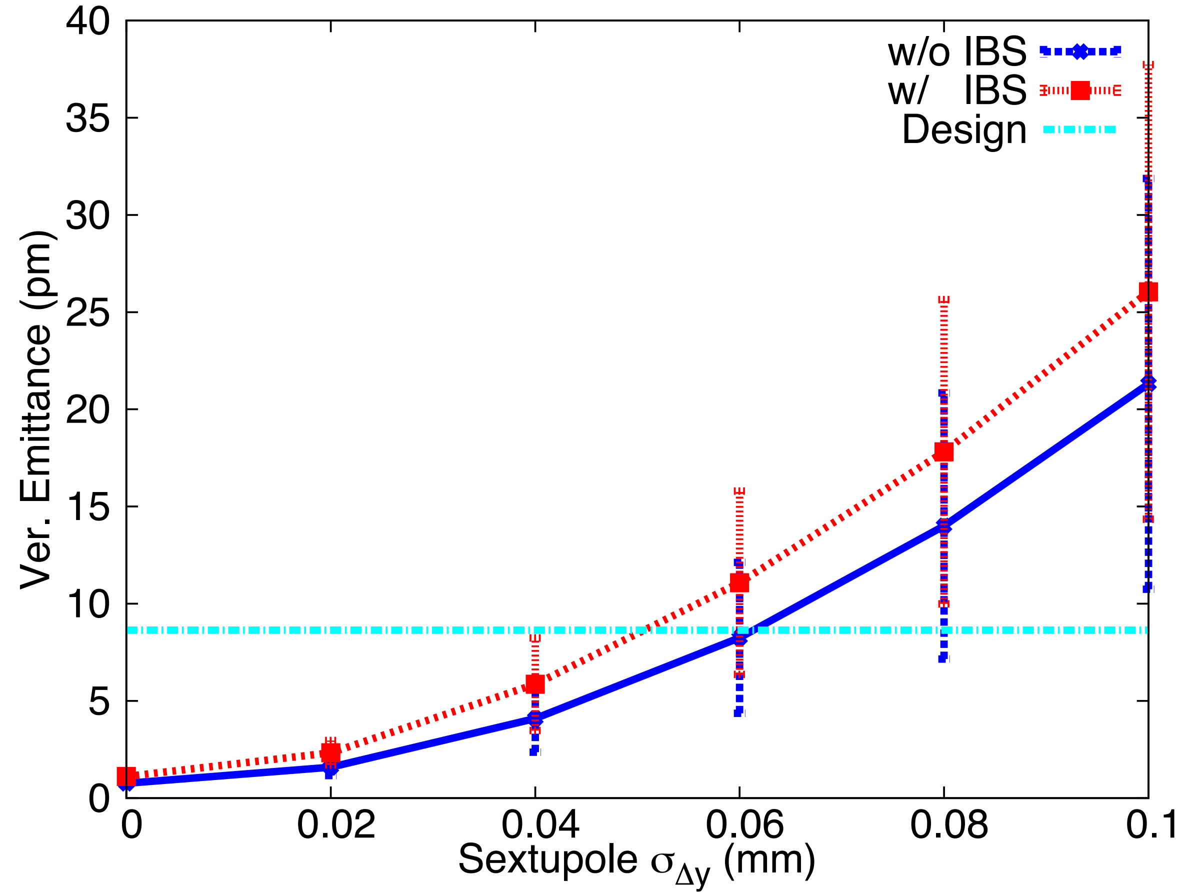
Detailed Studies are now ongoing.
- Optics matching
- Checking simulation code including SAD code itself.

6. Intra-beam scattering: LER: SAD simulation

➤ **Emittance growth due to IBS (w/ errors in sext.)**

- **ε_x decrease with increasing errors in sext.**
- **Tolerance: $\sigma_{\Delta y}$ < 0.06 mm w/o IBS, $\sigma_{\Delta y}$ < 0.05 mm w/ IBS**

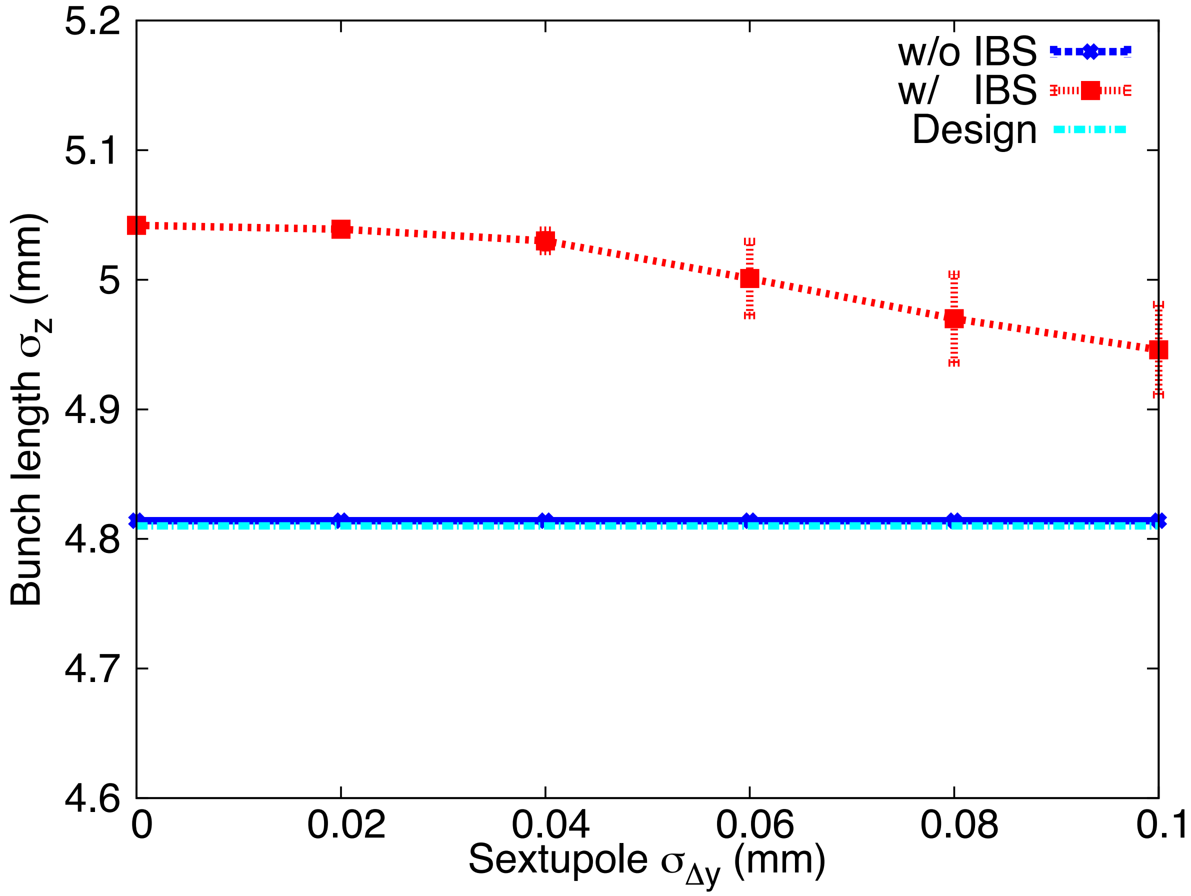


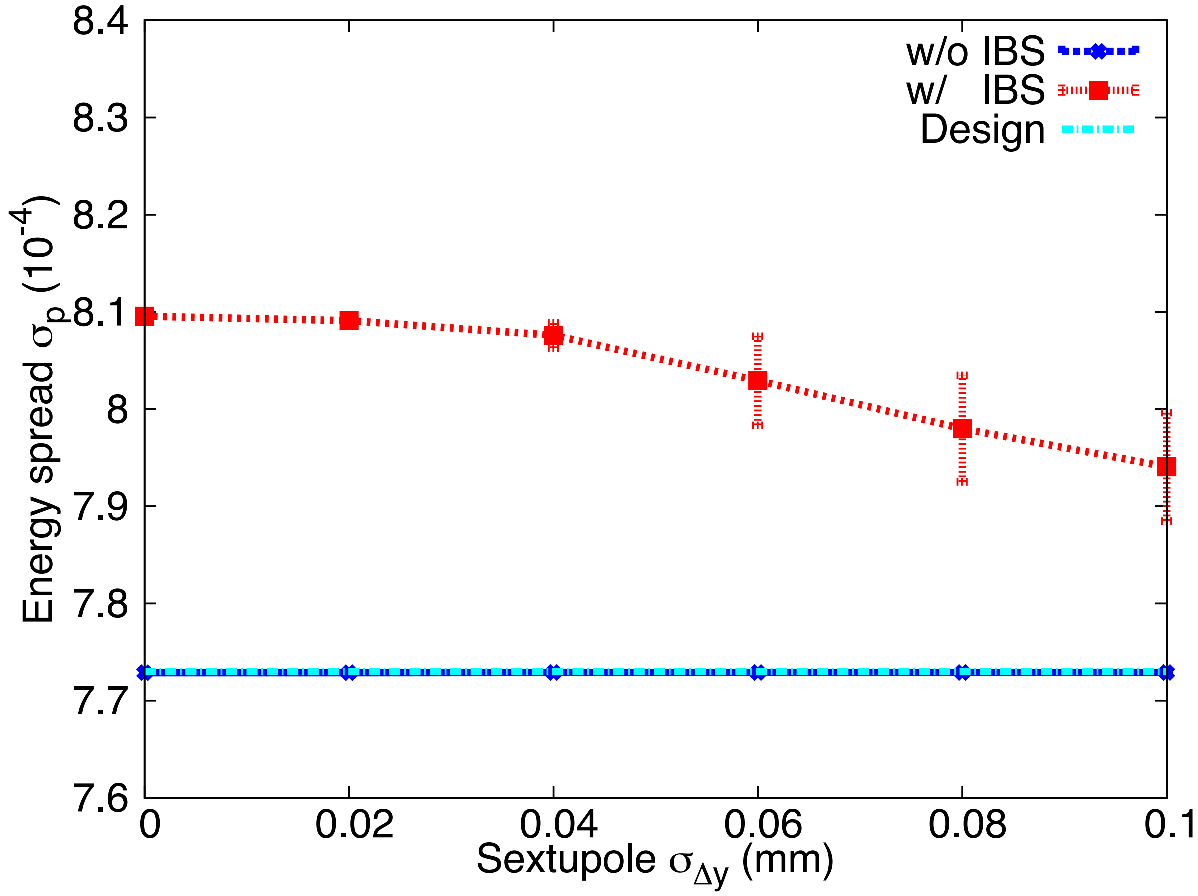


6. Intra-beam scattering: LER: SAD simulation

➤ Bunch lengthening and energy spread increase due to IBS (w/ errors in sext.)

- Both σ_z and σ_z slightly increase due to IBS
- Not negligible in LER

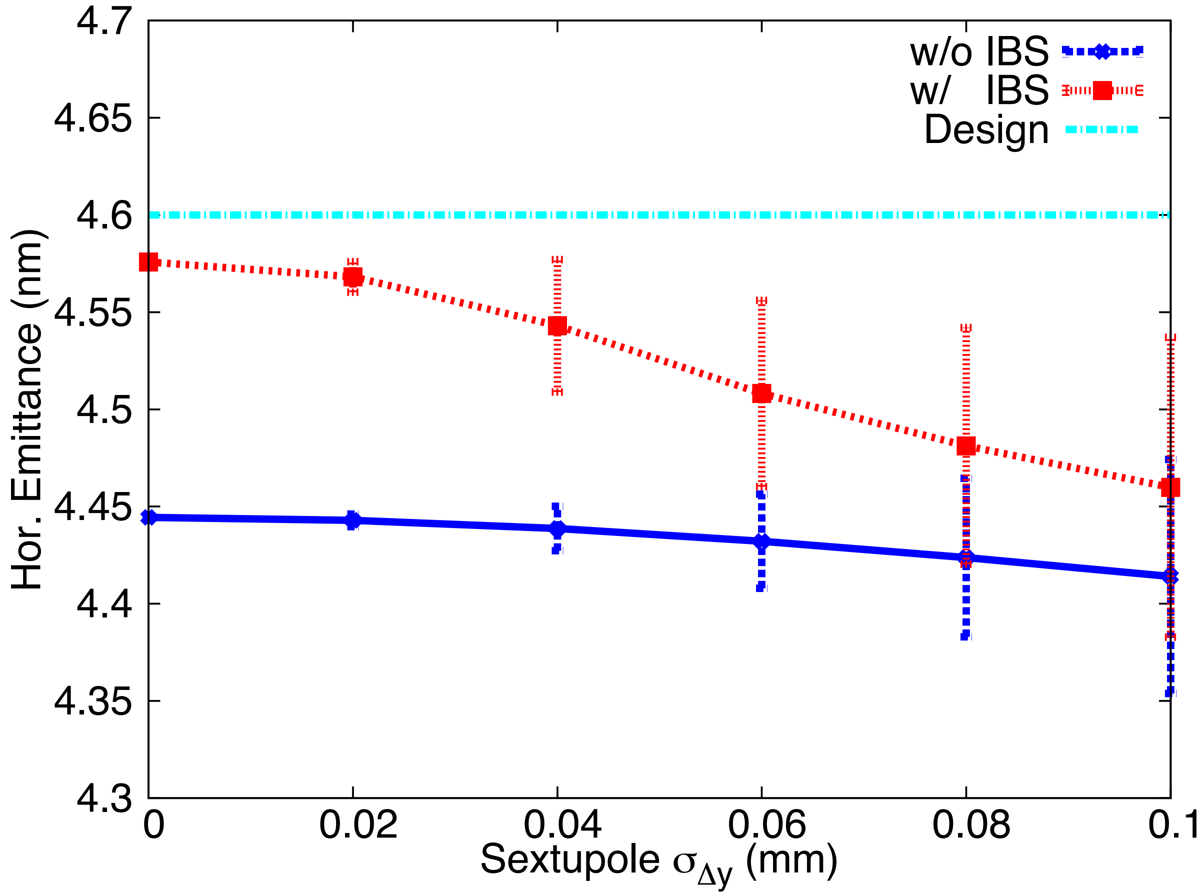


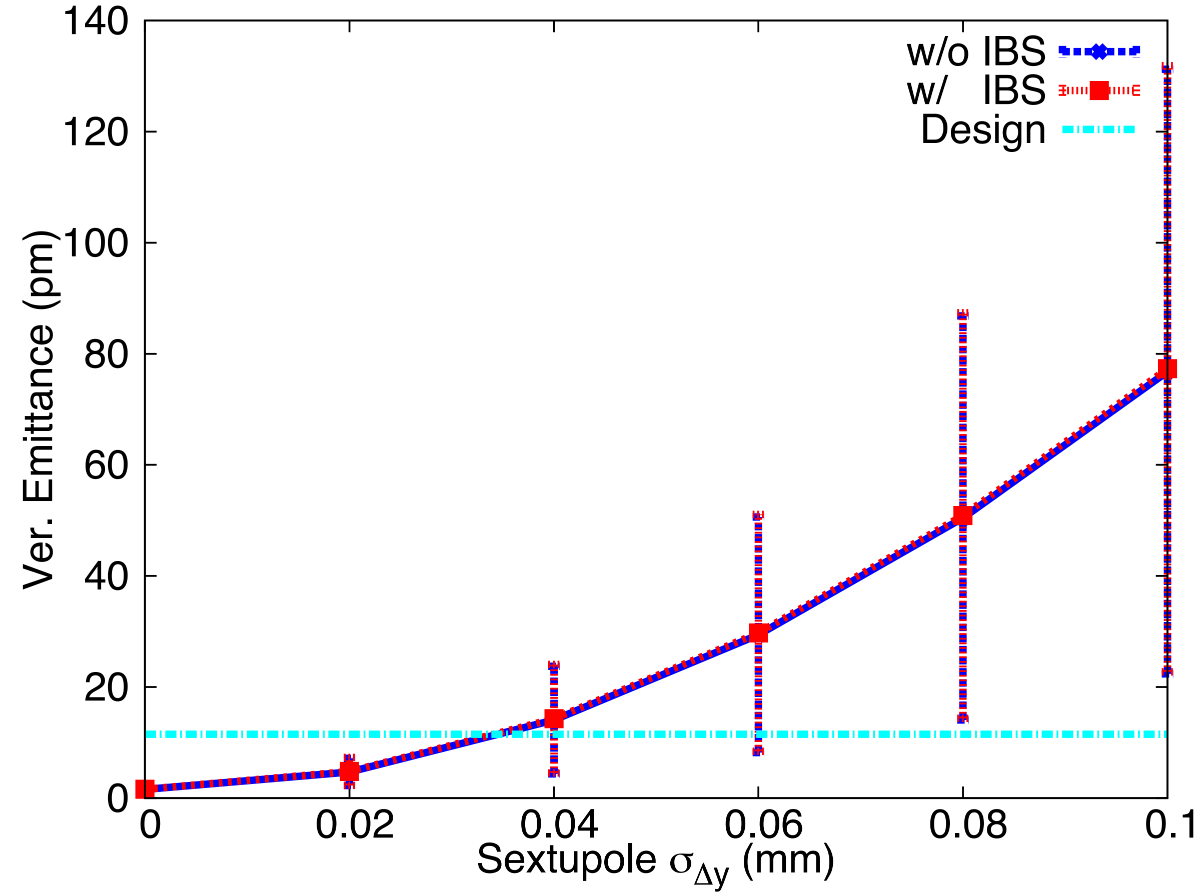


6. Intra-beam scattering: HER: SAD simulation

➤ **Emittance growth due to IBS (w/ errors in sext.)**

- **ε_x slightly decrease with increasing errors in sext. $\Delta\varepsilon_x$ < 3%**
- **Negligible in vert. direction**
- **Effects of IBS in HER almost negligible**

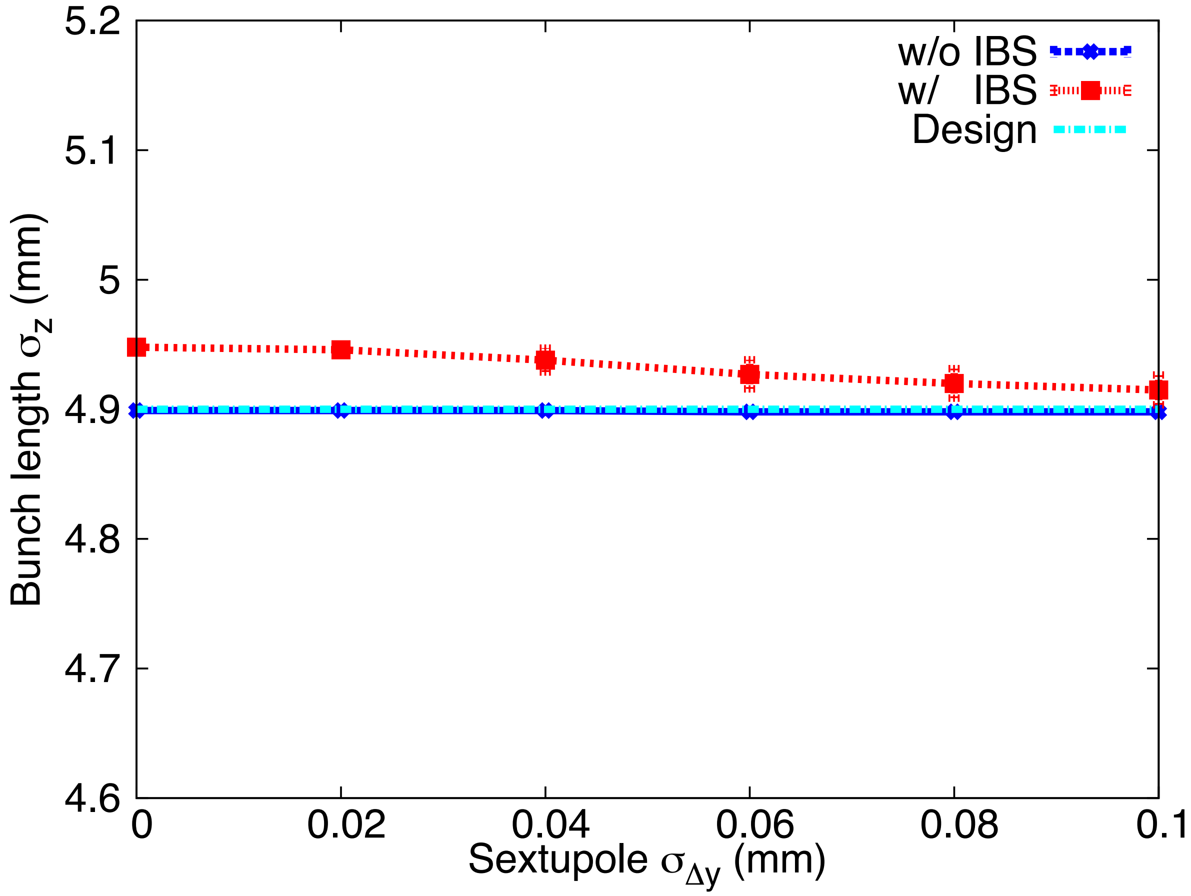


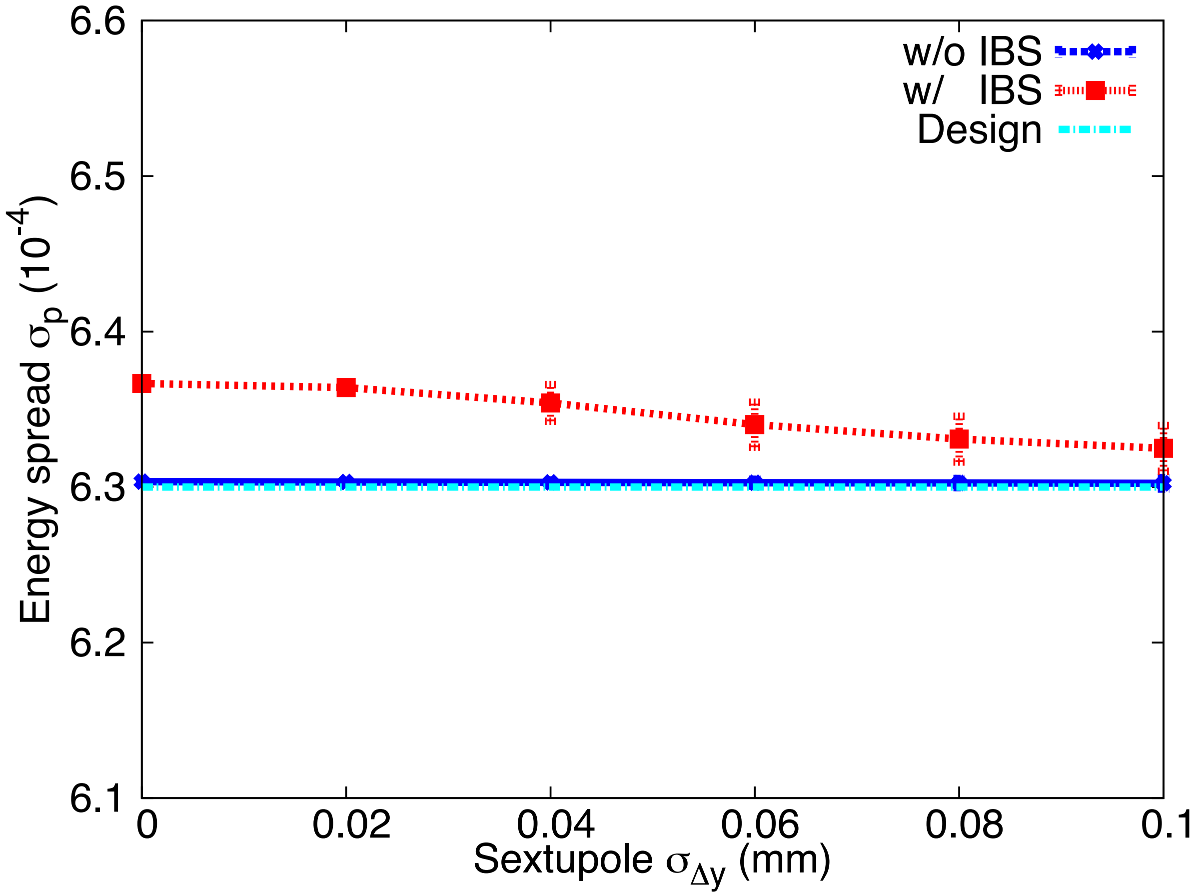


6. Intra-beam scattering: HER: SAD simulation

➤ **Bunch lengthening and energy spread increase due to IBS (w/ errors in sext.)**

- **Both σ_z and σ_z slightly increase due to IBS**
- **Effects of IBS in HER is negligible**





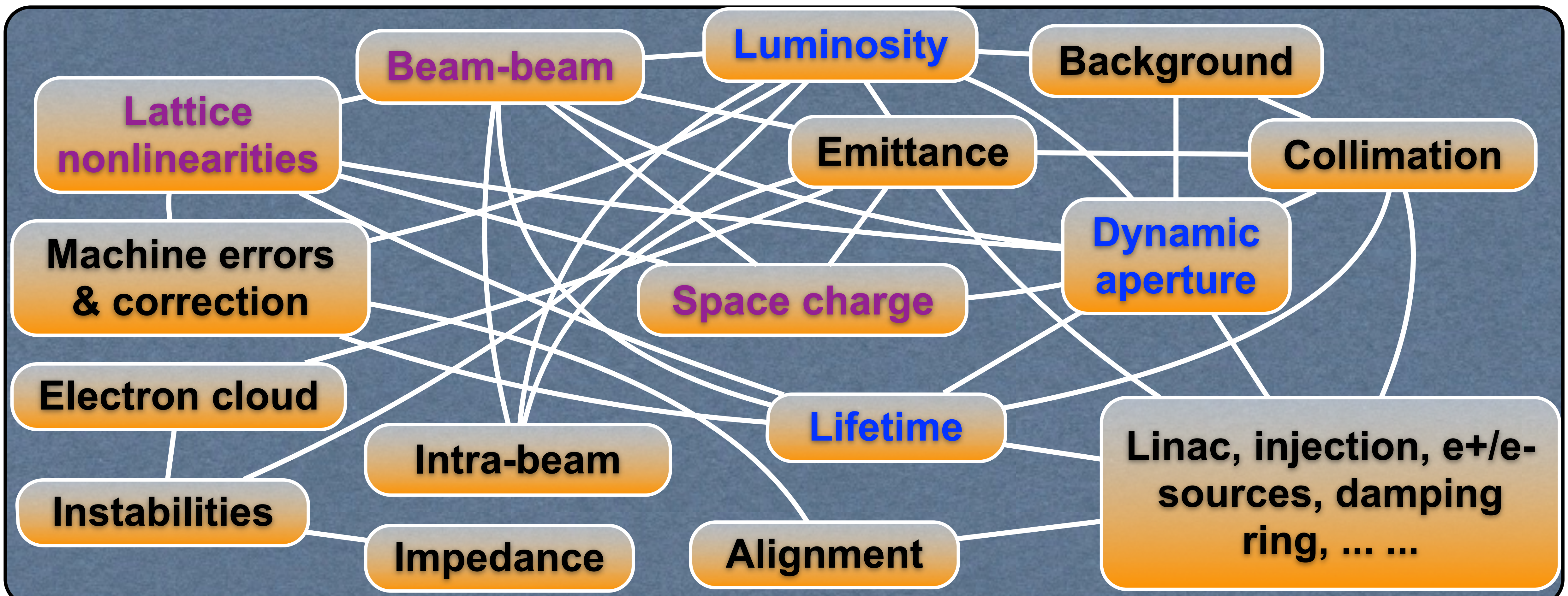
7. Summary

- **Beam-beam and luminosity**
  - Interplay of BB and LN is important issue in SuperKEKB
  - We need to optimise the optics design
- **Impedance and single-bunch effects**
  - Pseudo-Green function wakes are available
  - Beam tilt and TMCI are potentially important
- **Electron cloud**
  - Simulations of instability vs. varied $\beta_{x,y}$ and density were done
  - High-beta sections can be important
  - Ecloud density data need to be verified
- **Space charge**
  - A surprise to SuperKEKB and to be verified
  - Consider compensation scheme via optics correction
- **Intra-beam scattering**
  - To be an issue in LER and interplay with other collective effects

7. Summary

➤ Interplay of various issues

- Luminosity <= Emittance <= Beam-beam, Lattice nonlinearity, Space charge, Impedances, Electron cloud, Intra-beam scattering, etc.
- => Dynamic aperture and lifetime => Beam commissioning => Injection, Detector back ground, Alignments, etc. => Tolerance for hardwares => …



More details in the backup slides and my webpage: http://research.kek.jp/people/dmzhou/

Thanks for your attention!

AND

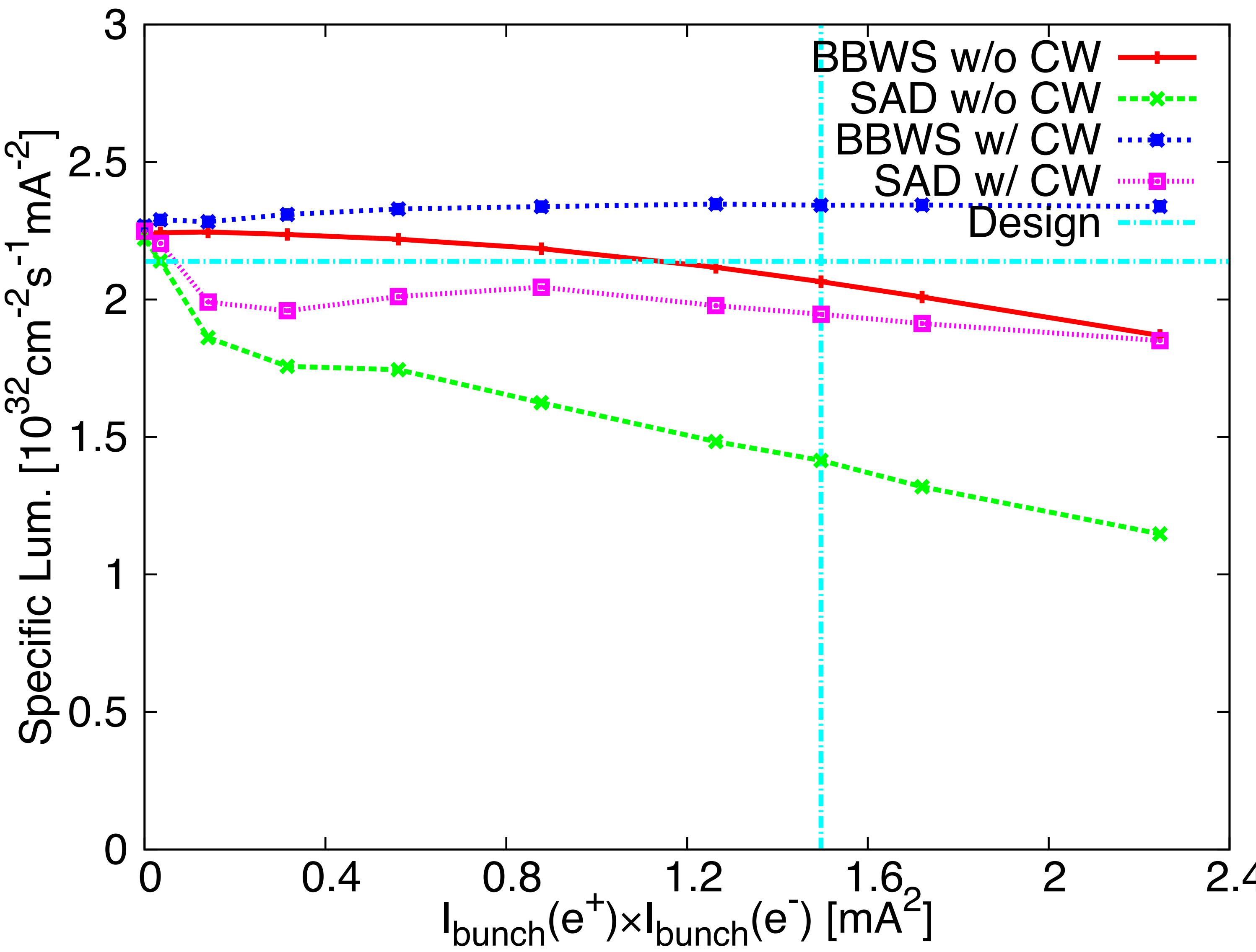
Welcome to KEK!

Backup

2. Beam-beam: Lattice nonlinearity: LER

➤ **Simple map for crab waist at IP**

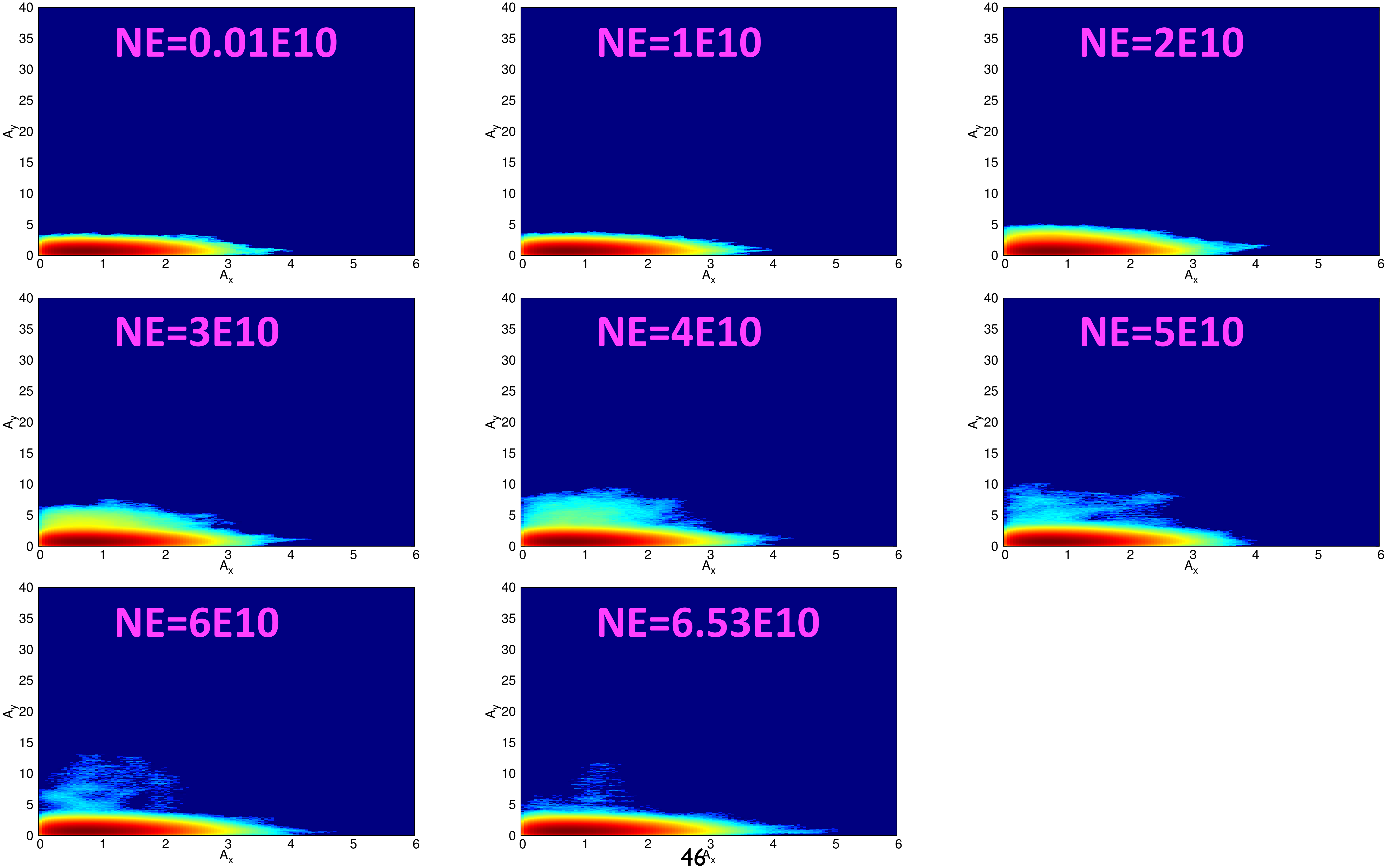
$$p_{x1} = p_{x0} - \frac{1}{2\mathrm{Tan}(2\phi)} p_{y0}^2 \qquad y_1 = y_0 + \frac{1}{\mathrm{Tan}(2\phi)} x_0 p_{y0}$$



sler_1684

2. Beam-beam: Lattice nonlinearity: LER

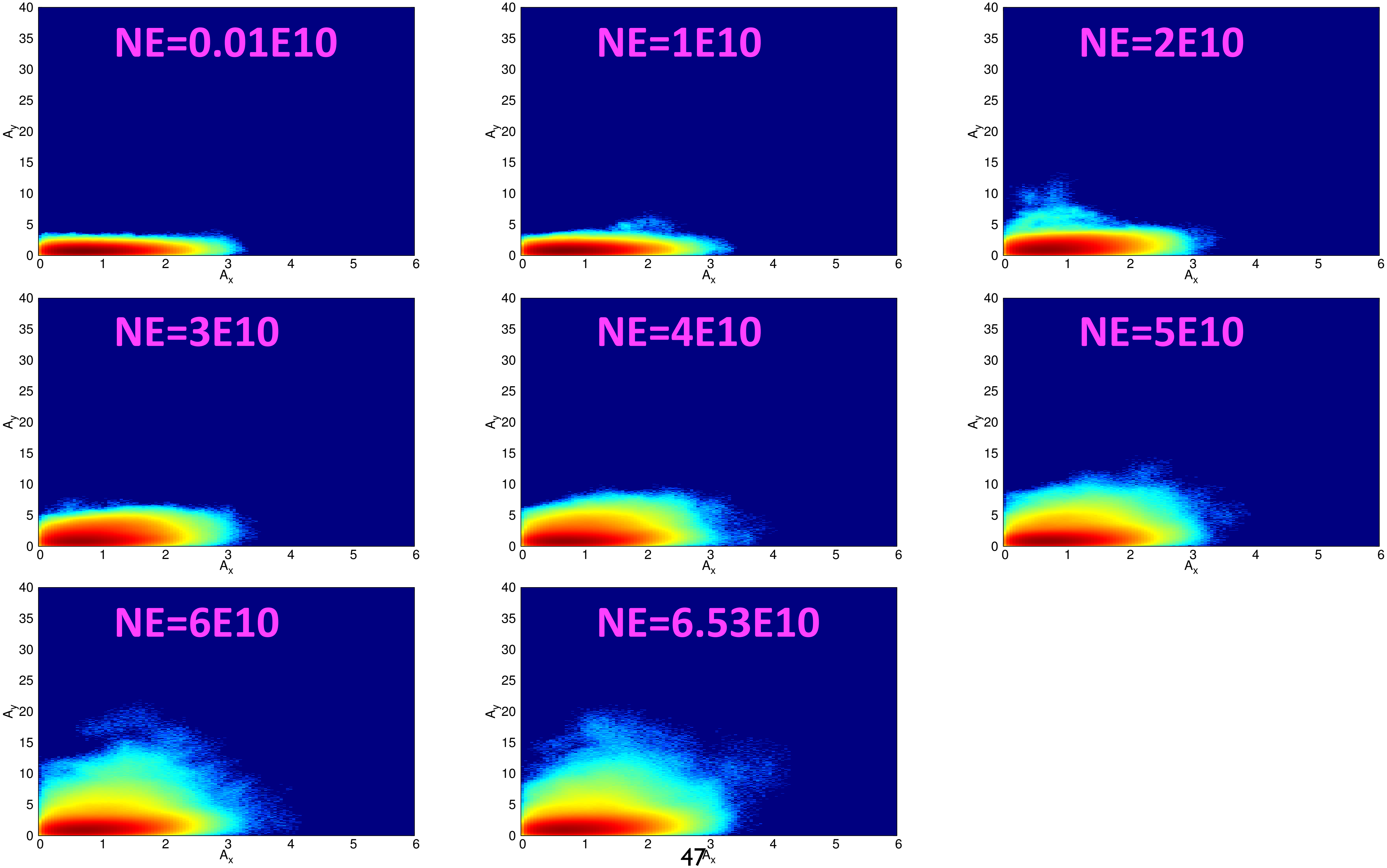
➤ Beam tail w/ BB+CW by BBWS



2. Beam-beam: Lattice nonlinearity: LER

➤ Beam tail w/ BB+CW+LN by SAD

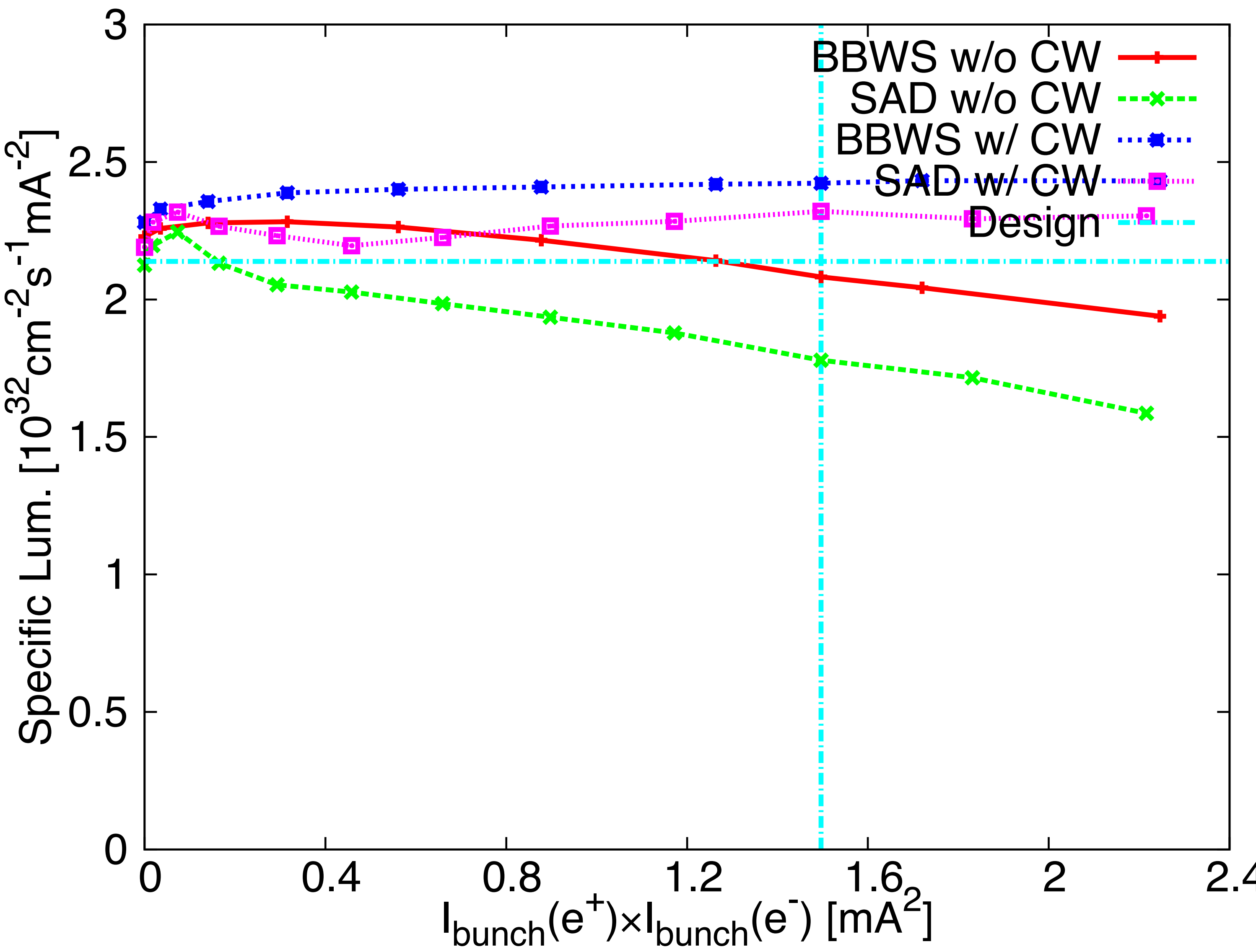
sler_1684



2. Beam-beam: Lattice nonlinearity: HER

➤ **Simple map for crab waist at IP**

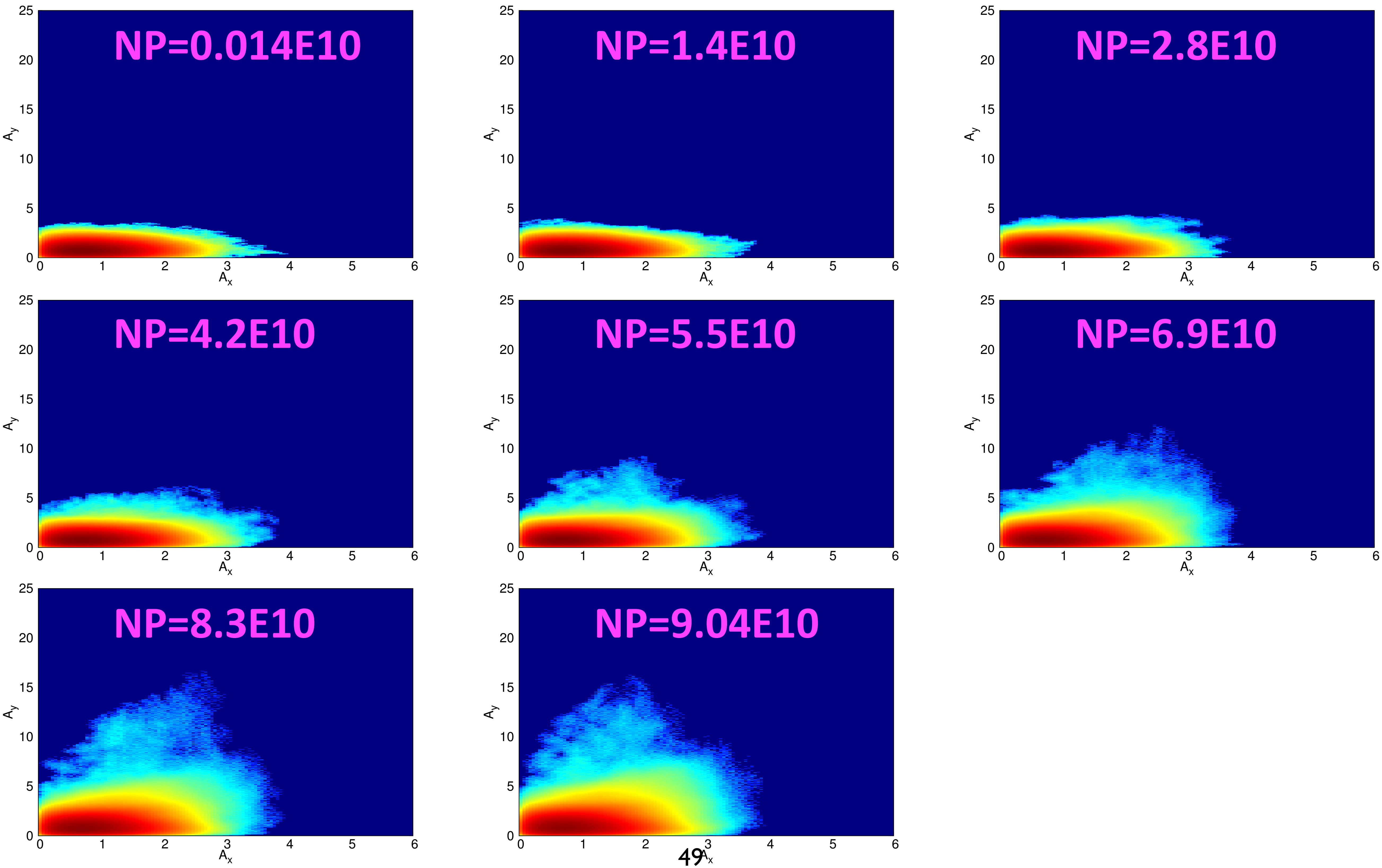
$$p_{x1} = p_{x0} - \frac{1}{2\mathrm{Tan}(2\phi)} p_{y0}^2 \qquad y_1 = y_0 + \frac{1}{\mathrm{Tan}(2\phi)} x_0 p_{y0}$$



sher_5755

2. Beam-beam: Lattice nonlinearity: HER

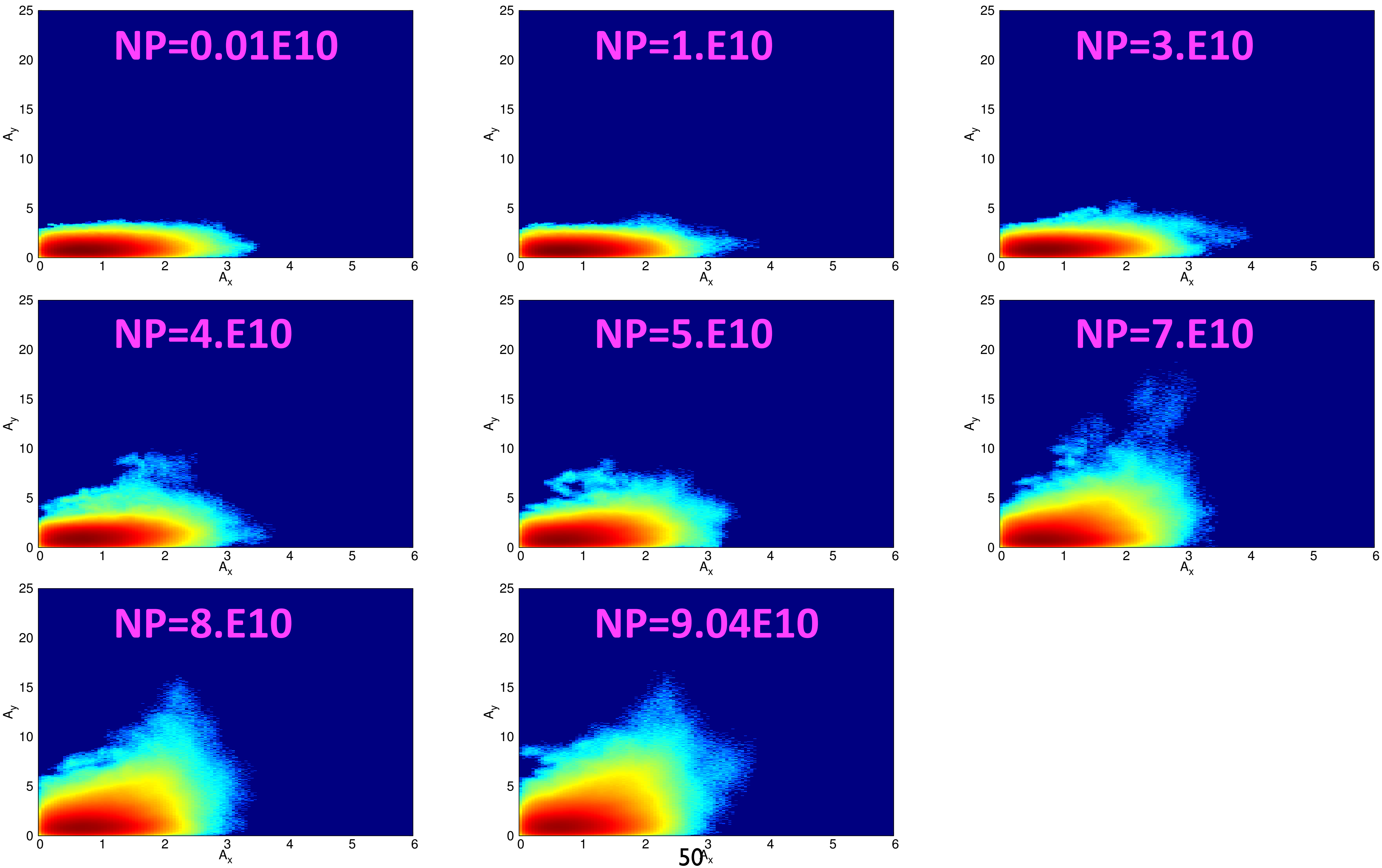
➤ Beam tail w/ BB by BBWS



2. Beam-beam: Lattice nonlinearity: HER

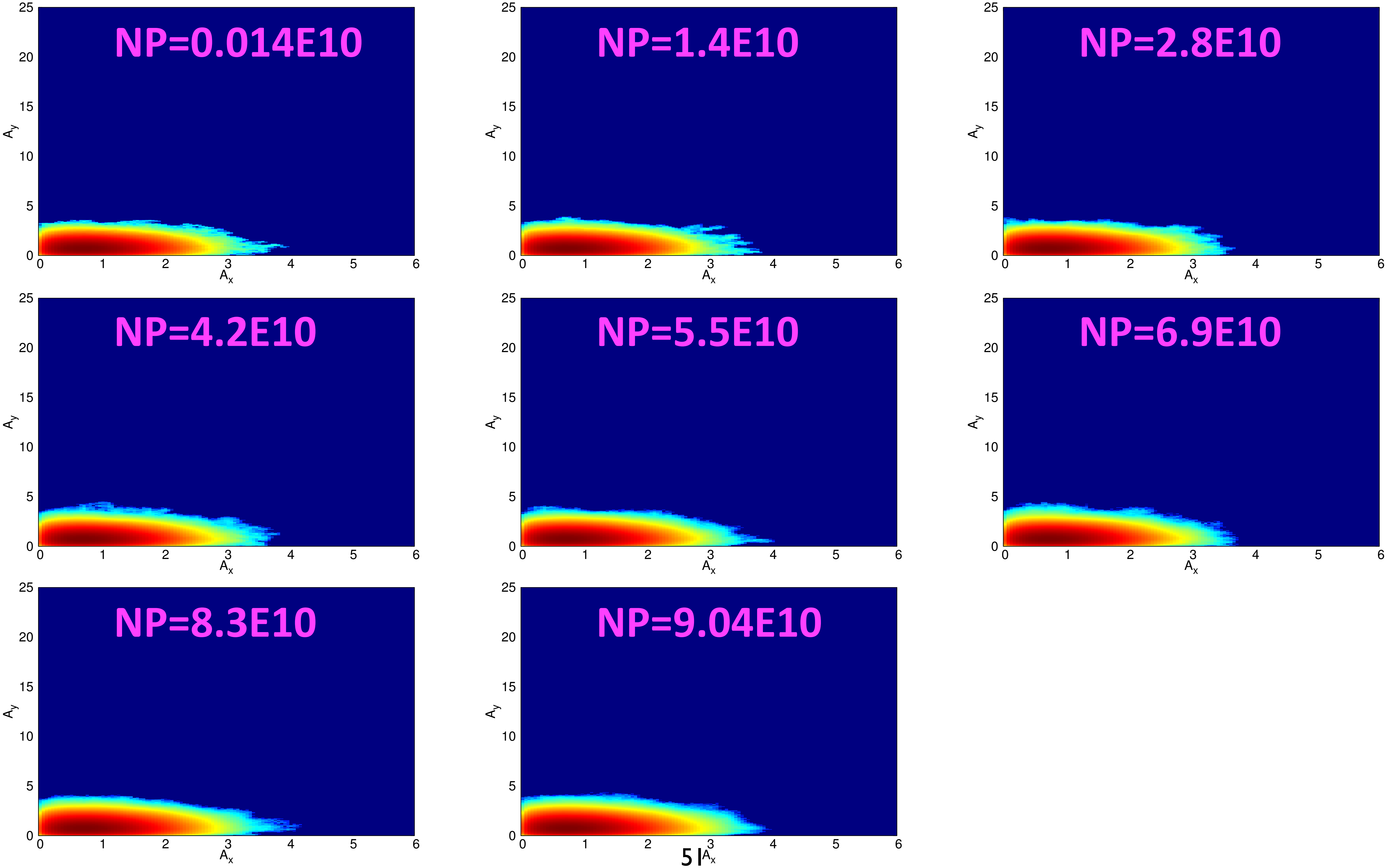
sher_5755

➤ Beam tail w/ BB+LN by SAD



2. Beam-beam: Lattice nonlinearity: HER

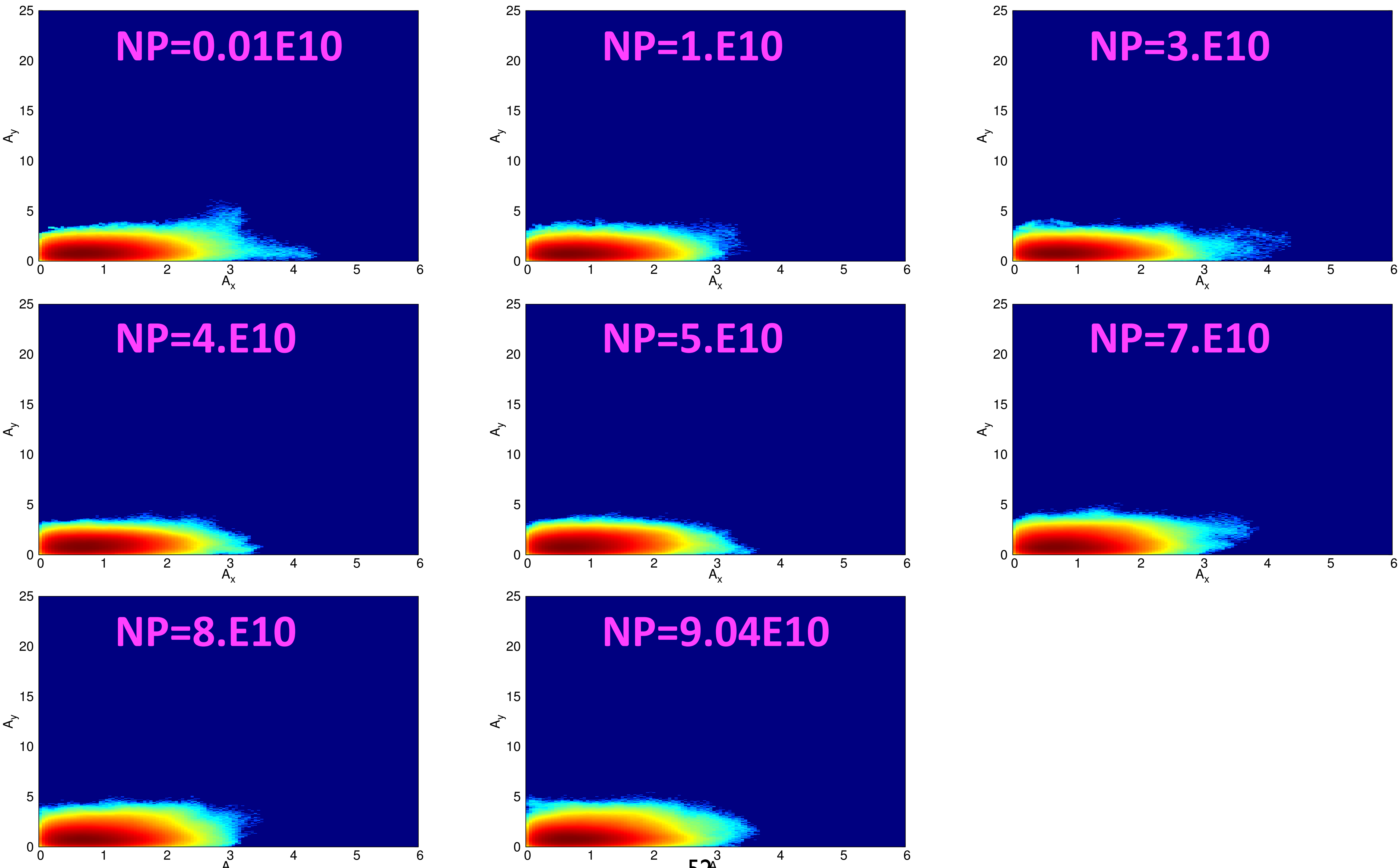
➤ Beam tail w/ BB+CW by BBWS



2. Beam-beam: Lattice nonlinearity: HER

sher_5755

➤ Beam tail w/ BB+CW+LN by SAD



2. Lum. calculation: Detuned lattice

➤ **Detuned lattice: sler_1689_d4-8/sher_5767_d4-8**

From Y. Ohnishi

Parameters	symbol	Phase 2.x		Phase 3.x		unit
		LER	HER	LER	HER	
Energy	E	4	7.007	4	7.007	GeV
#Bunches	n_b	2500		2500		
Emittance	ε_x	2.2	5.2	3.2	4.6	nm
Coupling	$\varepsilon_y/\varepsilon_x$	2	2	0.27	0.28	%
Hor. beta at IP	$\beta_x{}^*$	128	100	32	25	mm
Ver. beta at IP	$\beta_y{}^*$	2.16	2.4	0.27	0.30	mm
Beam current	I_b	1.0	0.8	3.6	2.6	A
Beam-beam	ξ_y	0.0240	0.0257	0.088	0.081	
Hor. beam size	$\sigma_x{}^*$	16.8	22.8	10	11	μm
Ver. beam size	$\sigma_y{}^*$	308	500	48	62	nm
Luminosity	L	1×10^{34}		8×10^{35}		$cm^{-2}s^{-1}$

LER

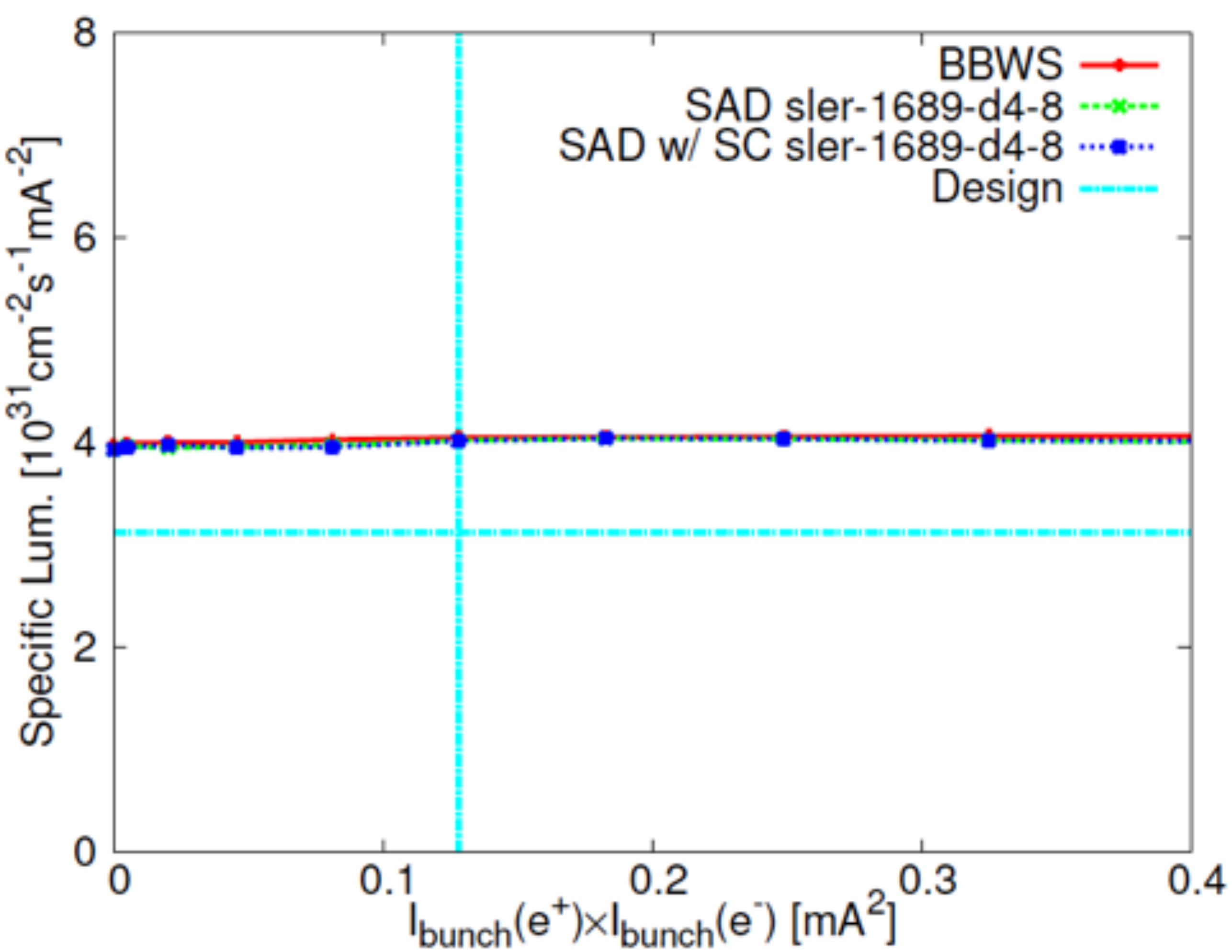
β_x at IP	128	mm
β_y at IP	2.16	mm
I_b	1	A
n_b	2500	
ε_x	1.75	nm
$\varepsilon_y/\varepsilon_x$	2	%

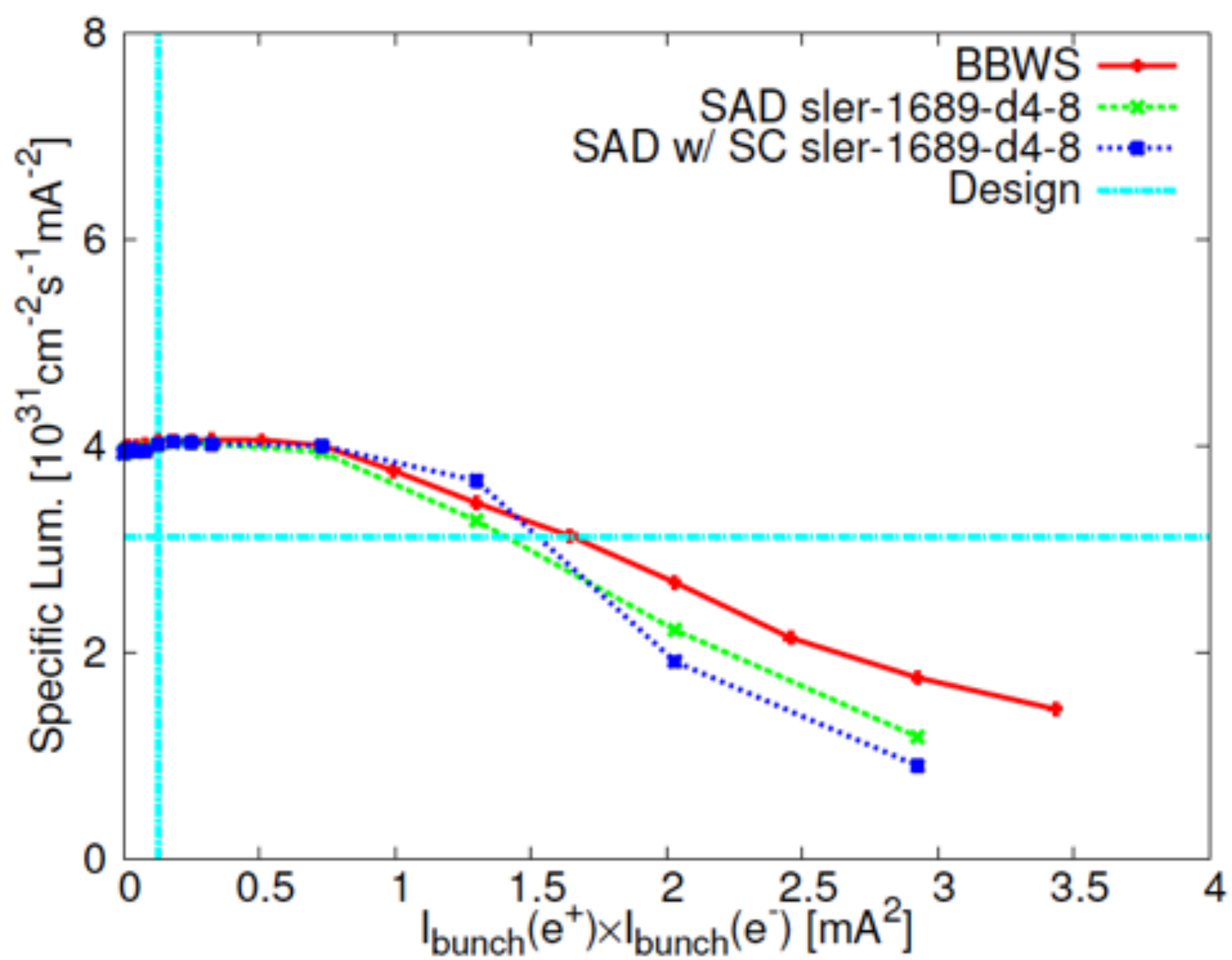
HER

β_x at IP	100	mm
β_y at IP	2.40	mm
I_b	0.8	A
n_b	2500	
ε_x	4.5	nm
$\varepsilon_y/\varepsilon_x$	2	%

2. Lum. calculation: Detuned lattice

- ➤ Assume: ε_x=1.75nm, coupling = 2%
- ➤ Space-charge is not important
- ➤ Lattice nonlinearity is not very important
- ➤ $L=1\times10^{34}cm^{-2}s^{-1}$ is promising
- ➤ $L=10\times10^{34}cm^{-2}s^{-1}$ is possible by increasing beam currents?

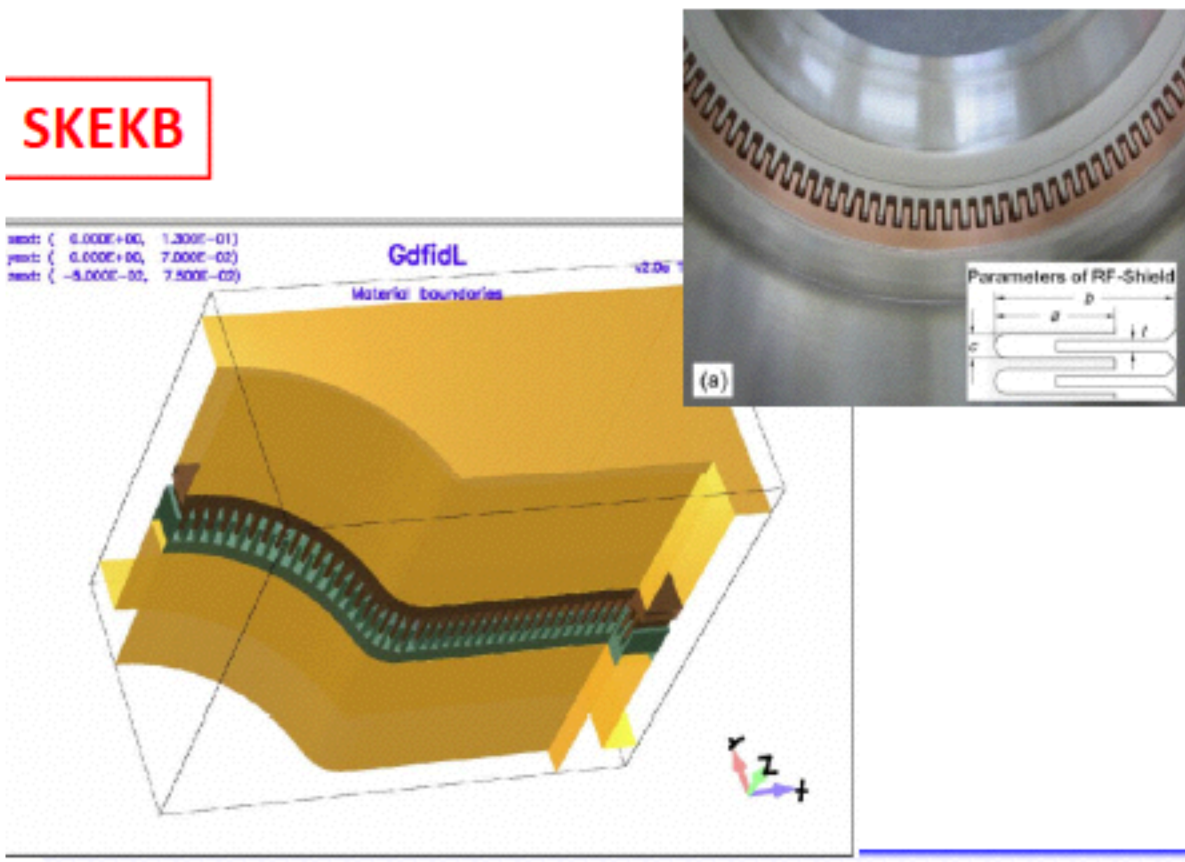




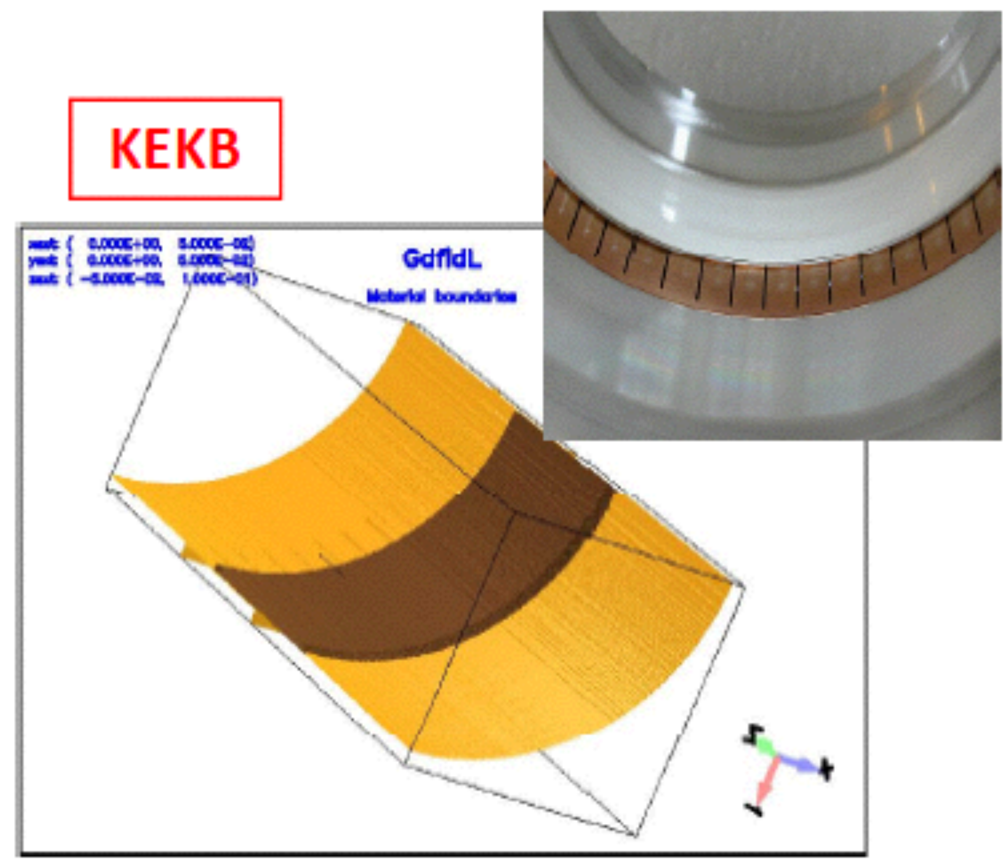
Bellows

- Bellows chamber with comb-type RF shield will be used in SKEKB.
  - There is no radial step on the inner surface.
    (There is a small step (~1 mm) in a conventional bellows chamber.)
  - RF is shielded by nested comb teeth.
    length : 10 mm
    radial thickness : 10 mm

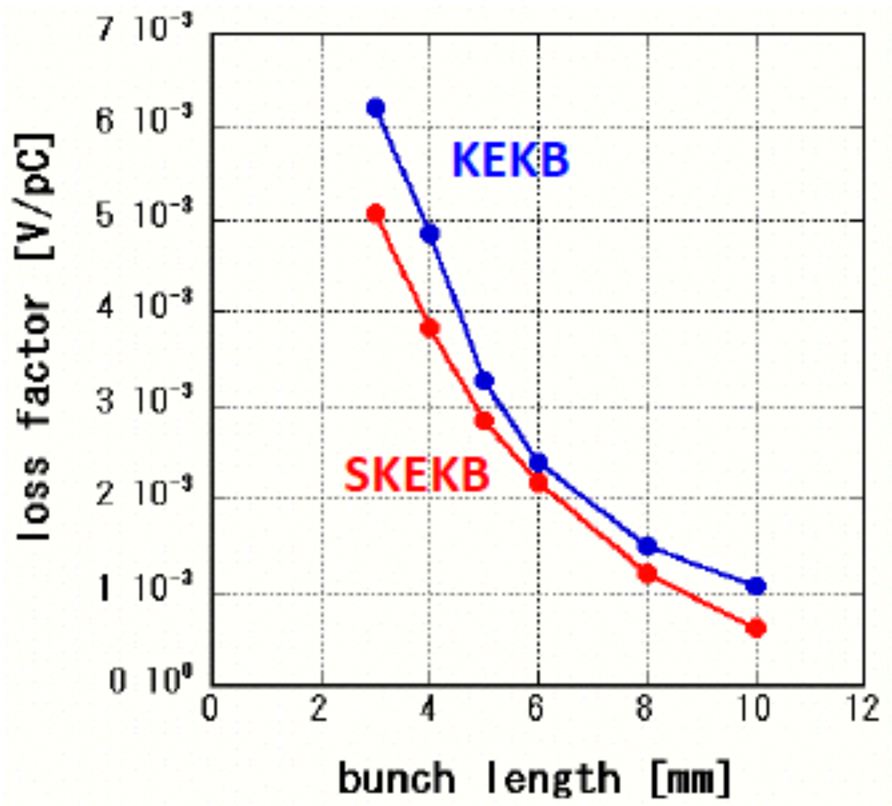
SKEKB

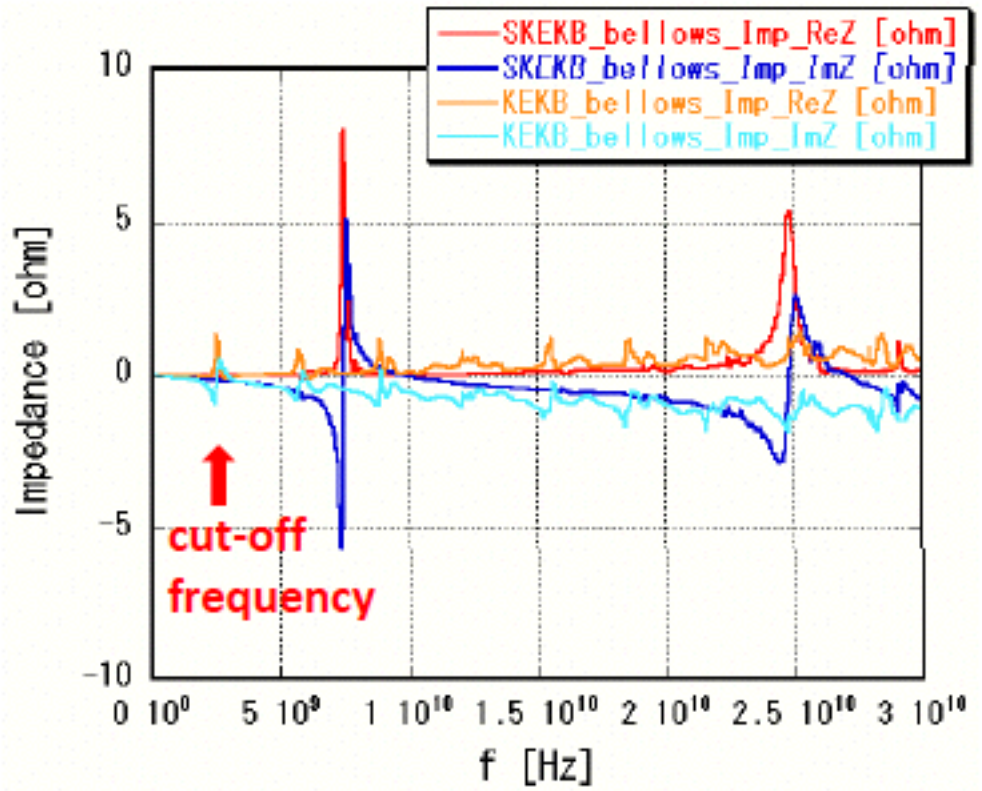


KEKB



Bellows





- Loss factor (σ_z = 6 mm)

  $k = 2.2\times10^{-3}$ V/pC

  ⇩ 1000 pieces in one ring

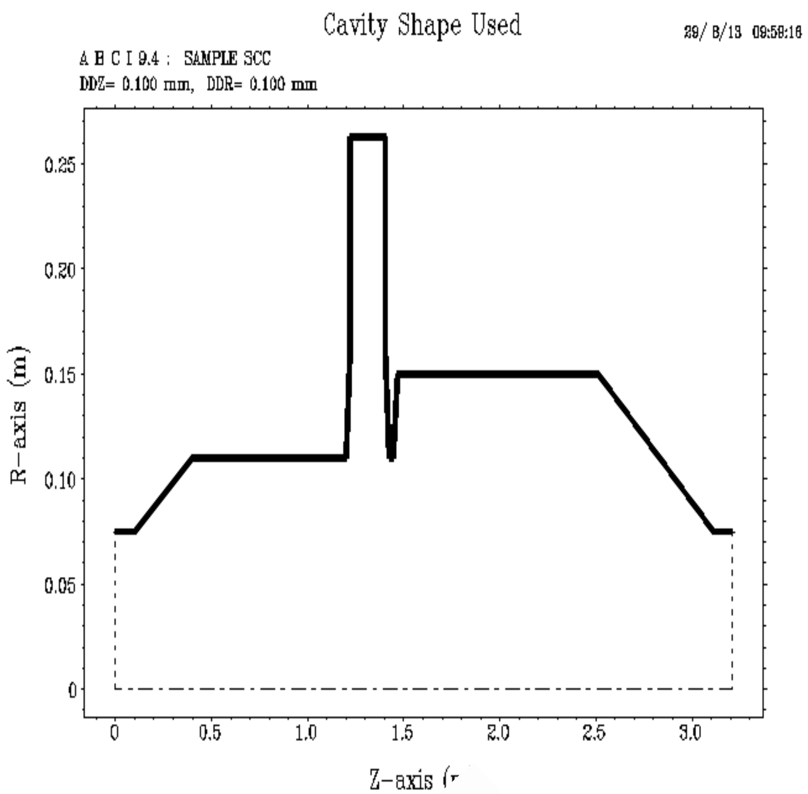
  ***k*_total = 2.2 V/pC**

- Impedance

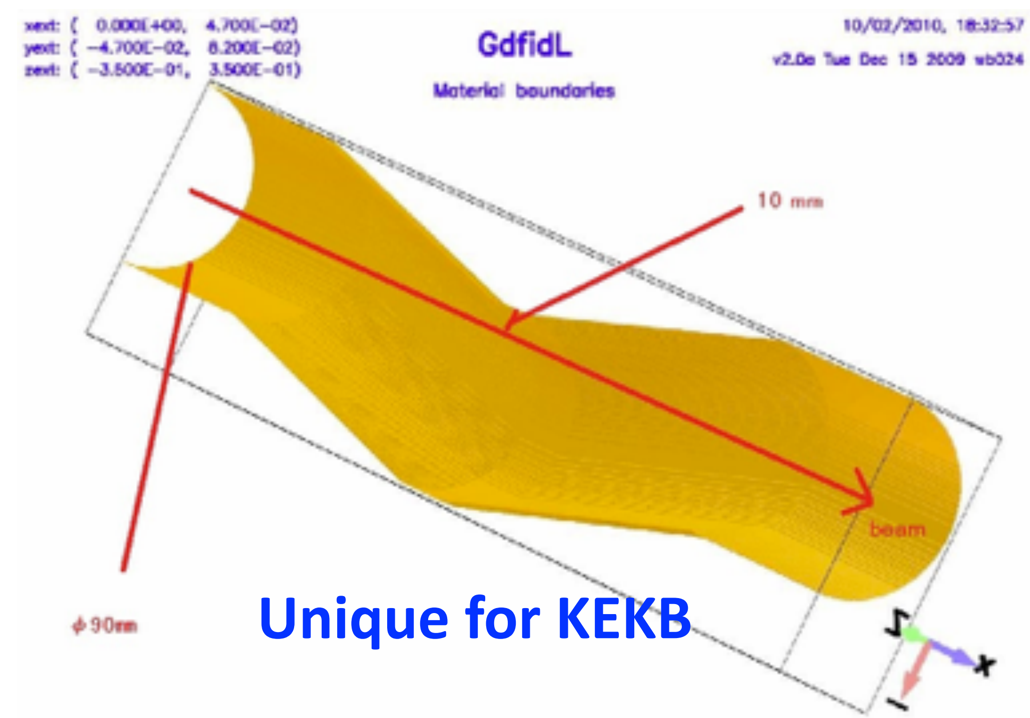
  It was found that there are trapped modes at 7.5 GHz and 25 GHz (over cut-off frequency (2.5GHz)). Effects of these trapped modes on the beams will be investigated.

3. Impedance: Modelling: HER

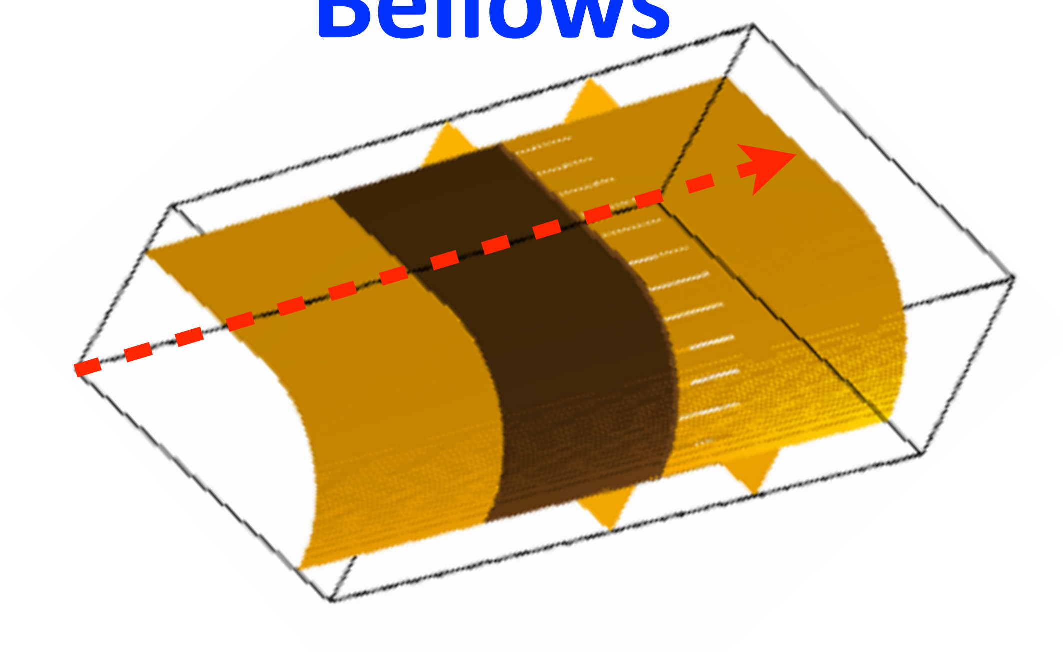
SCC (by ABCI)



Movable mask (KEKB type)



Bellows

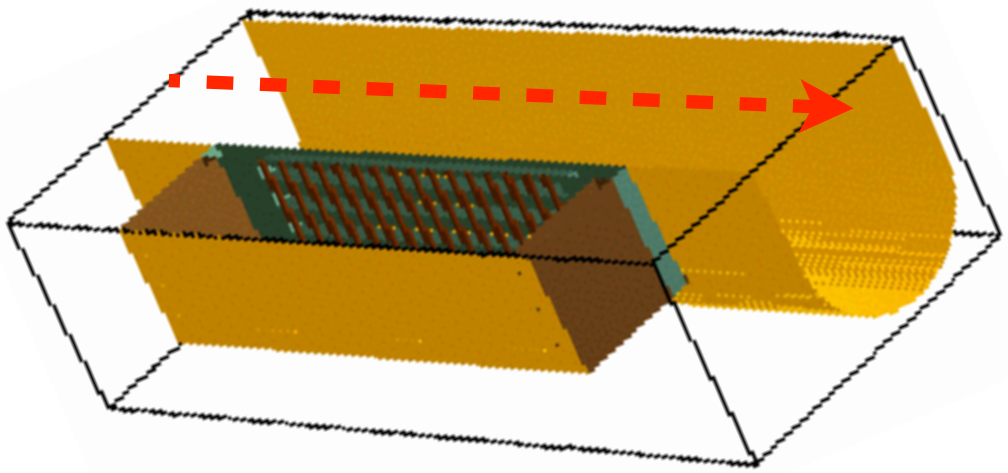


ARES

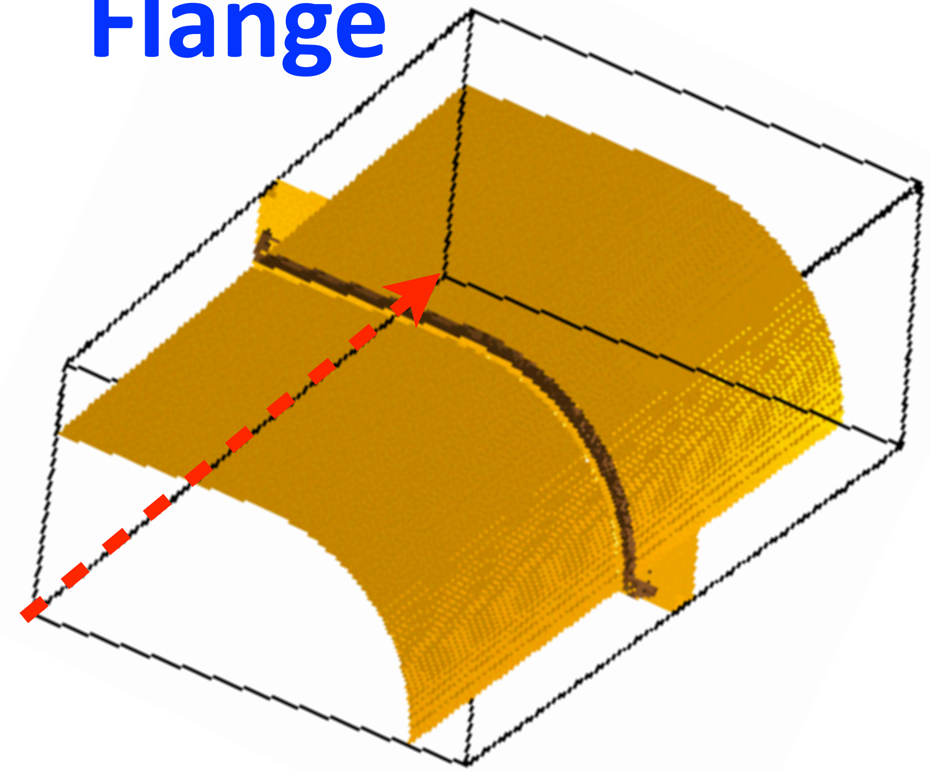
From T. Abe, Y. Morita, and K. Shibata

3. Impedance: Modelling: HER

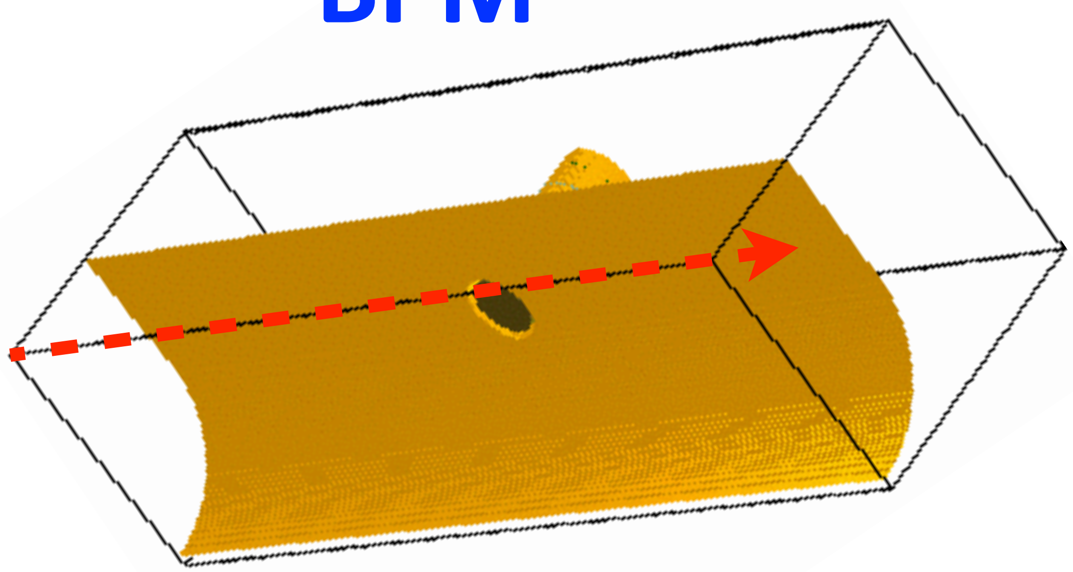
Pumping port



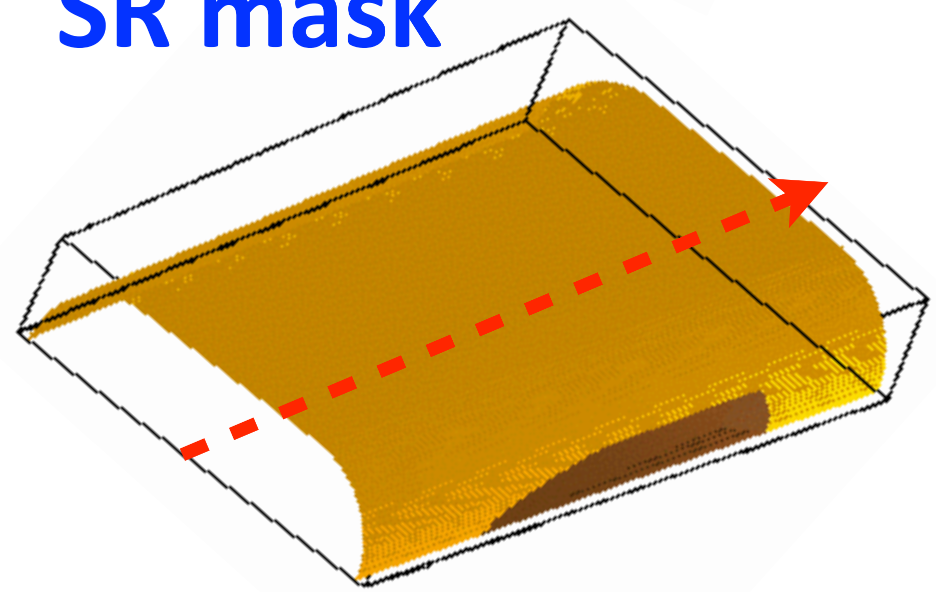
Flange



BPM



SR mask



From K. Shibata and M. Tobiyama

3. Impedance calculations: Impedance budget

➤ **Impedance budget with σ_z=5/4.9mm:**

- **Loss factors, resistance and inductance are calculated at nominal bunch lengths**
- **Bellows, flanges and pumping ports contribute more impedance in HER than in LER**

Table 2: Key parameters of SuperKEKB main rings for MWI simulations.

Parameter	LER	HER
Circumference (m)	3016.25	3016.25
Beam energy (GeV)	4	7.007
Bunch population (10^{10})	9.04	6.53
Nominal bunch length (mm)	5	4.9
Synchrotron tune	0.0244	0.028
Long. damping time (ms)	21.6	29.0
Energy spread (10^{-4})	8.1	6.37

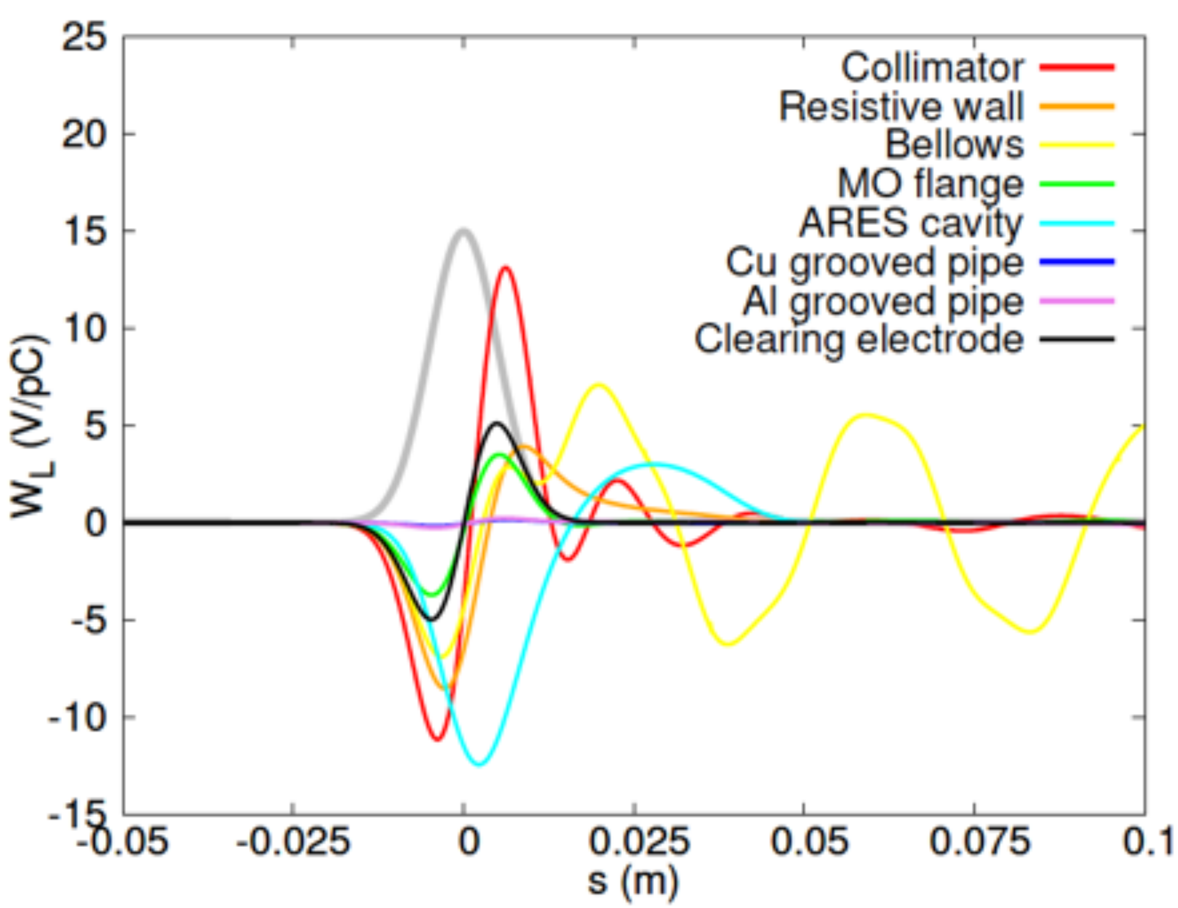
Component	LER			HER		
	$k_{\|\|}$	R	L	$k_{\|\|}$	R	L
ARES cavity	8.9	524	-	3.3	190	-
SC cavity	-	-	-	7.8	454	-
Collimator	1.1	62.4	13.0	5.3	309	10.8
Res. wall	3.9	231	5.7	5.9	340	8.2
Bellows	2.7	159	5.1	4.6	265	16.0
Flange	0.2	13.7	4.1	0.6	34.1	19.3
Pump. port	0.0	0.0	0.0	0.6	34.1	6.6
SR mask	0.0	0.0	0.0	0.4	21.4	0.7
IR duct	0.0	2.2	0.5	0.0	2.2	0.5
BPM	0.1	8.2	0.6	0.0	0.0	0.0
FB kicker	0.4	26.3	0.0	0.5	26.2	0.0
FB BPM	0.0	1.1	0.0	0.0	1.1	0.0
Long. kicker	1.8	105	1.2	-	-	-
Groove pipe	0.1	3.8	0.5	-	-	-
Electrode	0.0	0.7	5.7	-	-	-
Total	19.2	1137	36.4	29.0	1677	62.1

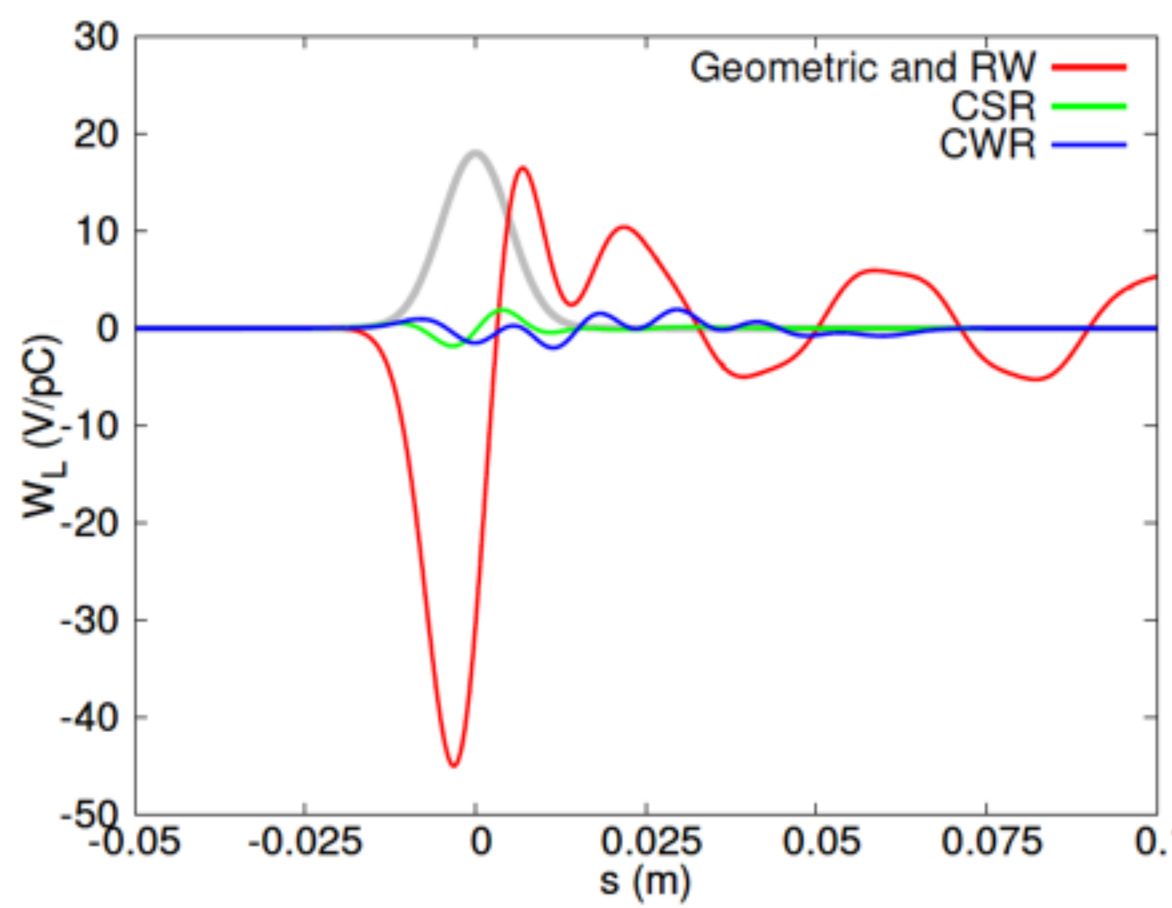
Ref. D. Zhou, IPAC14, TUPRI021

3. Impedance: Results: LER

➤ **Wake potential with nominal bunch length**

- σ_z=5mm
- Main sources: Collimators, Resistive wall, ARES cavity, Bellows, MO flanges, Clearing electrodes
- CSR and CWR are not strong if no microbunching happens

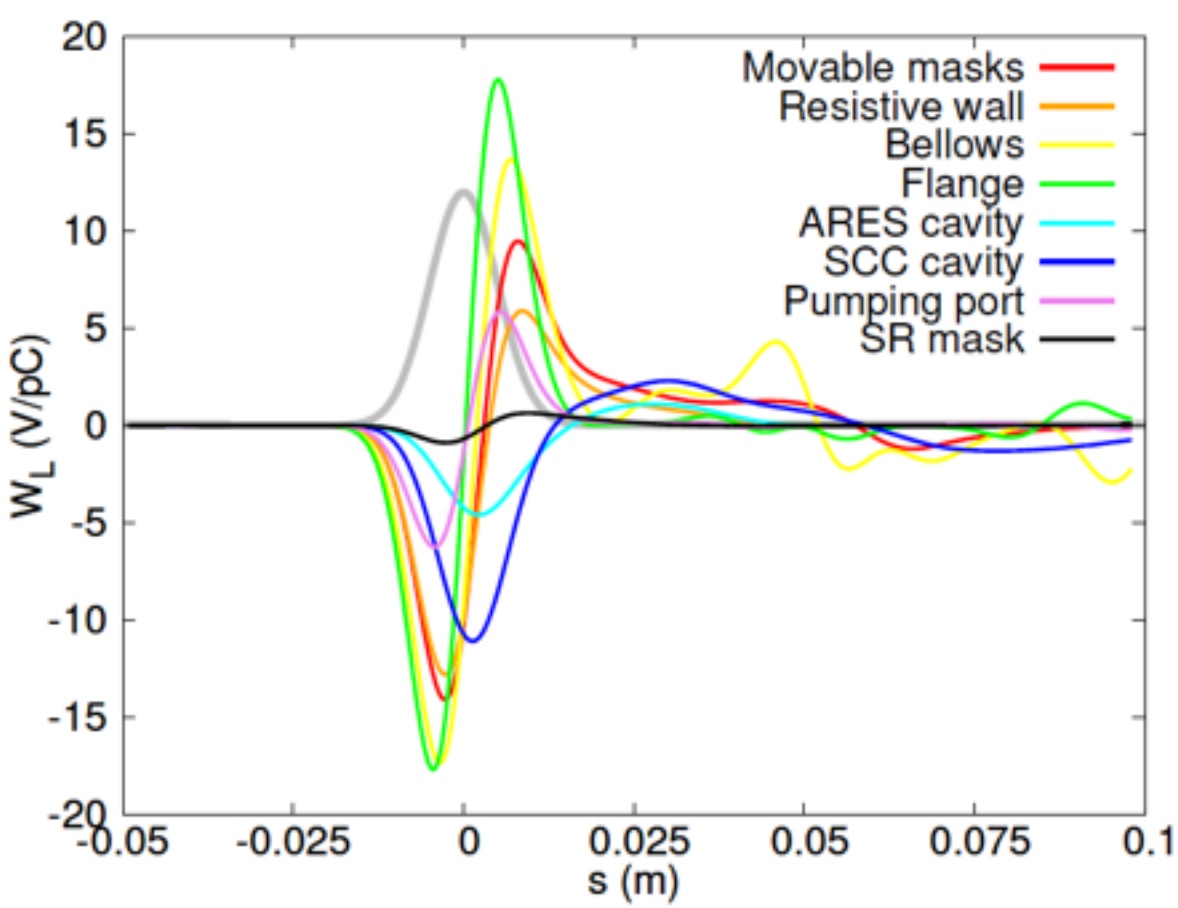


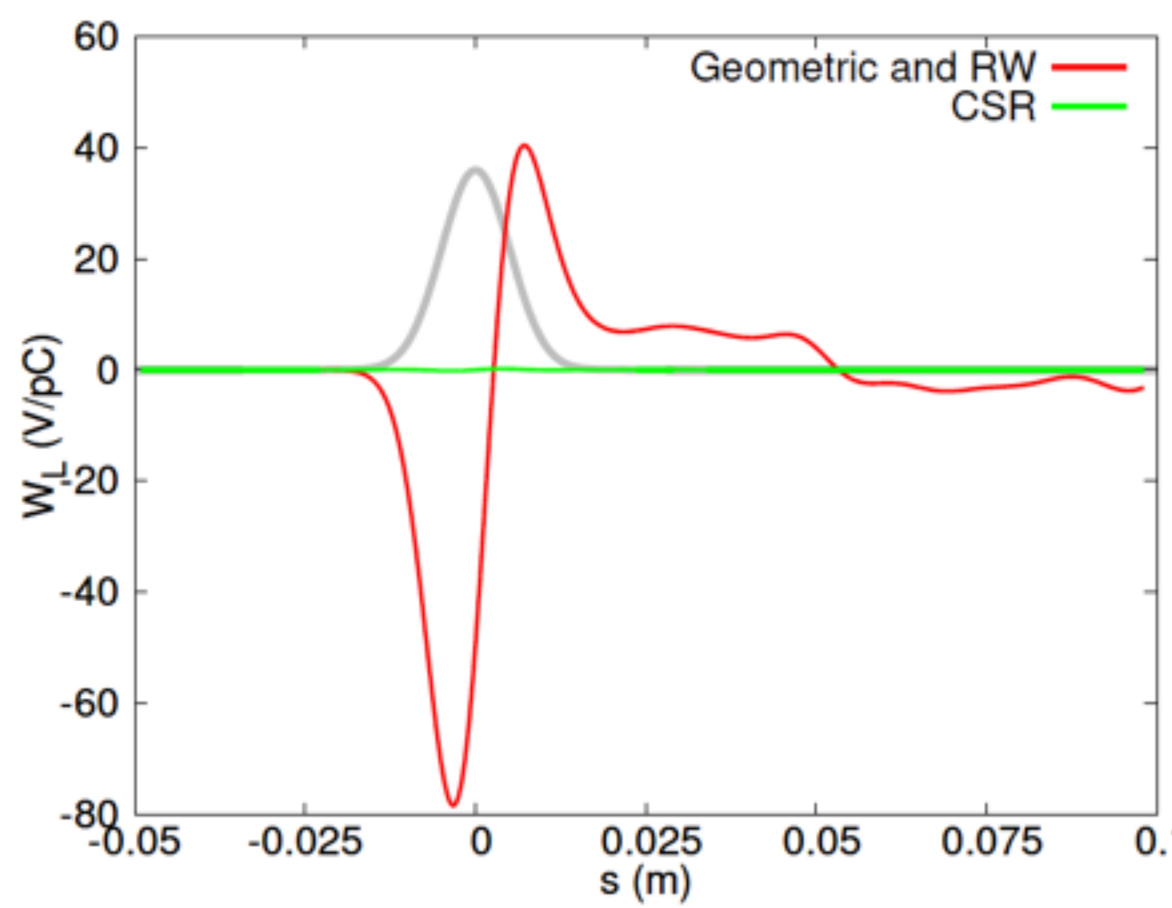


3. Impedance calculations: Results: HER

➤ **Wake potential with nominal bunch length**

- **σ_z=5mm**
- **Main sources: Movable masks, Resistive wall, Flange gaps, Bellows, SCC cavities, ARES cavities, Pumping port**
- **CSR is weak if no microbunching happens**



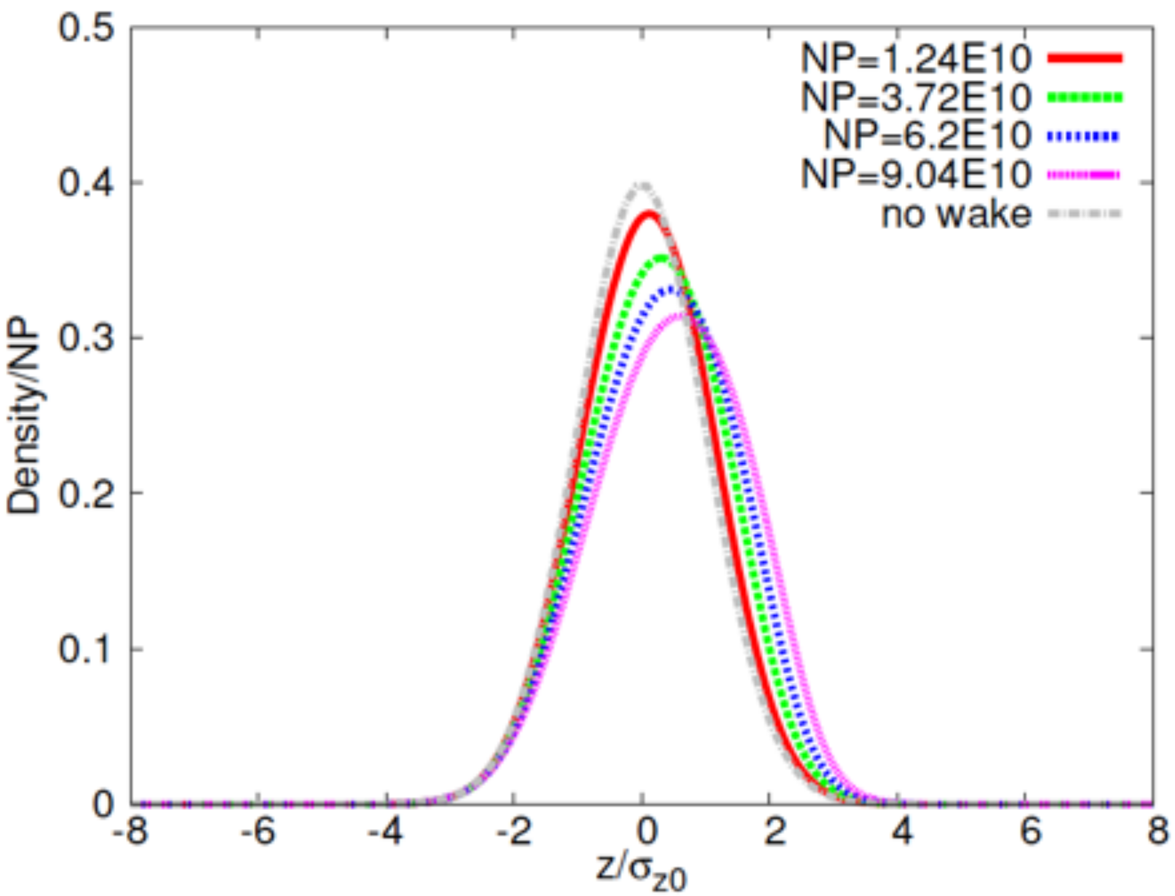


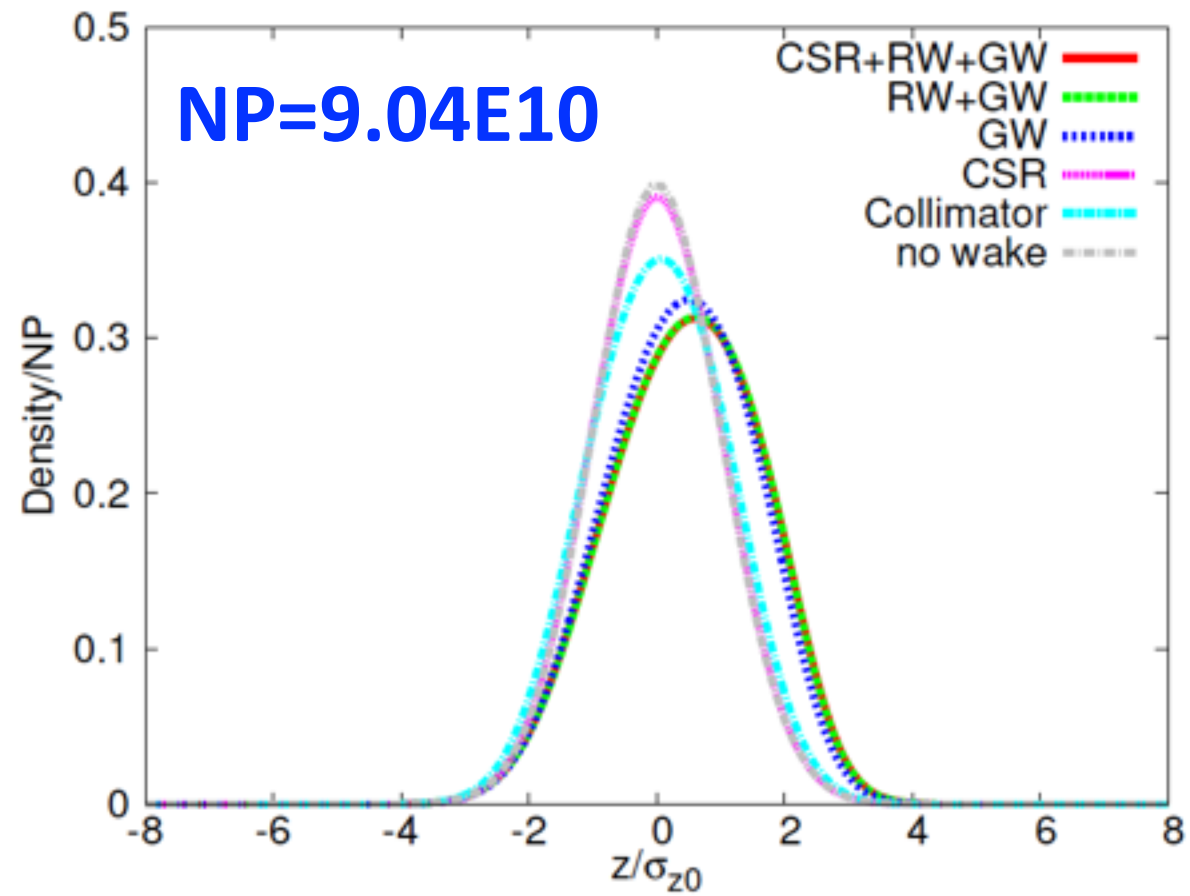
3. Single-bunch effects: Longitudinal: LER

➤ **Simulations with input of Pseudo-Green wake:**

● **BUT, pseudo-Green wakes for CSR, CWR and RW are not good choices. => To be improved.**

● **Potential-well distortion => Longitudinal beam tilt => Impact on luminosity to be evaluated**





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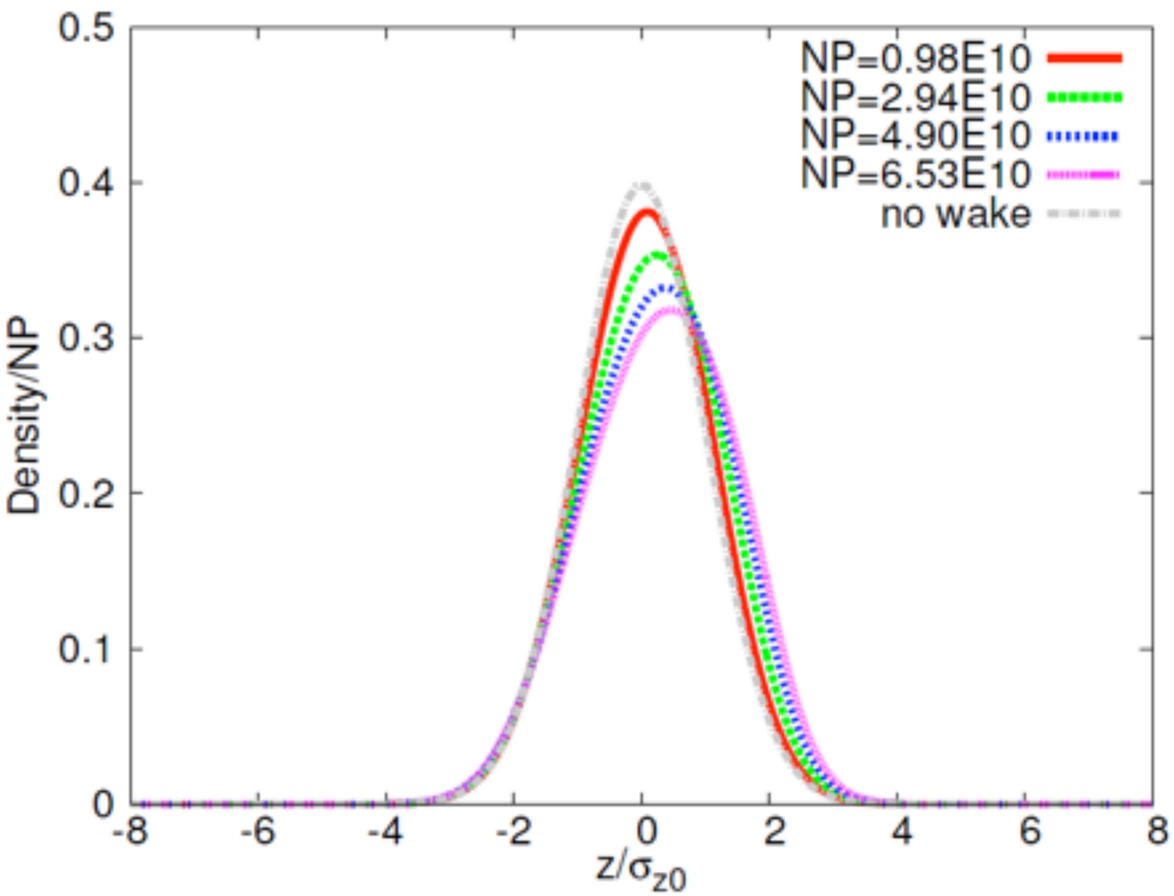
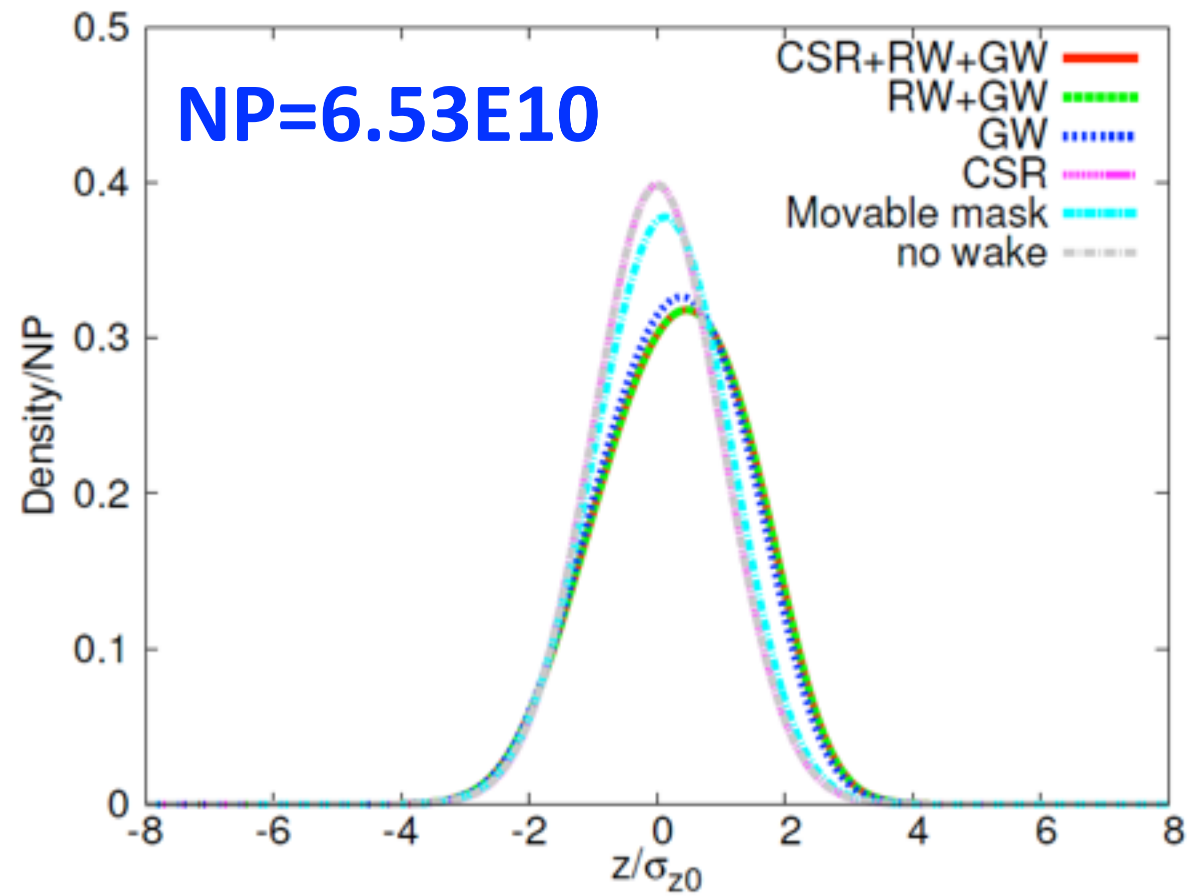


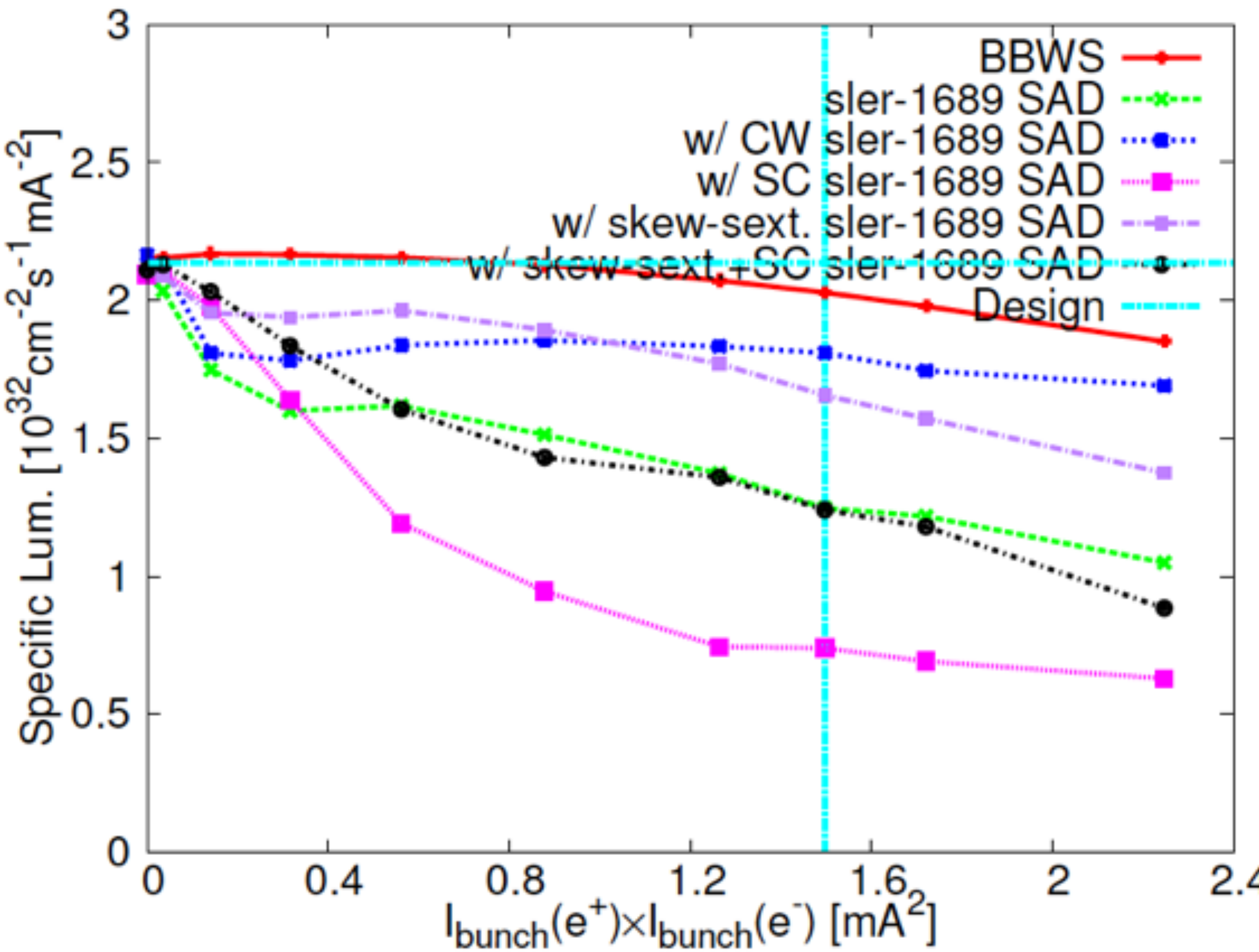


5. Space charge: LER: Luminosity

➤ **Test by inserting a map of $H=K*x^2y$ into the LER lattice**

➤ **Skew-sext. map:**

- **to cancel the nonlinear term from solenoid**
- **work well at both low and high currents**
- **interplay of SC and lattice nonlin. also mitigated partially**



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