Beam-beam simulations for FCC-ee

D. Zhou

Acknowledgements: K. Ohmi

Special beam-beam meeting for FCC-ee, Feb. 05, 2016

Outline

- **Introduction**
  - **FCC-ee baseline parameters - v2 [Ref. Dec. 9, 2015, F. Zimmermann]**
- **Beam-beam simulations**
  - **BBWS: Weak-strong, Beamstrahlung (BS) included, Crab waist (CW) modelled**
  - **Z, WW, ZH, tt**
- **Summary and discussions**

1. Baseline parameters - v2[1)]

parameter	FCC-ee crab waist (2 IPs)			
	Z	W	H	t
E_{beam} [GeV]	45.5	80	120	175
current [mA]	1450	152	30	6.6
$P_{SR,tot}$ [MW]	100	100	100	100
no. bunches	90300	5162	770	78
N_b [10^{11}]	0.33	0.6	0.8	1.7
ε_x [nm]	**0.09**	**0.27**	**0.61**	**1.3**
ε_y [pm]	**1.0**	**1.0**	**1.2**	**2.5**
β^*_x [m]	**1**	**1**	**1**	**1**
β^*_y [mm]	**2**	**2**	**2**	**2**
σ^*_y [nm]	45	45	51	72
σ^*_x [μm]	9.5	16	25	36

[1)]Ref. F. Zimmermann, FCC-ee design meeting, Dec. 9, 2015

1. Baseline parameters - v2[1)]

parameter	FCC-ee crab waist (2 IPs)			
	Z	W	H	t
RF frequency [MHz]	400	400	400	400
RF voltage [GV]	0.08	0.8	3.0	10
energy loss / turn [GeV]	0.03	0.33	1.67	7.55
circumference [km]	100	100	100	100
momentum compaction [10^{-5}]	0.7	0.7	0.7	0.7
synchrotron tune	0.015	0.037	0.056	0.075
$\sigma_{z,SR}$ [mm]	2.70	1.98	2.0	2.1
$\sigma_{z,tot}$ [mm] (w beamstr.)	4.97	3.04	2.4	2.5
$\sigma_{\delta,SR}$ [%]	0.037	0.065	0.10	0.14
$\sigma_{\delta,tot}$ [%] (w beamstr.)	0.068	0.10	0.12	0.17
hourglass factor F_{hg}	0.98	0.95	0.91	0.88

[1)] Ref. F. Zimmermann, FCC-ee design meeting, Dec. 9, 2015

1. Baseline parameters - v2[1)]

parameter	FCC-ee crab waist (2 IPs)			
	Z	W	H	t
beam-beam par. ξ_y/IP (2 IPs)	0.05,0.13	0.07,0.16	0.08, 0.14	0.08, 0.12
τ_{beam} [min] (2 IPs) [θ=1.6%]	>10000	>10000	>10000	4600
τ_{Bhabha} [min] (2 IPs)	247	109	78	63
L/IP [10^{34} cm^{-2}s^{-1}] (2 IPs)	68	19	4.9	1.3
L/IP [10^{34} cm^{-2}s^{-1}] (2 IPs) (Dmitry Shatilov)	68	21	5.2	1.4
L/IP [10^{34} cm^{-2}s^{-1}] (2 IPs) (pres. summer 2015)	200	30	9	2
L/IP [10^{34} cm^{-2}s^{-1}] (2 IPs) (baseline 2014)	28	12	6.0	1.8

[1)]Ref. F. Zimmermann, FCC-ee design meeting, Dec. 9, 2015

2. BBWS simulations

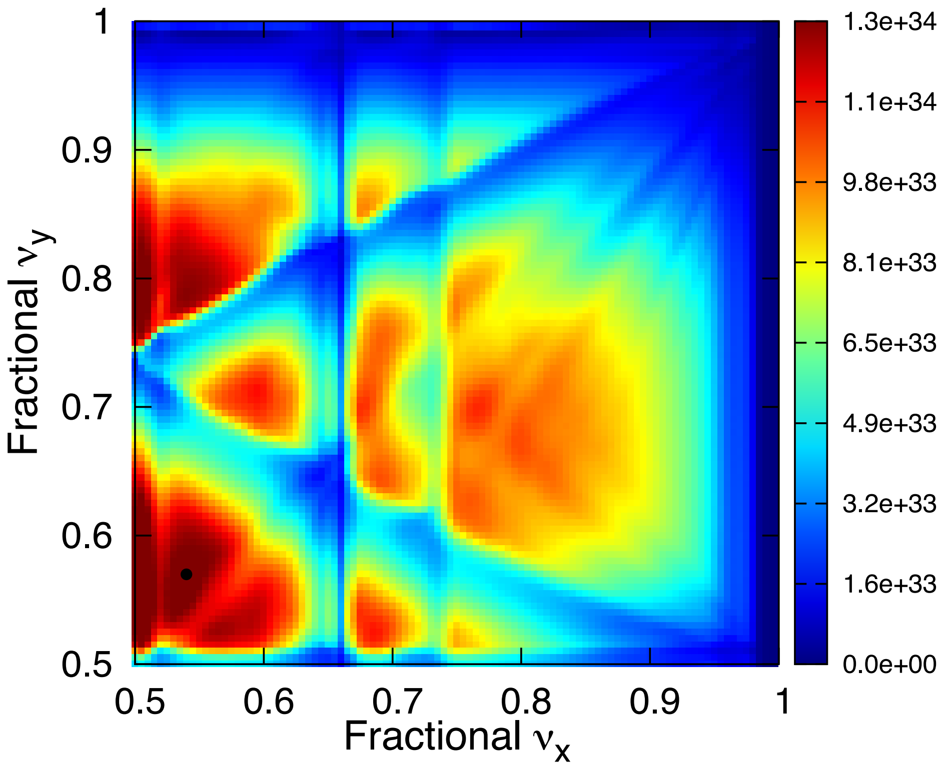
➤ **BBWS developed by K. Ohmi**

- **Weak-strong model**
- **Crab waist (CW) transform for weak beam**
- **No CW for strong beam**
- **Beamstrahlung included. For symmetric beams, the bunch length of the strong beam is also updated, but its transverse beam sizes not updated.**
- **Beam tail distribution**

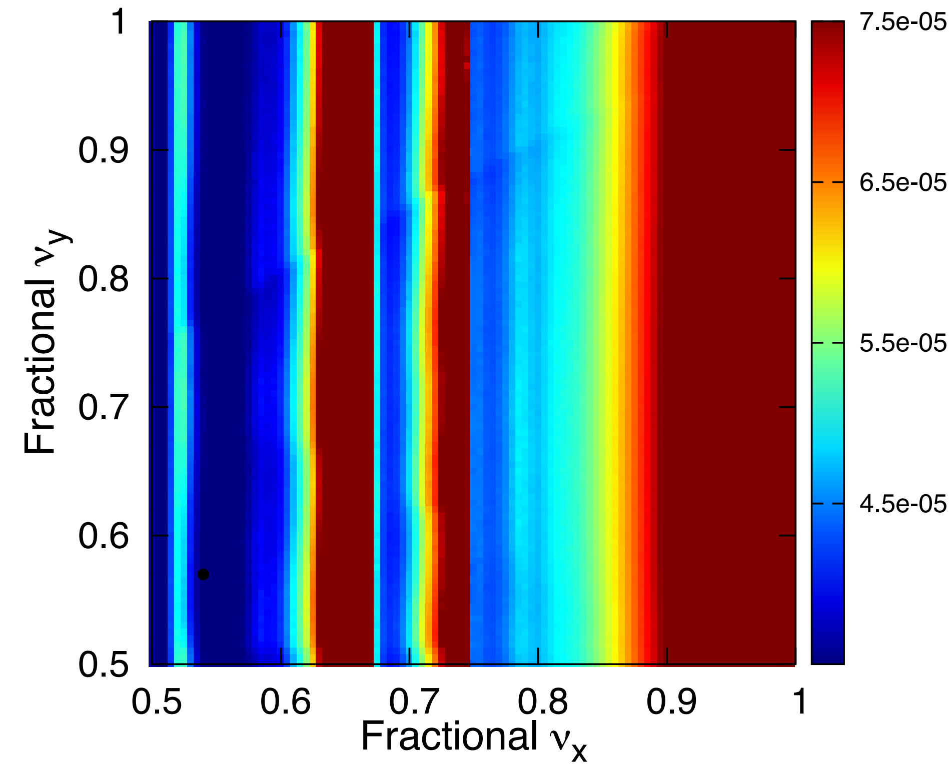
2. BBWS simulations: Lum. tune scan: tt

➤ **w/o CW** w/ BS (Black dot indicates [.54,.57]/IP)

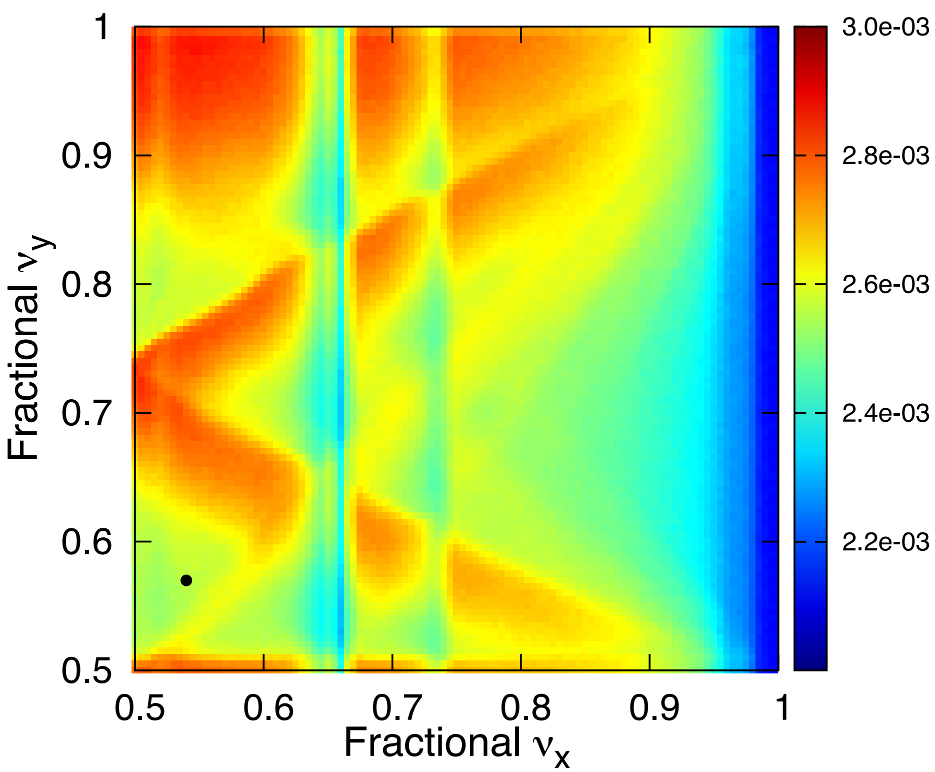
Lum.



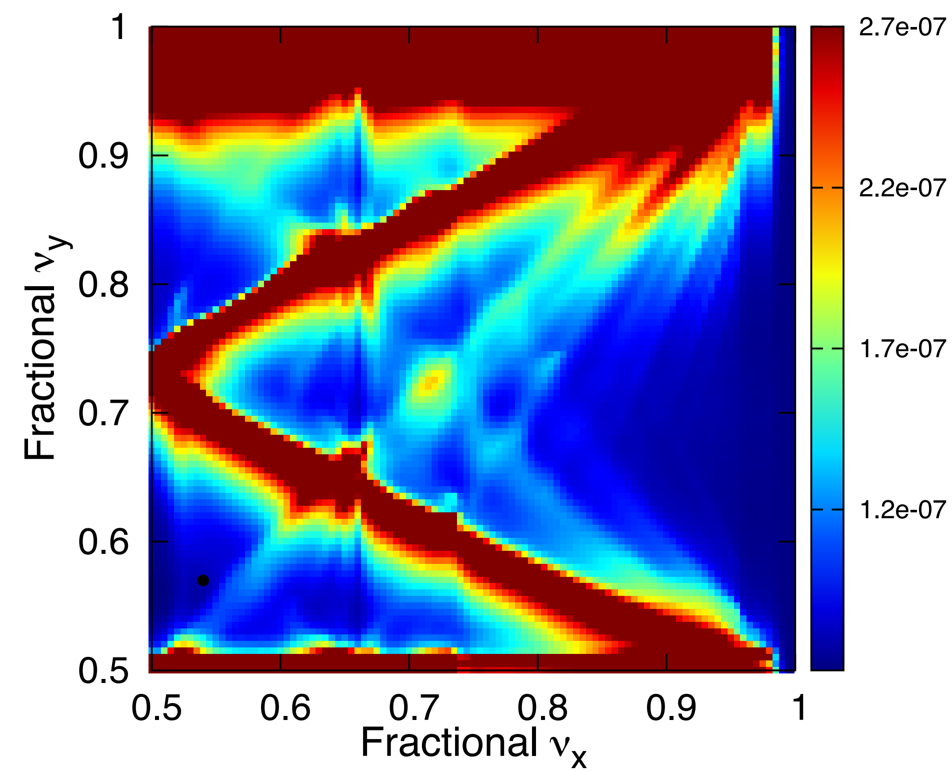
σ_x



σ_z



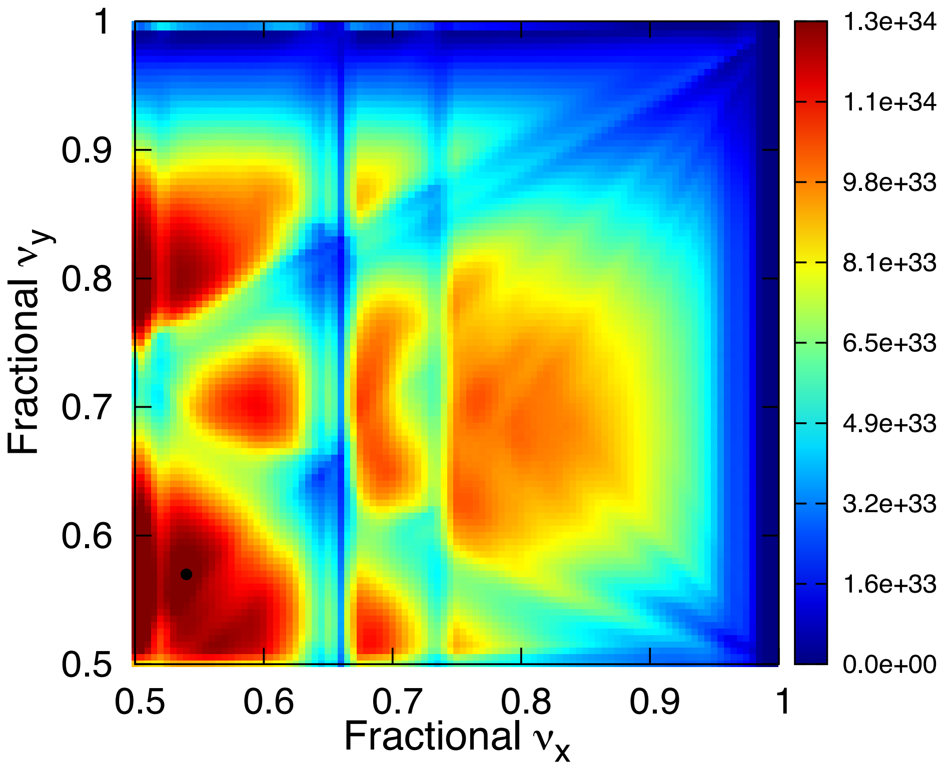
σ_y



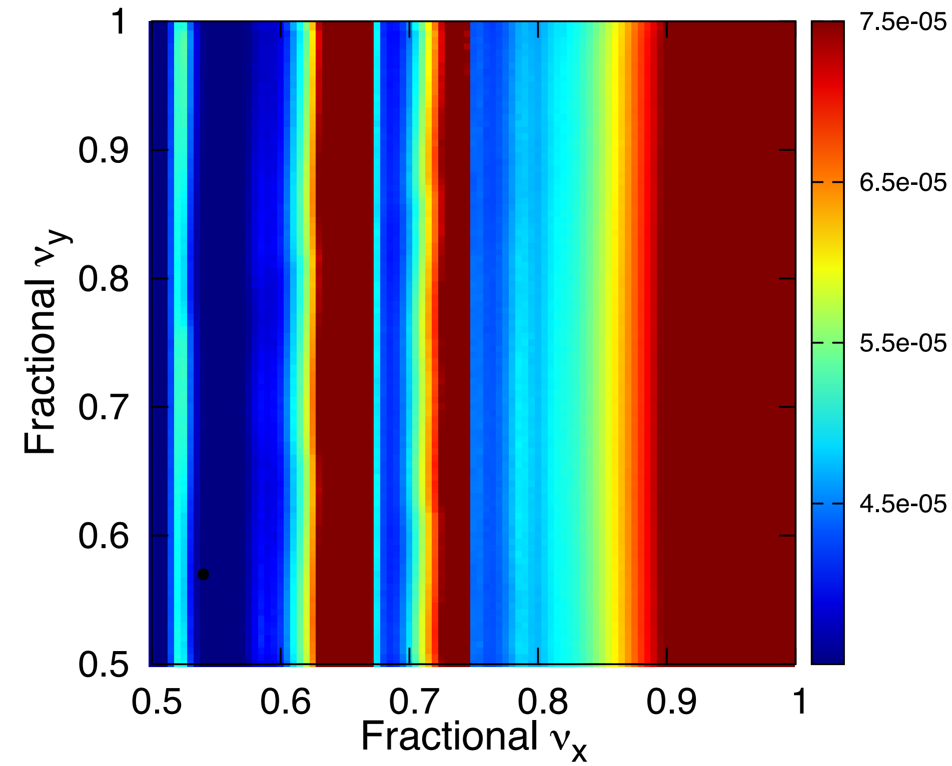
2. BBWS simulations: Lum. tune scan: tt

➤ **w/ CW** w/ BS (Black dot indicates [.54,.57]/IP)

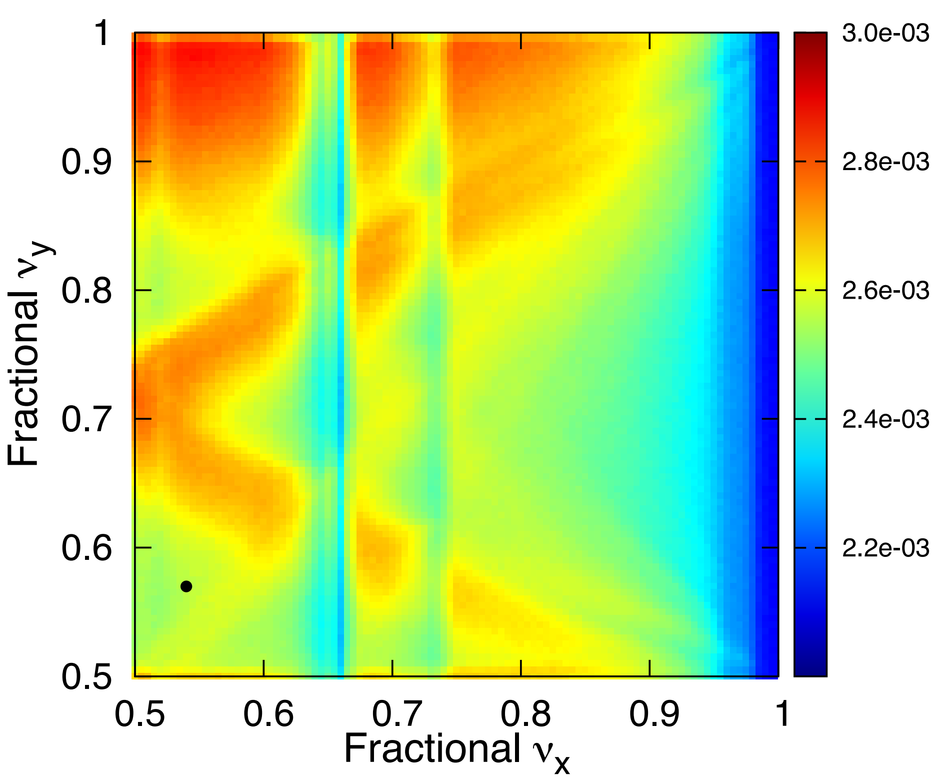
Lum.



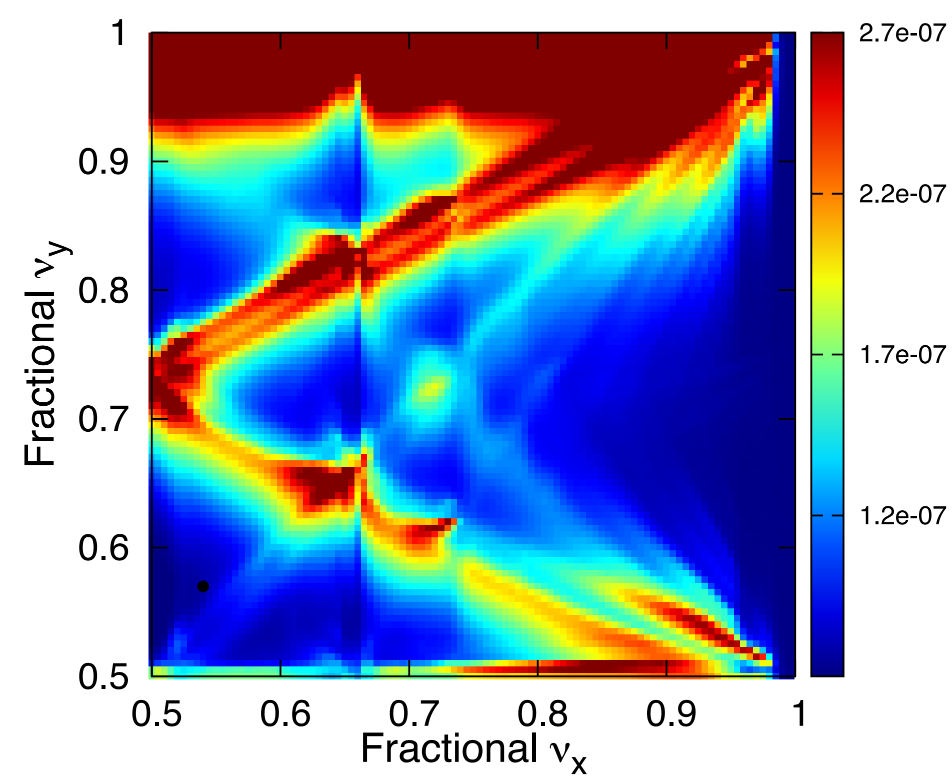
σ_x



σ_z



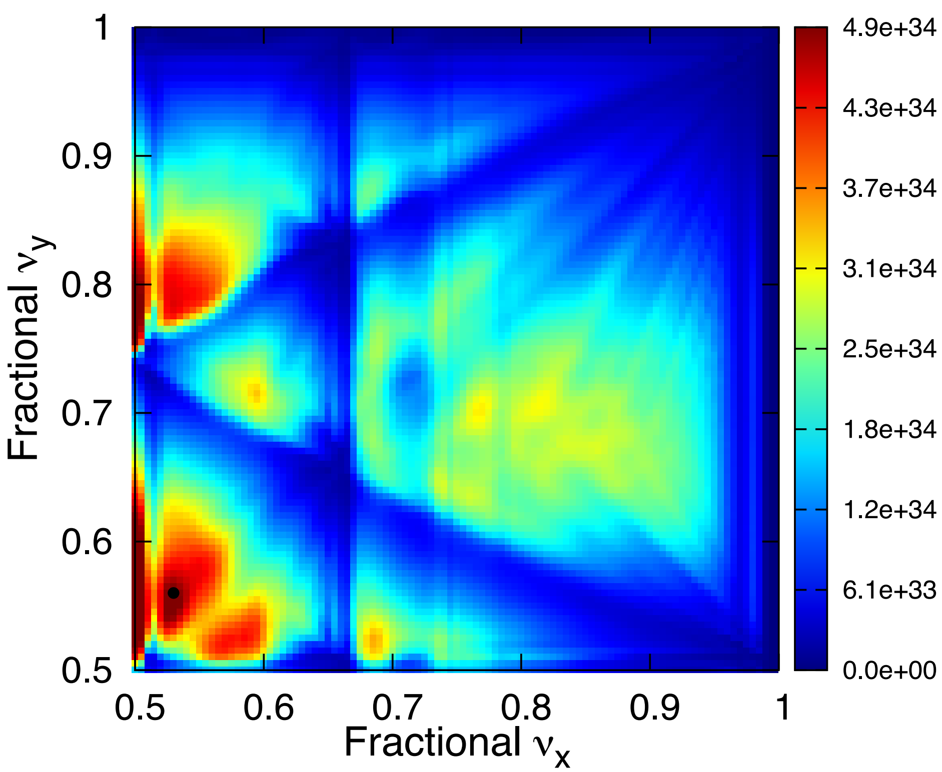
σ_y



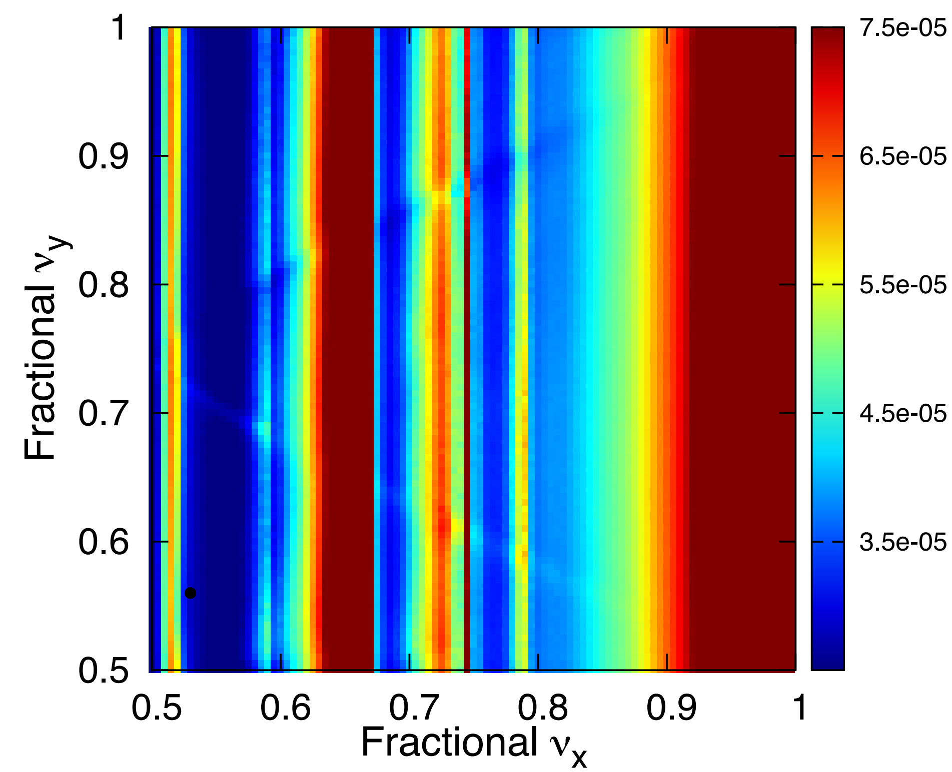
2. BBWS simulations: Lum. tune scan: ZH

➤ w/o CW w/ BS (Black dot indicates [.53,.56]/IP)

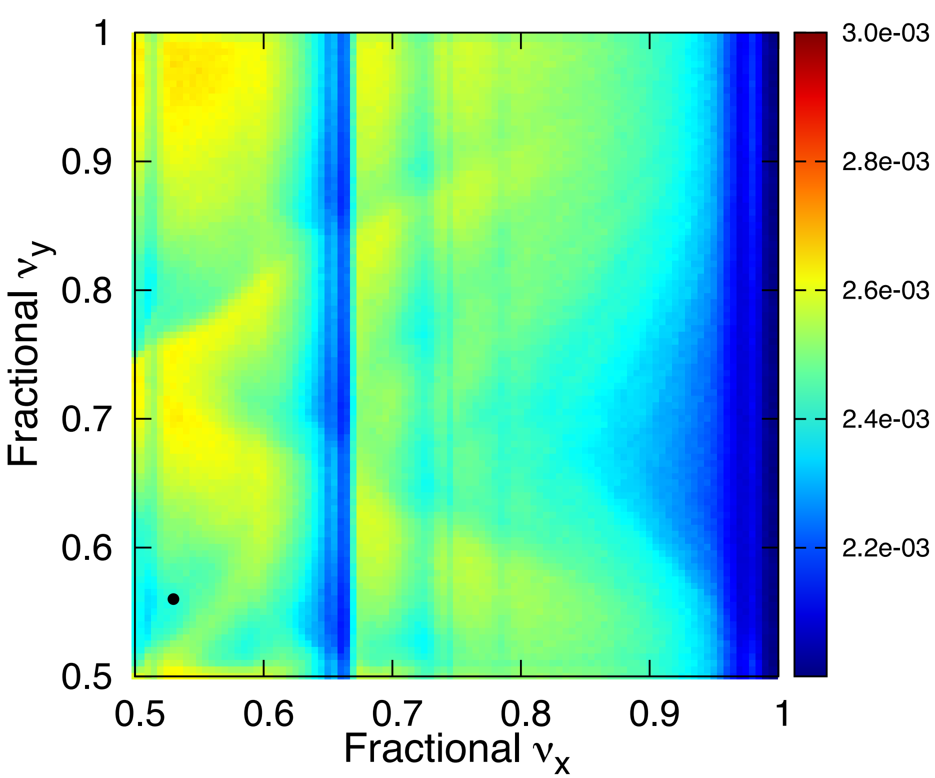
Lum.



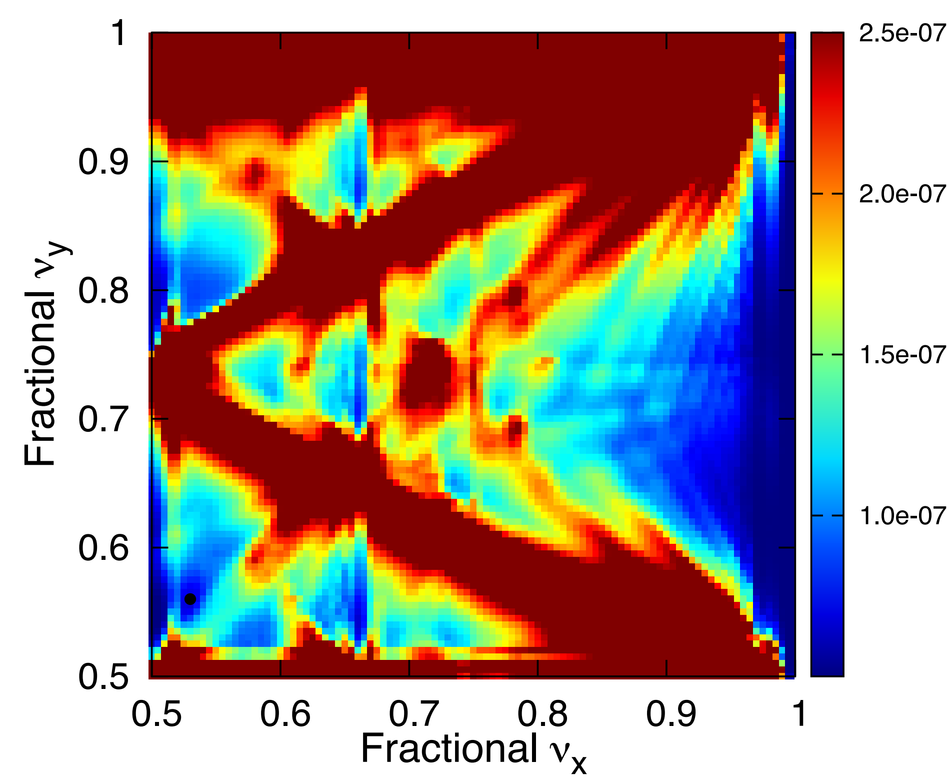
σ_x



σ_z

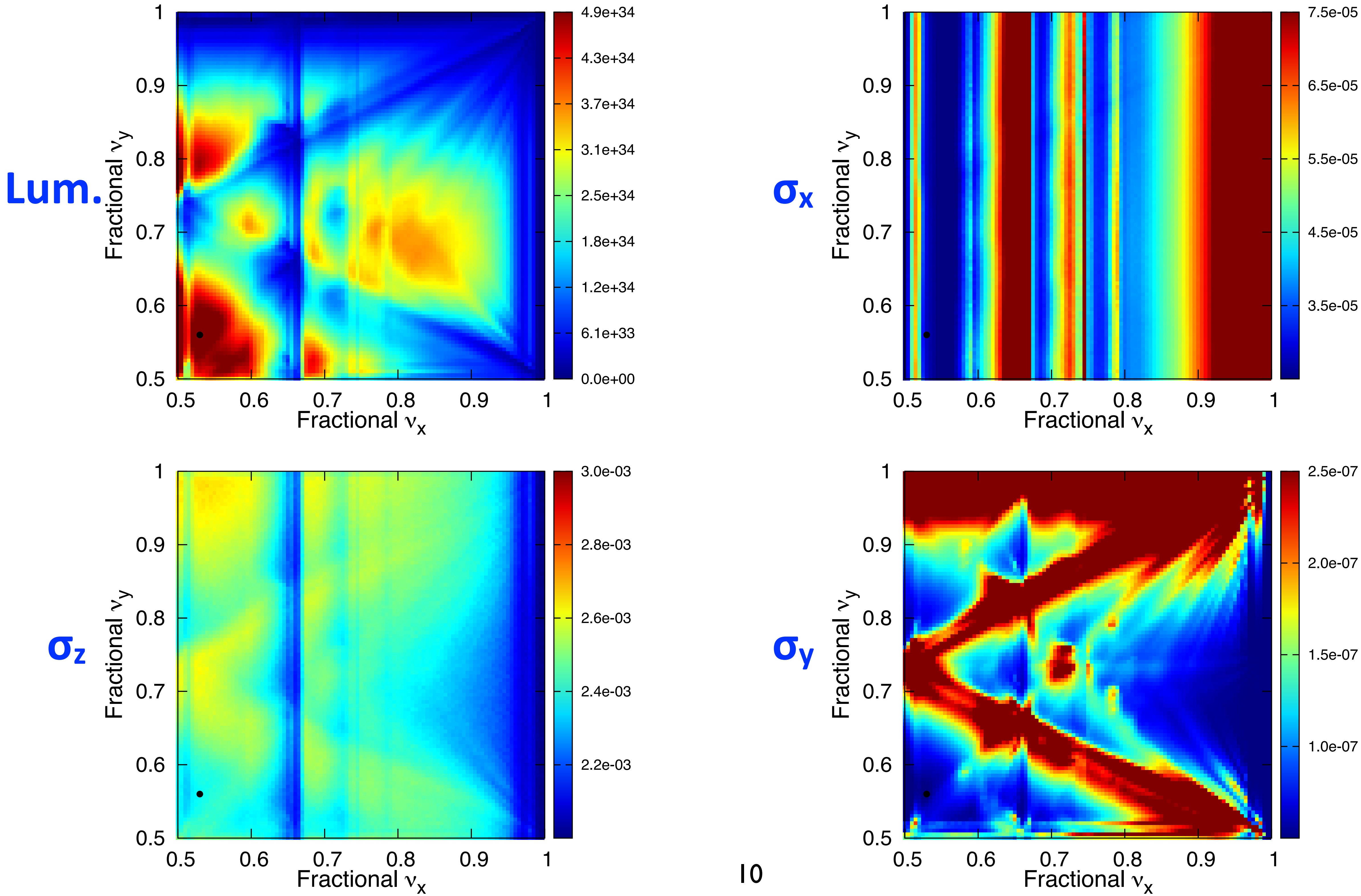


σ_y



2. BBWS simulations: Lum. tune scan: ZH

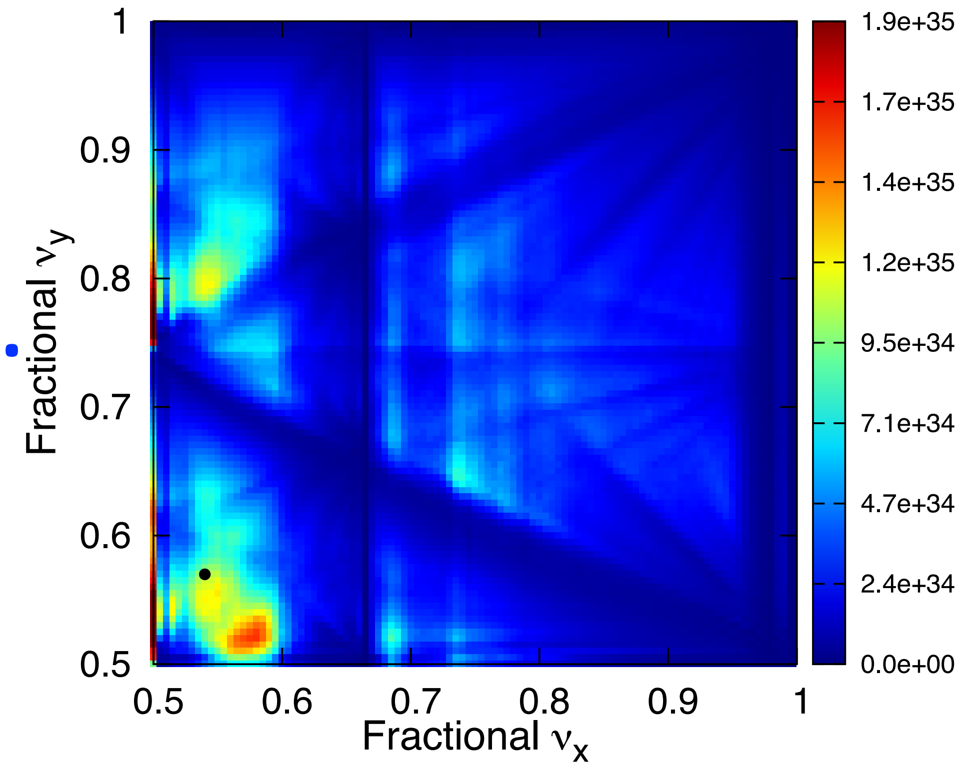
➤ **w/ CW w/ BS (Black dot indicates [.53,.56]/IP)**



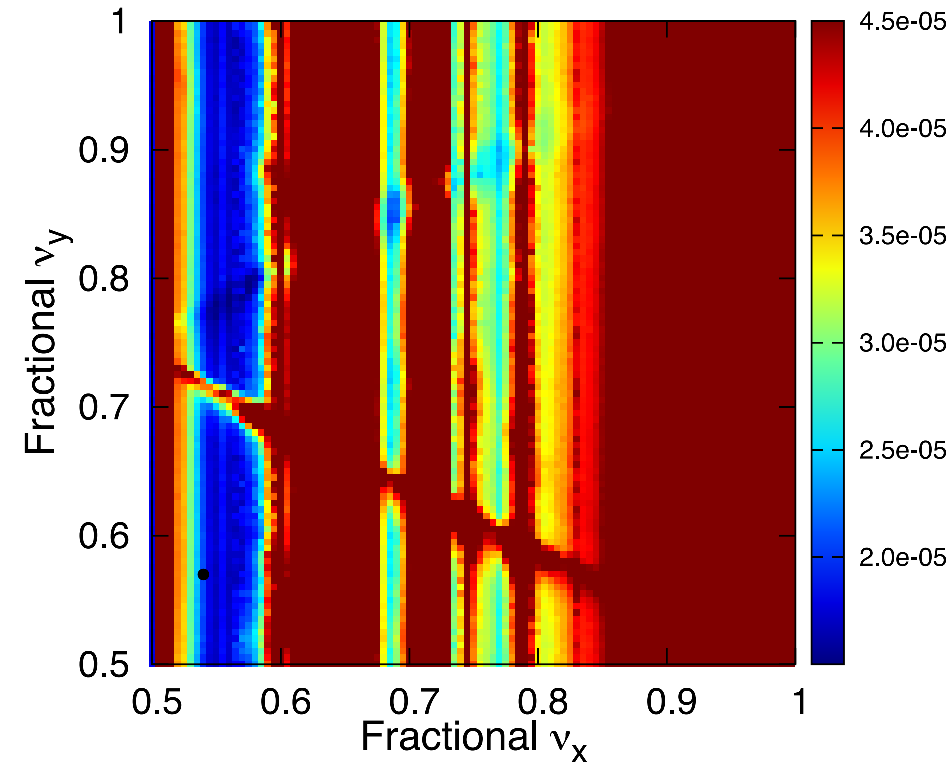
2. BBWS simulations: Lum. tune scan: WW

➤ w/o CW w/ BS (Black dot indicates [.54,.57]/IP)

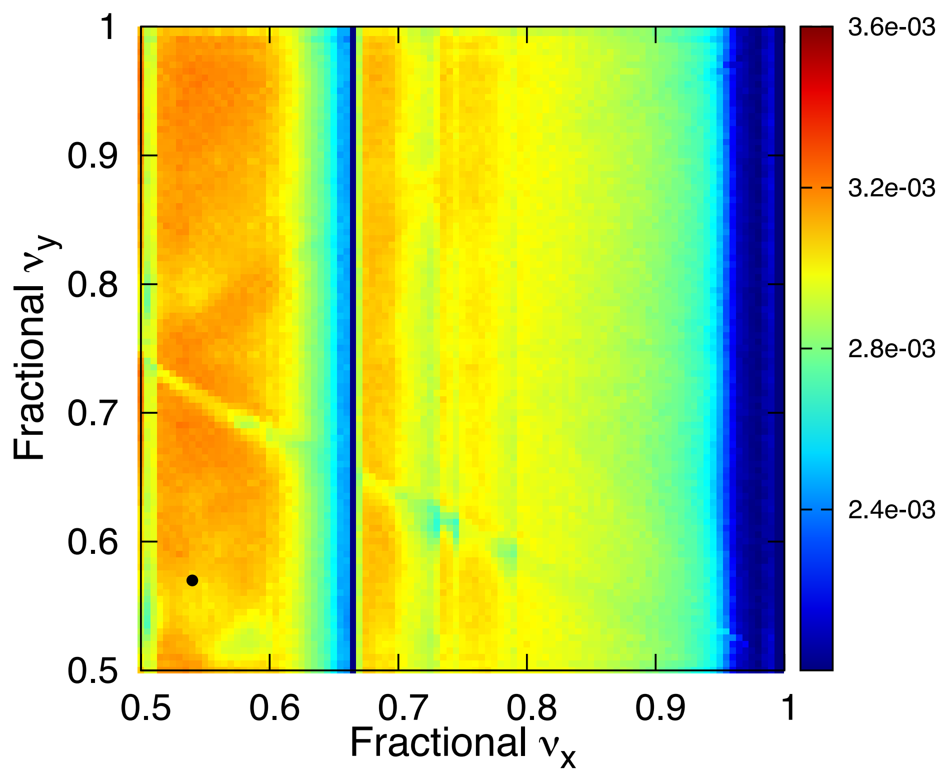
Lum.



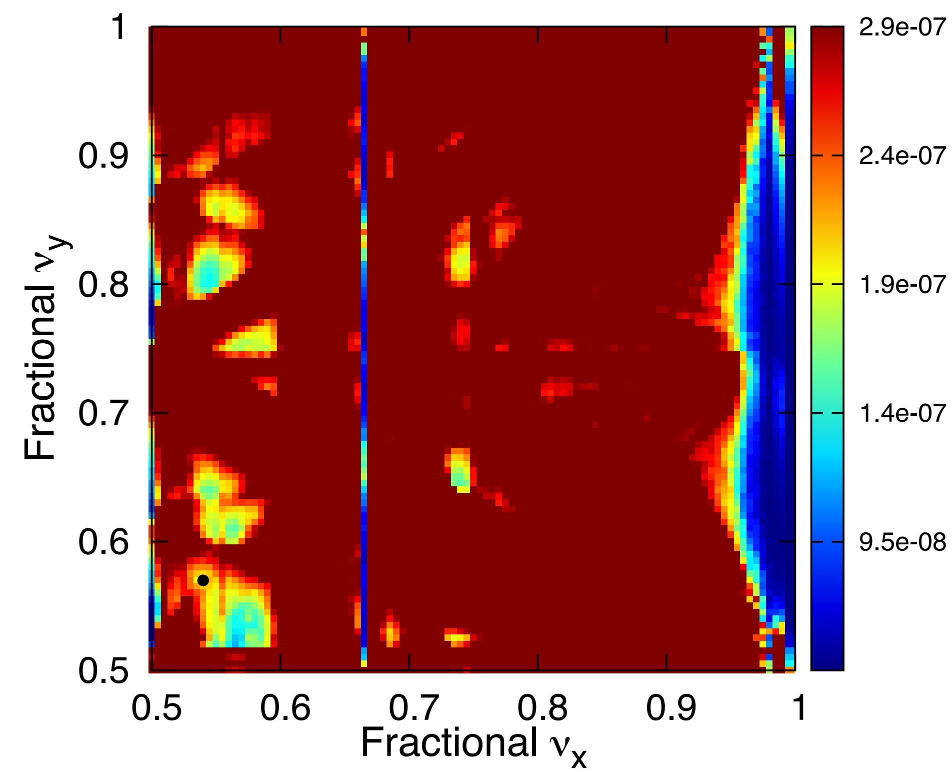
σ_x



σ_z



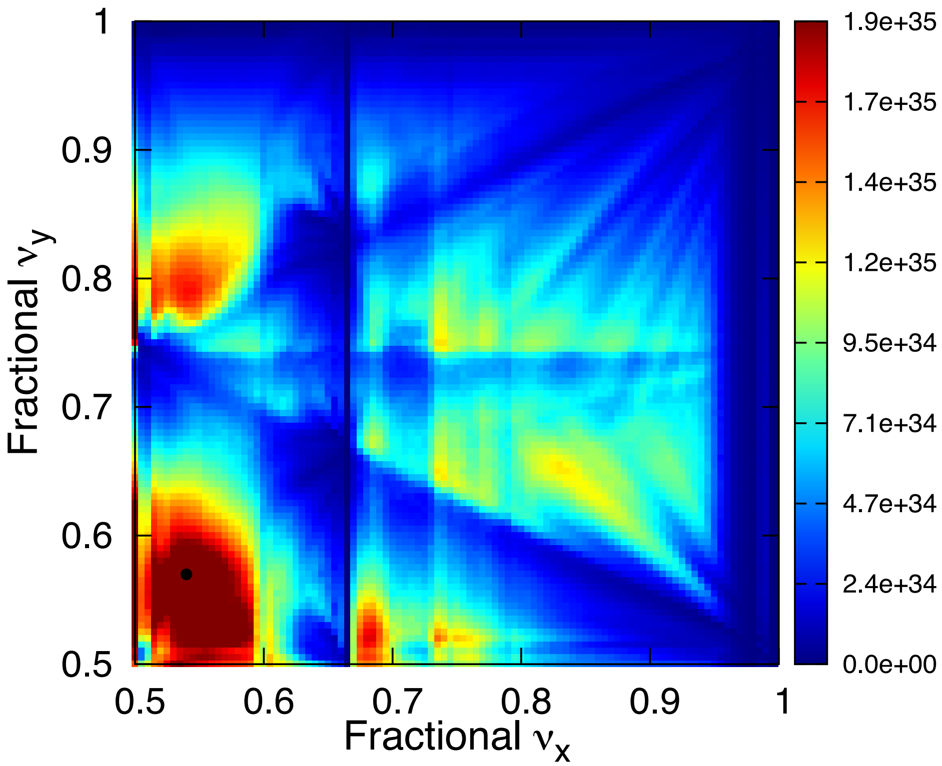
σ_y



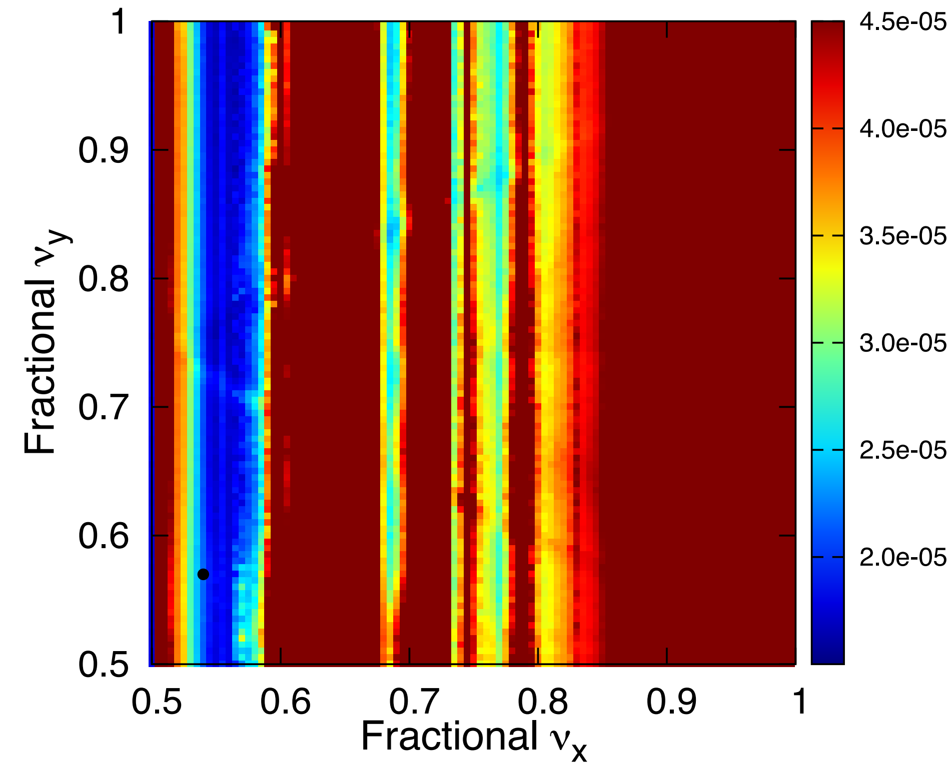
2. BBWS simulations: Lum. tune scan: WW

➤ w/ CW w/ BS (Black dot indicates [.54,.57]/IP)

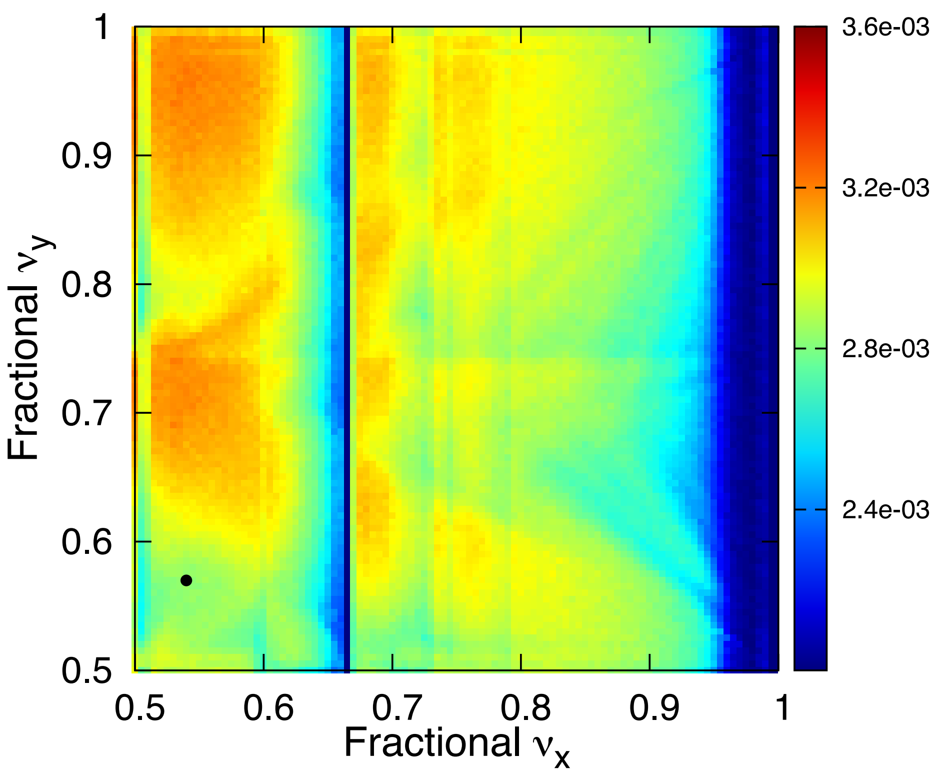
Lum.



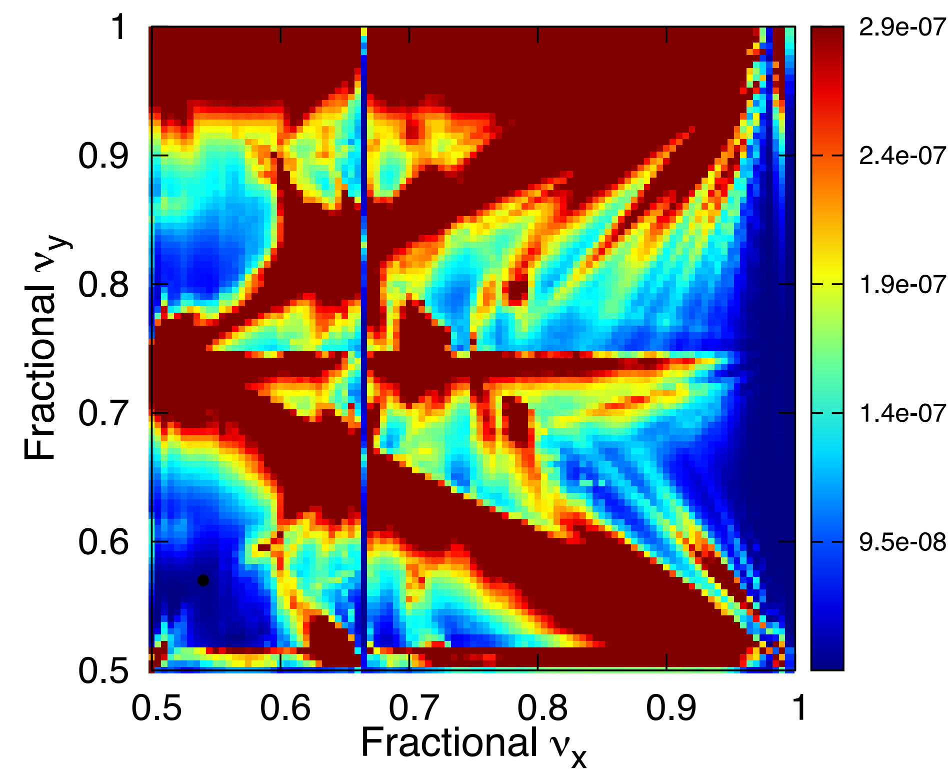
σ_x



σ_z

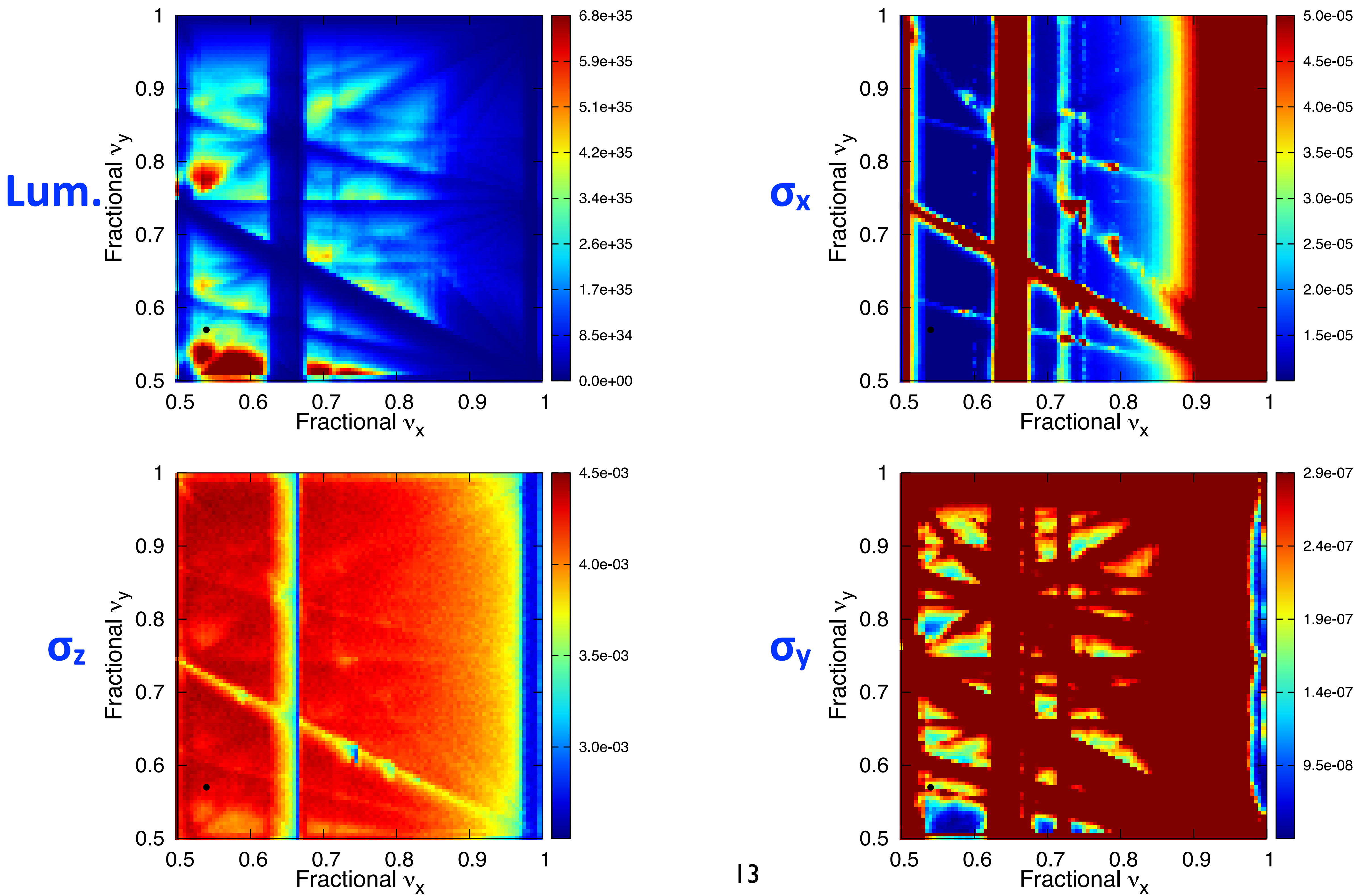


σ_y



2. BBWS simulations: Lum. tune scan: Z

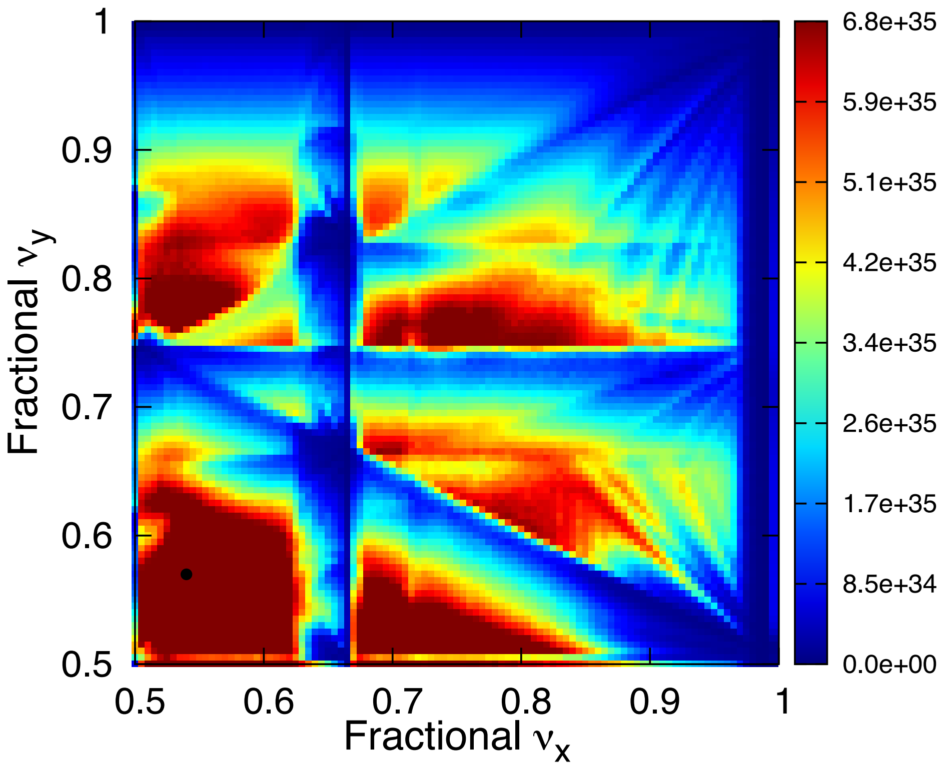
- ➤ **w/o CW** w/ BS (Black dot indicates [.54,.57]/IP)



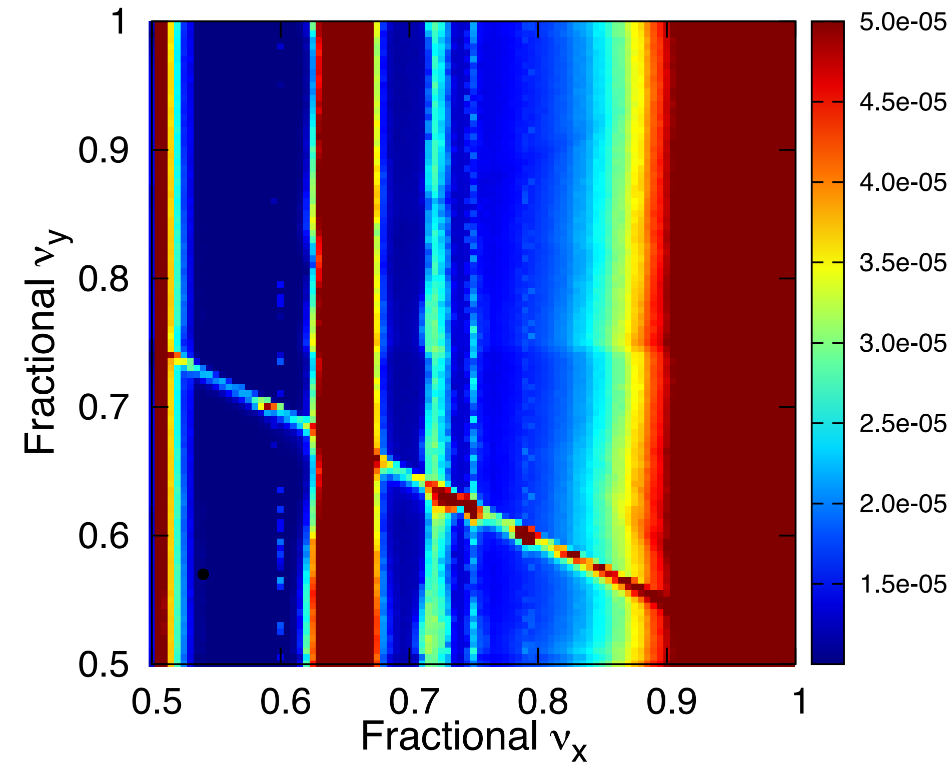
2. BBWS simulations: Lum. tune scan: Z

➤ w/ CW w/ BS (Black dot indicates [.54,.57]/IP)

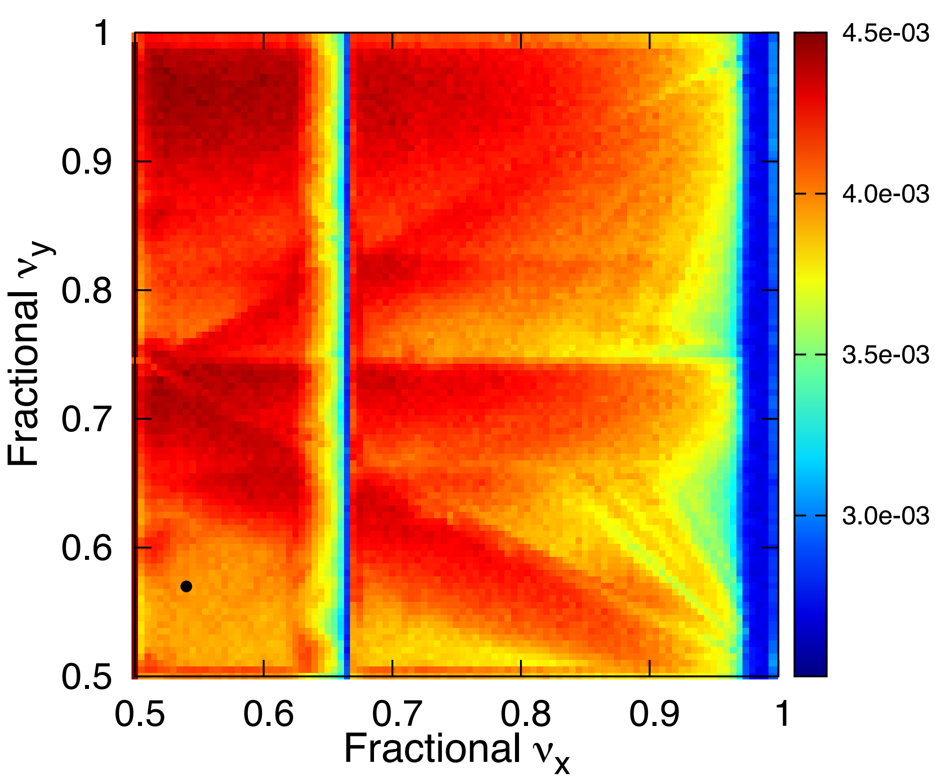
Lum.



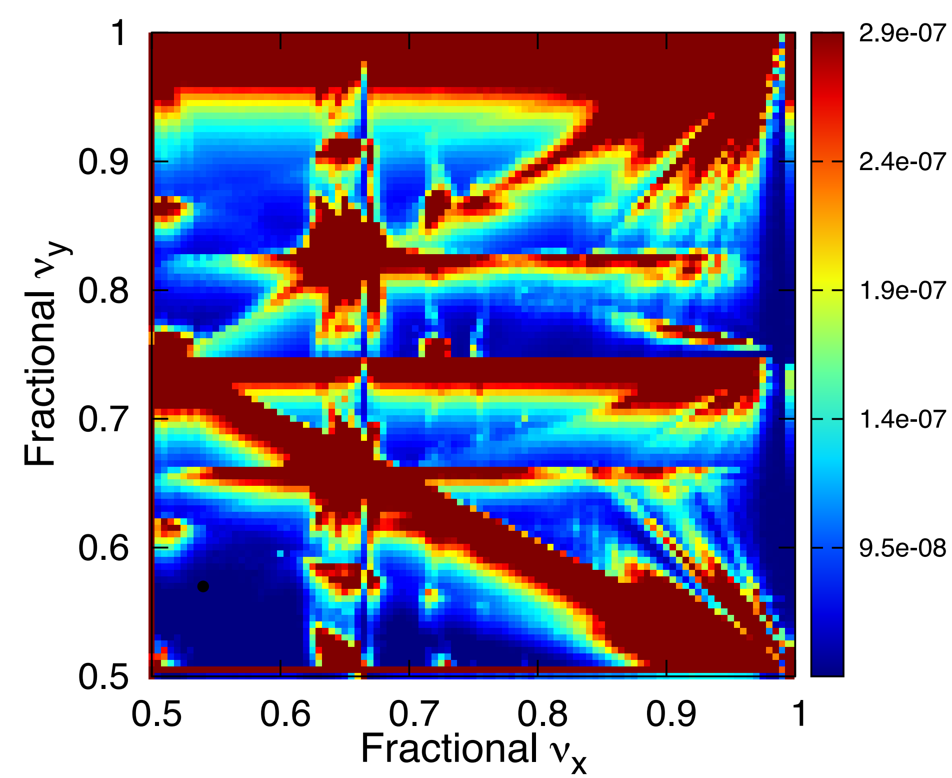
σ_x



σ_z

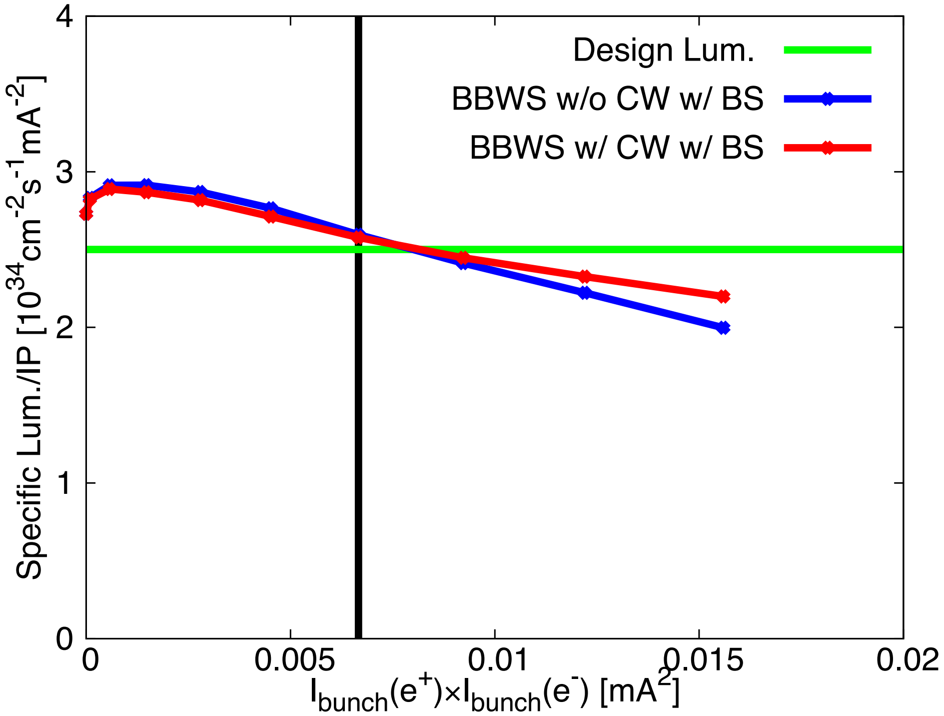


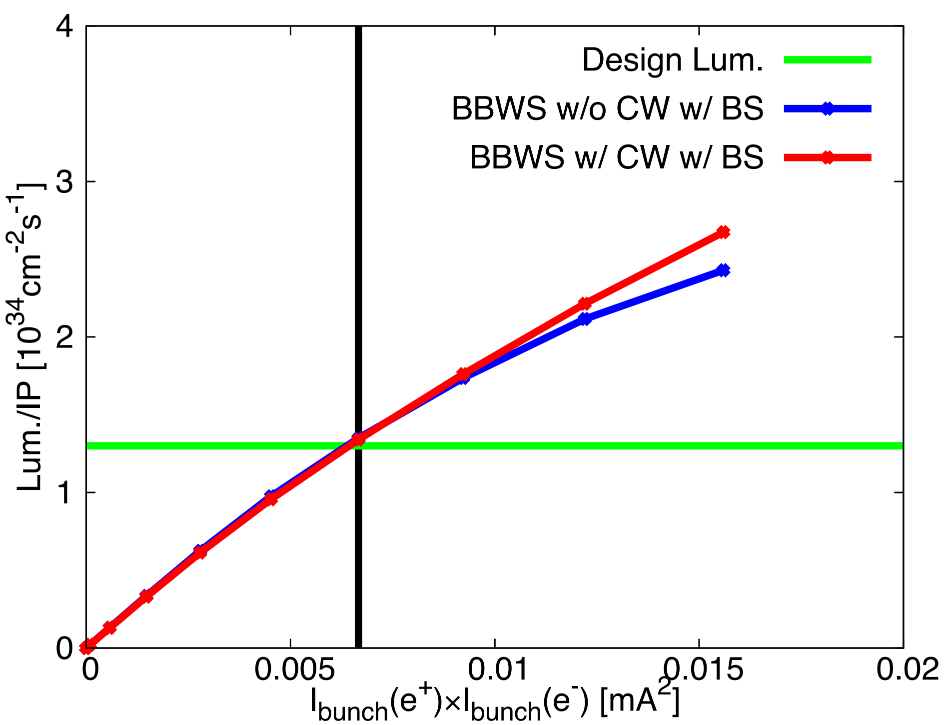
σ_y



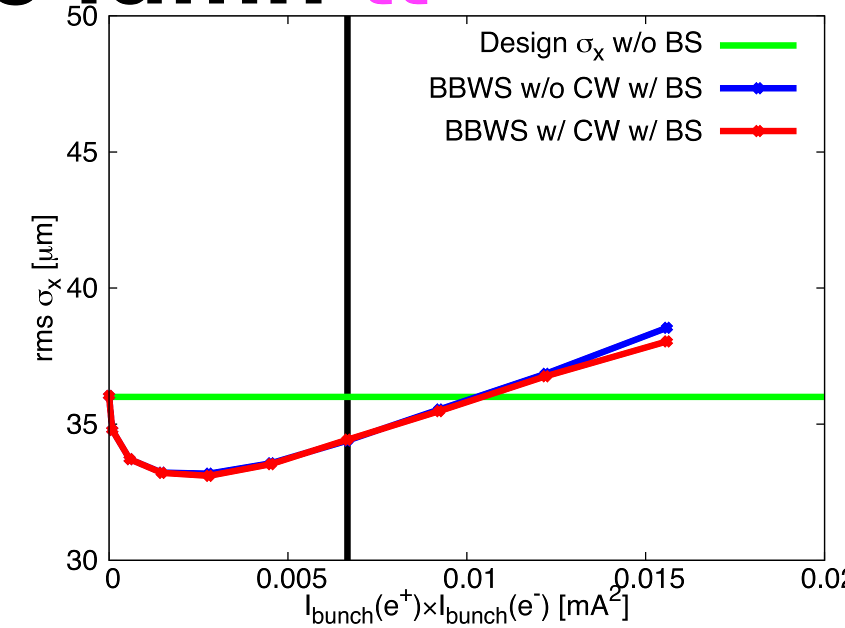
2. BBWS simulations: Specific lum.: tt

➤ [.54,.57]/IP

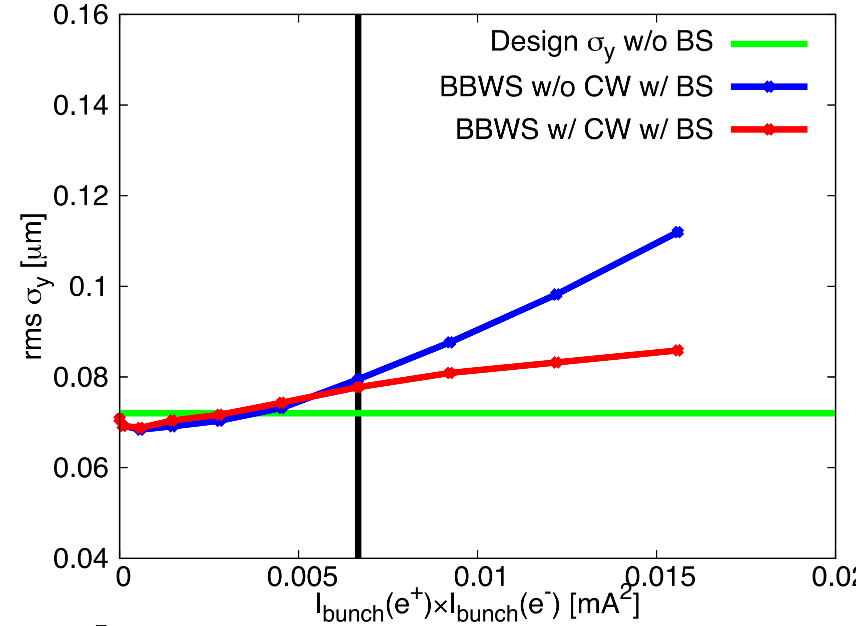




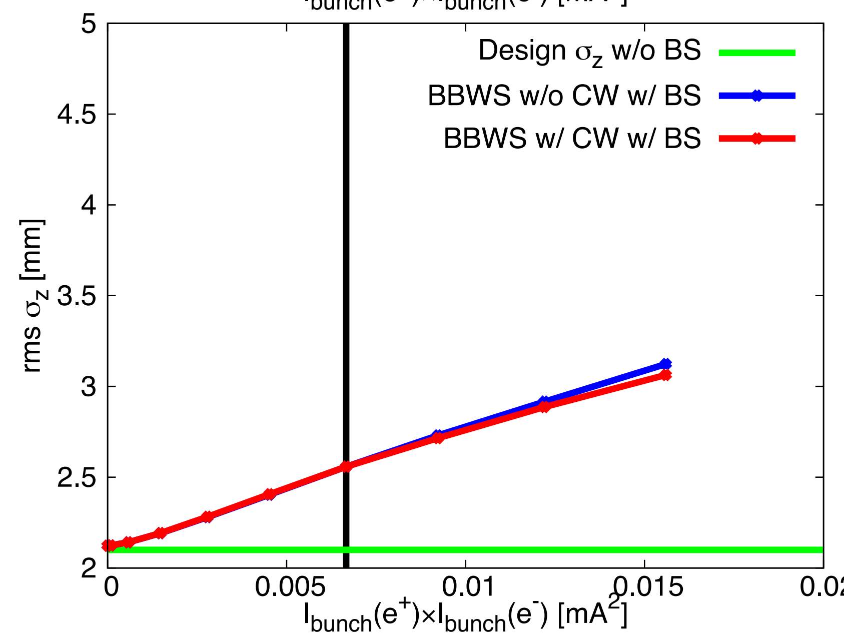
σ_x



σ_y

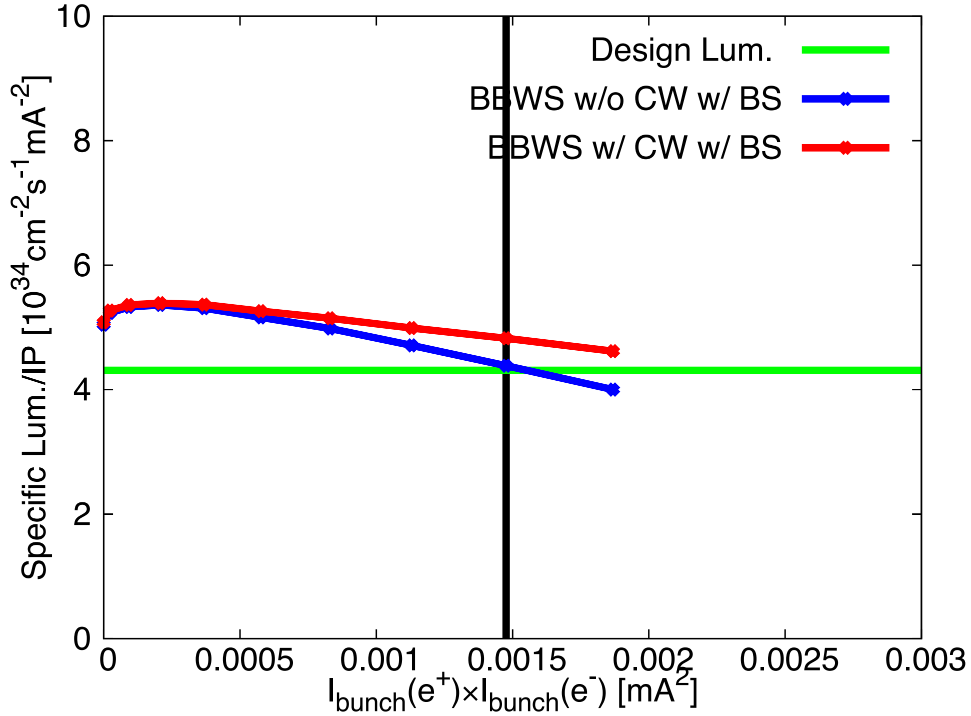


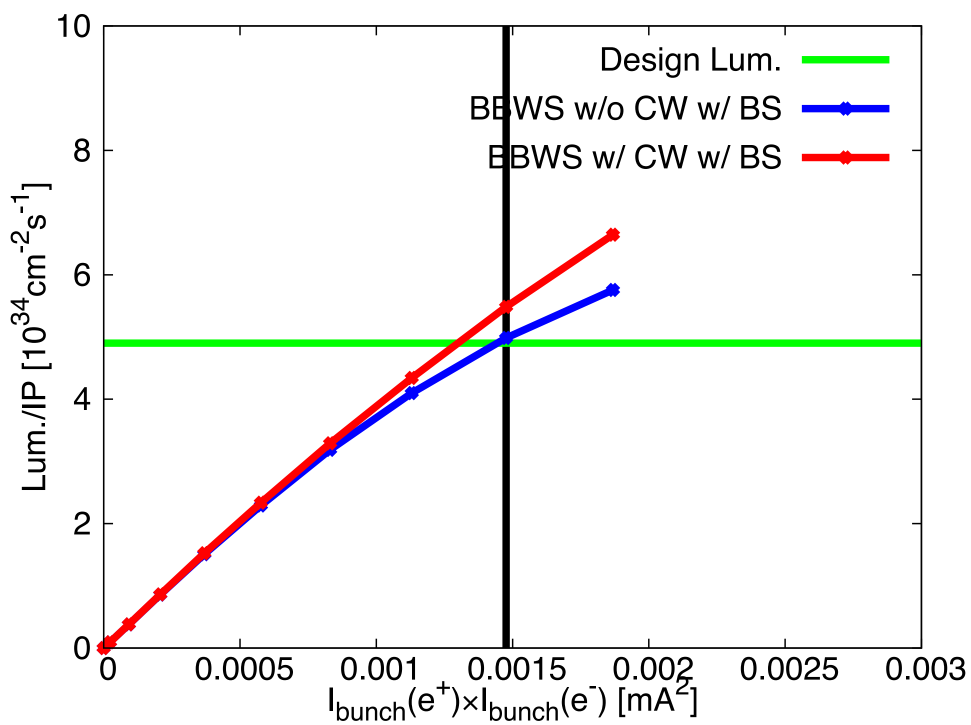
σ_z



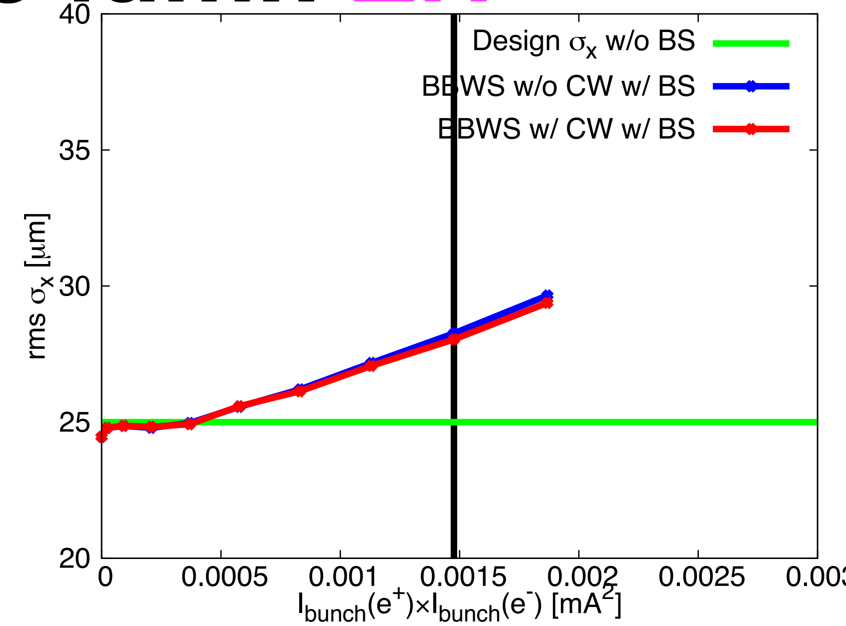
2. BBWS simulations: Specific lum.: ZH

➤ [.53,.56]/IP

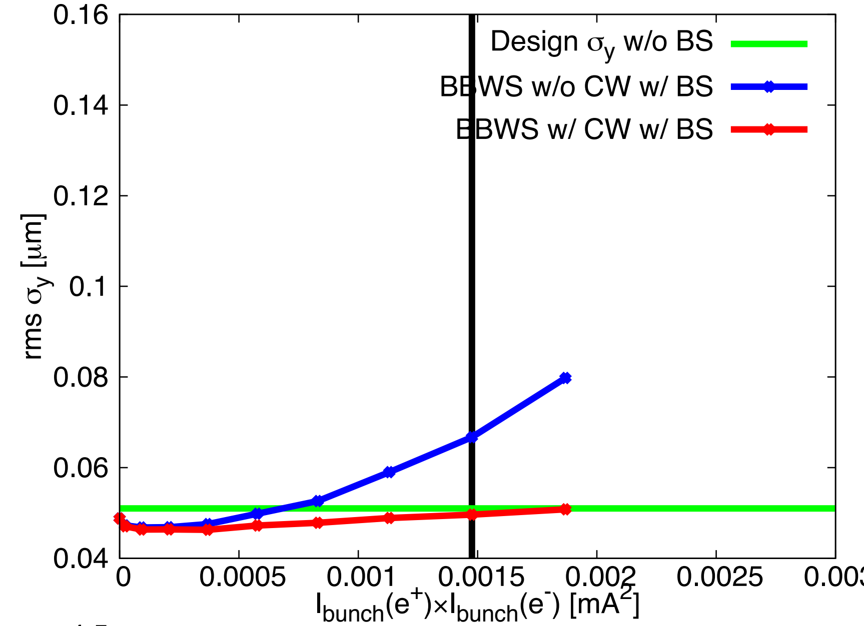




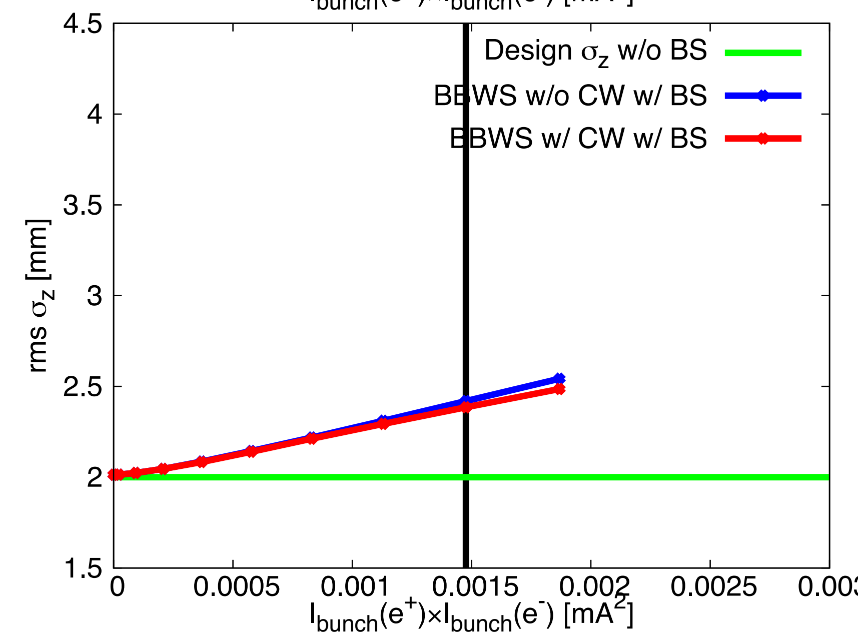
σ_x



σ_y

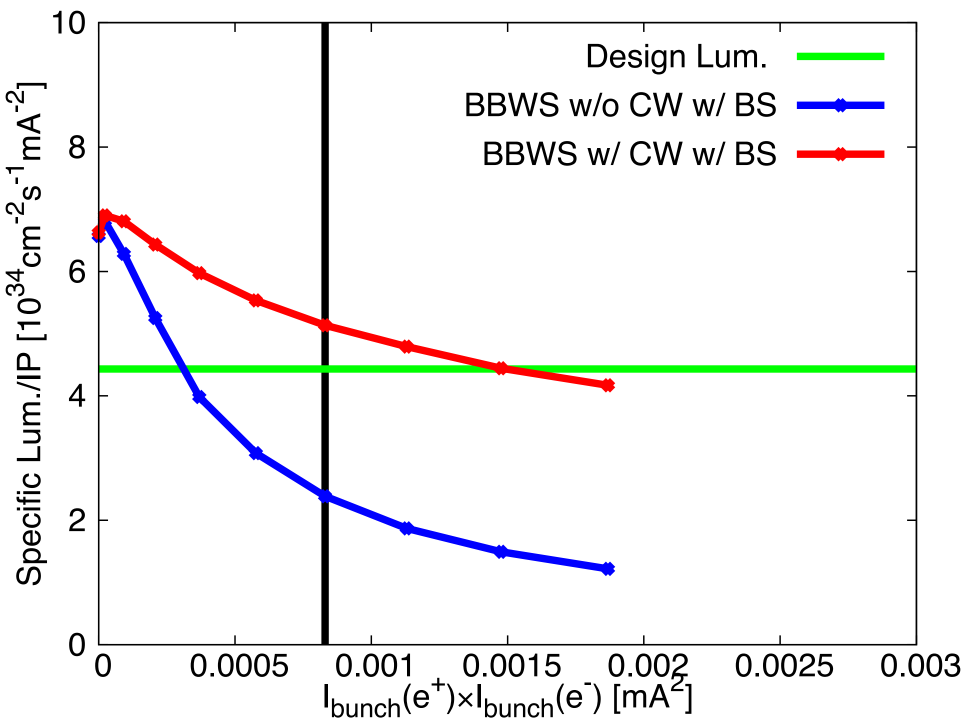


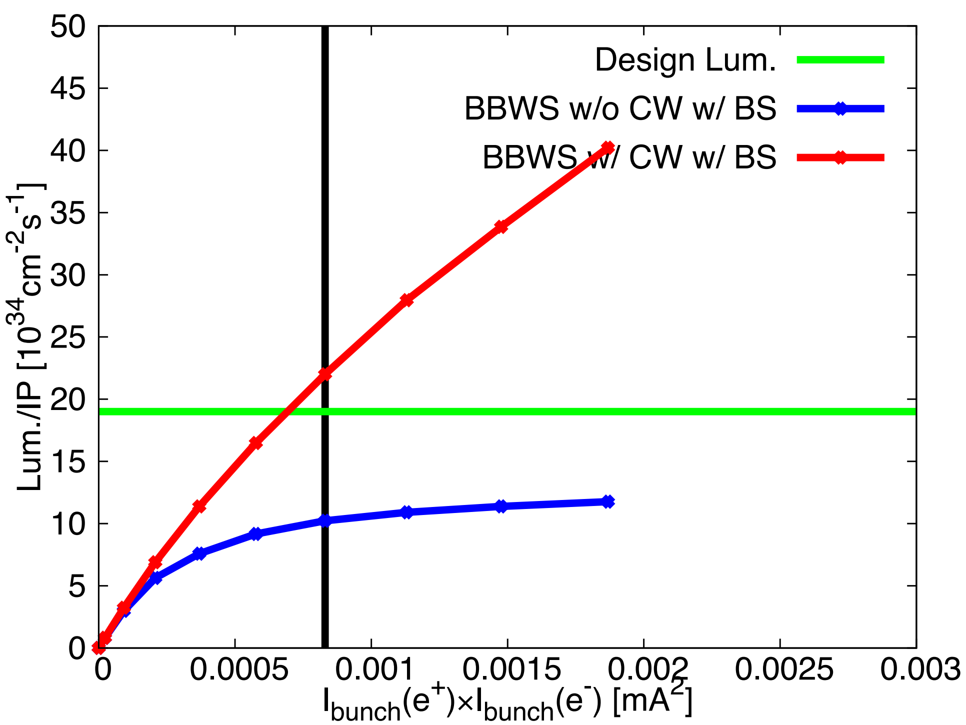
σ_z

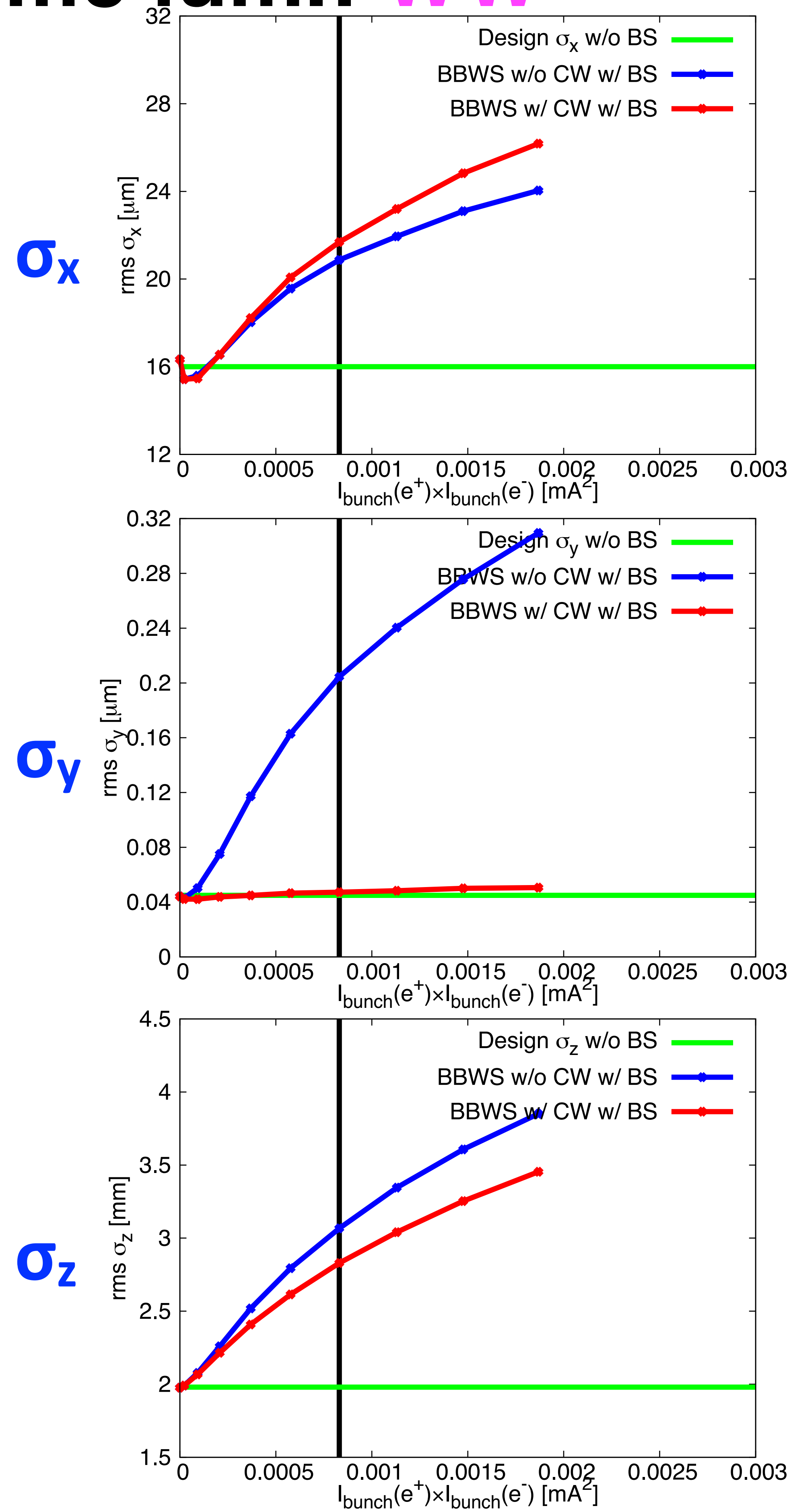


2. BBWS simulations: Specific lum.: WW

- [.54,.57]/IP

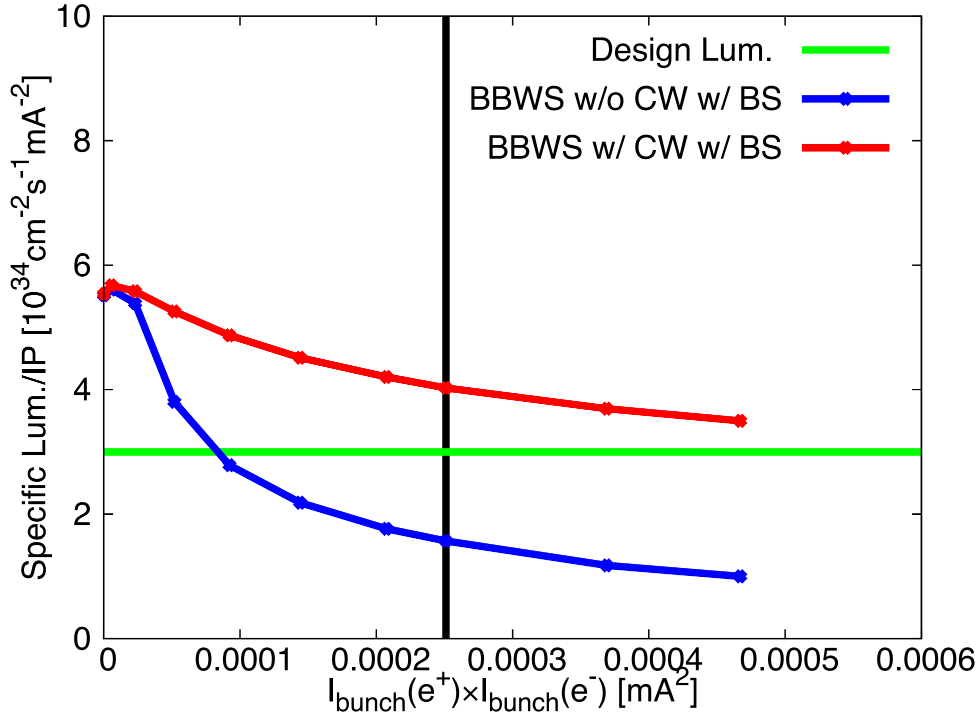


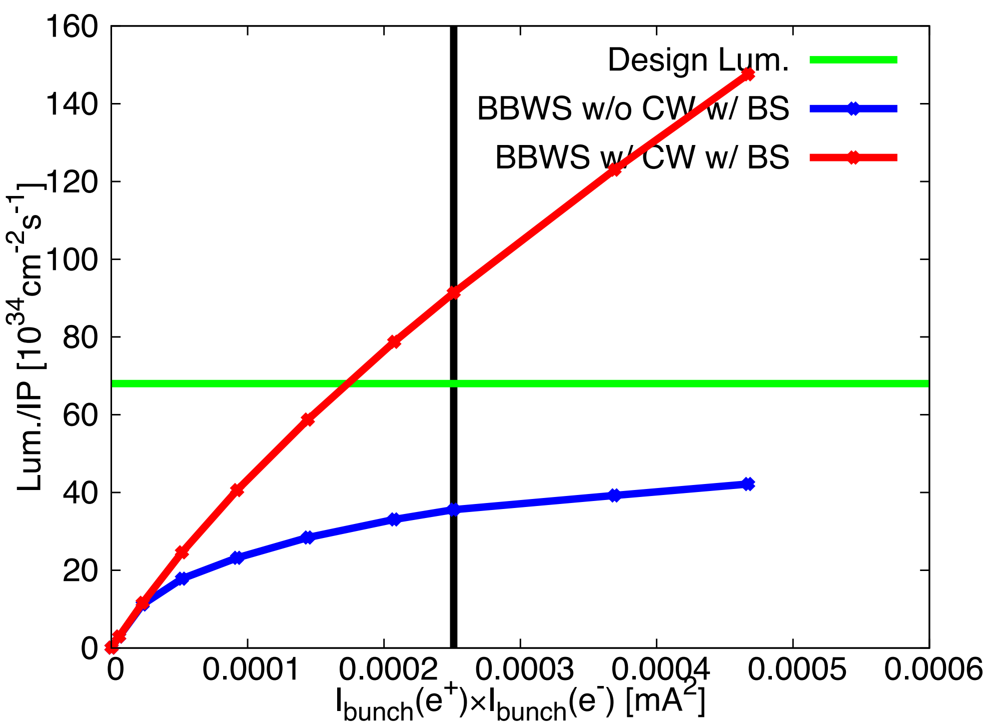




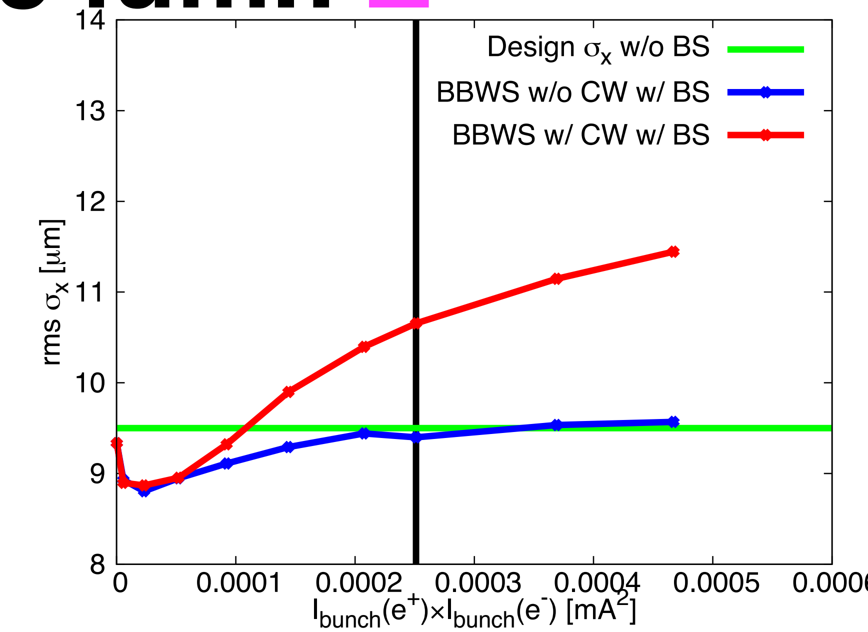
2. BBWS simulations: Specific lum.: Z

➤ [.54,.57]/IP

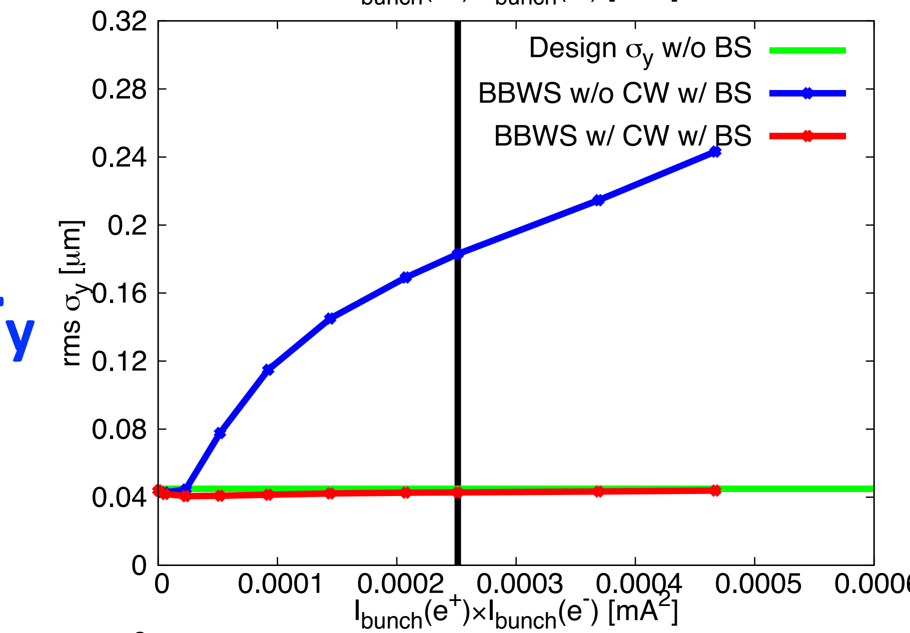




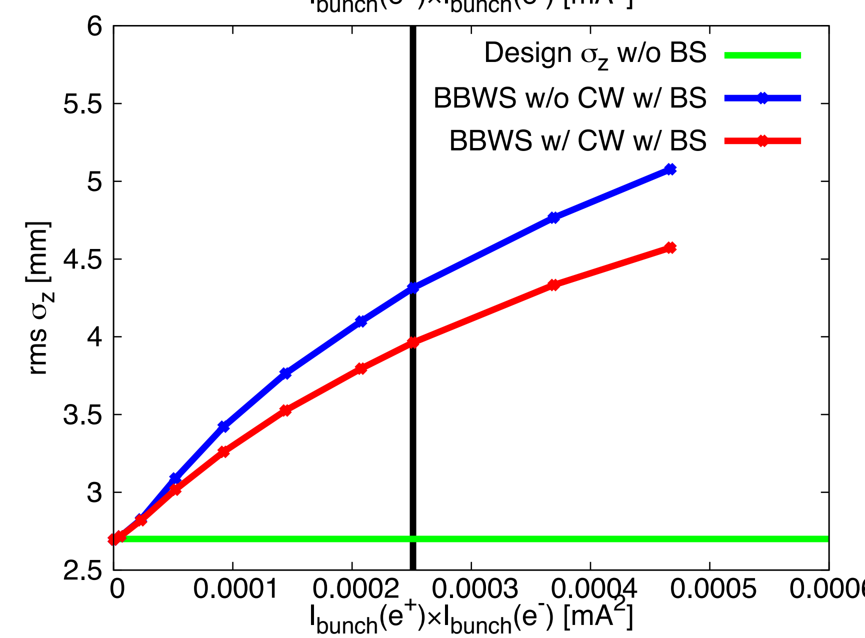
σ_x



σ_y

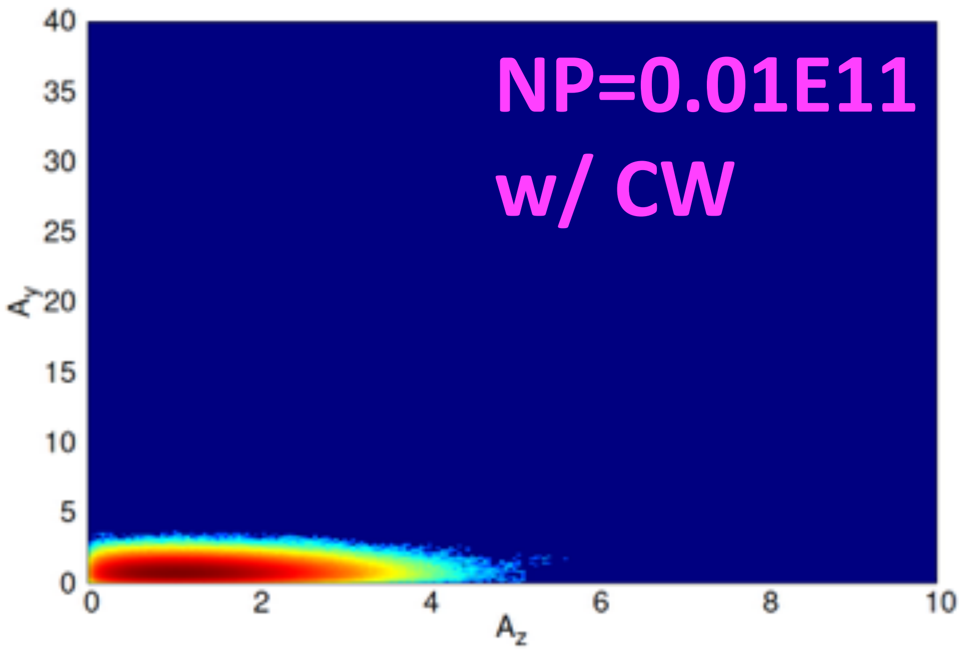


σ_z



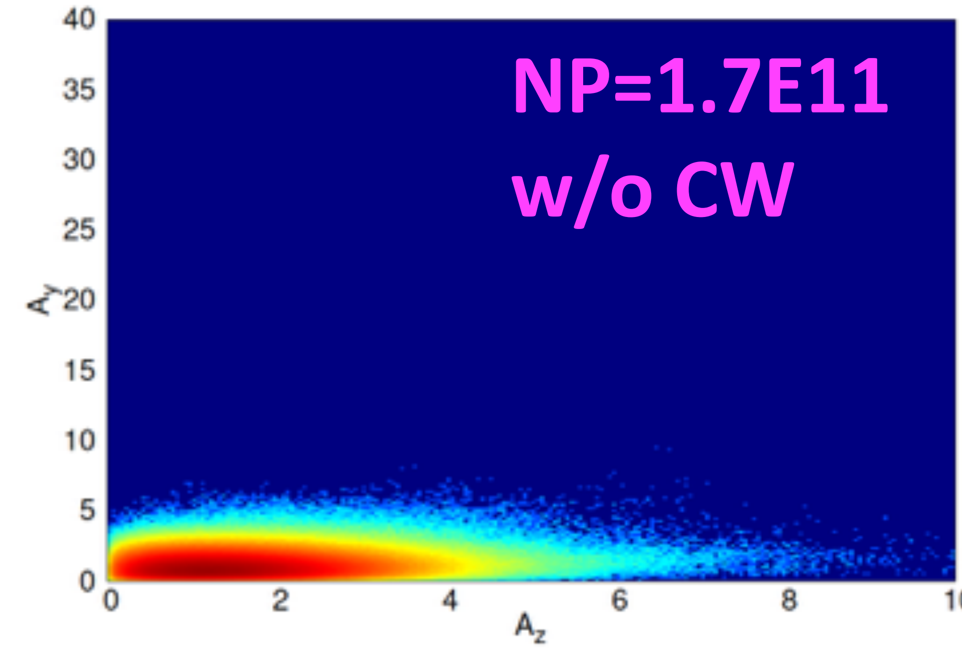
2. BBWS simulations: Beam tail: tt

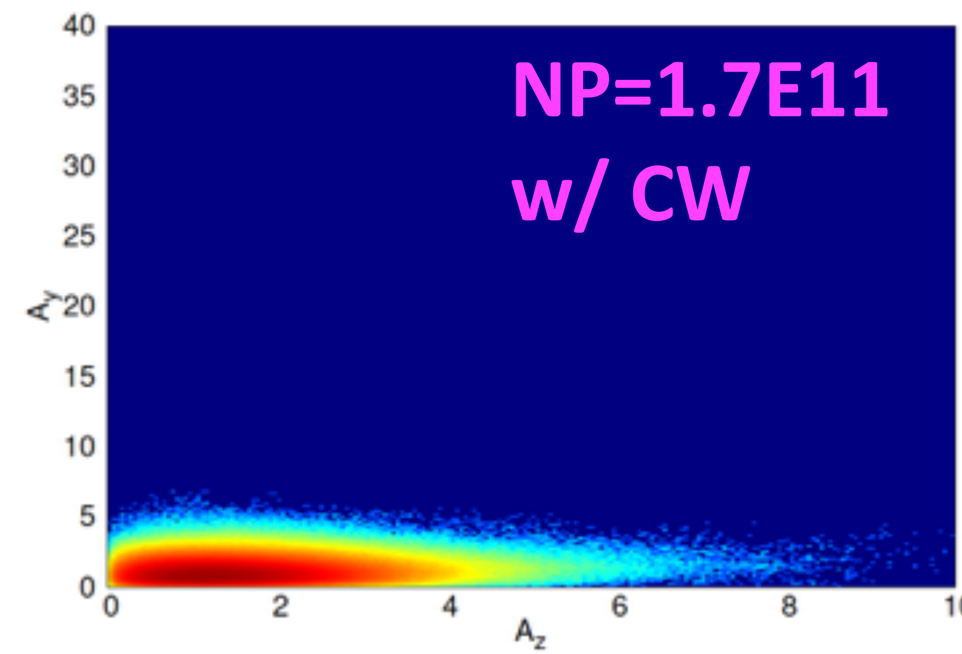
➤ w/ BS, [.54,.57]/IP, y-z distribution



$$A_y = \sqrt{2J_y/\epsilon_y}$$

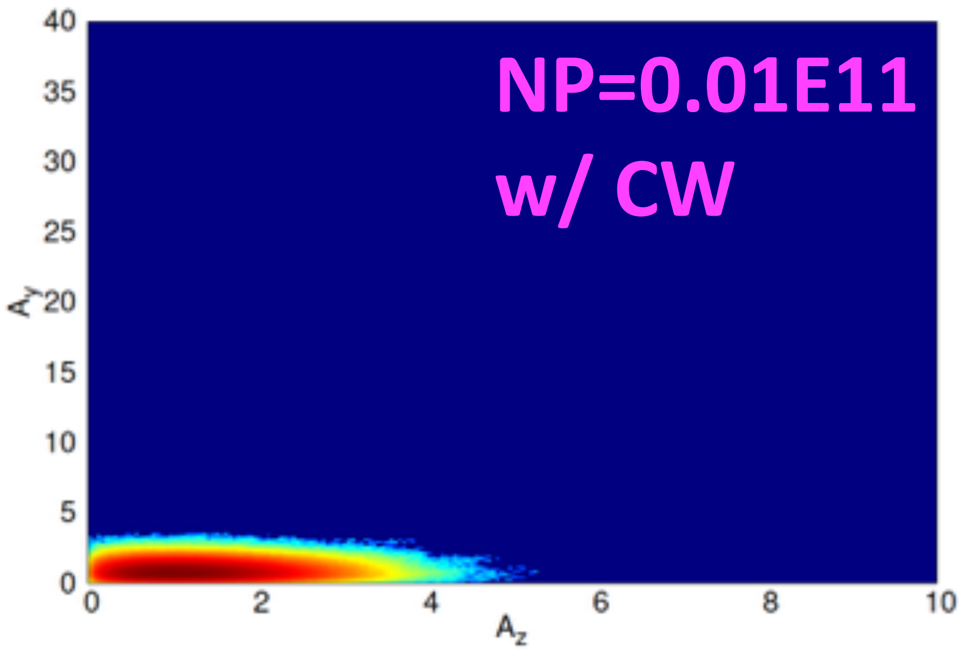
$$A_z = \sqrt{2J_z/\epsilon_z}$$

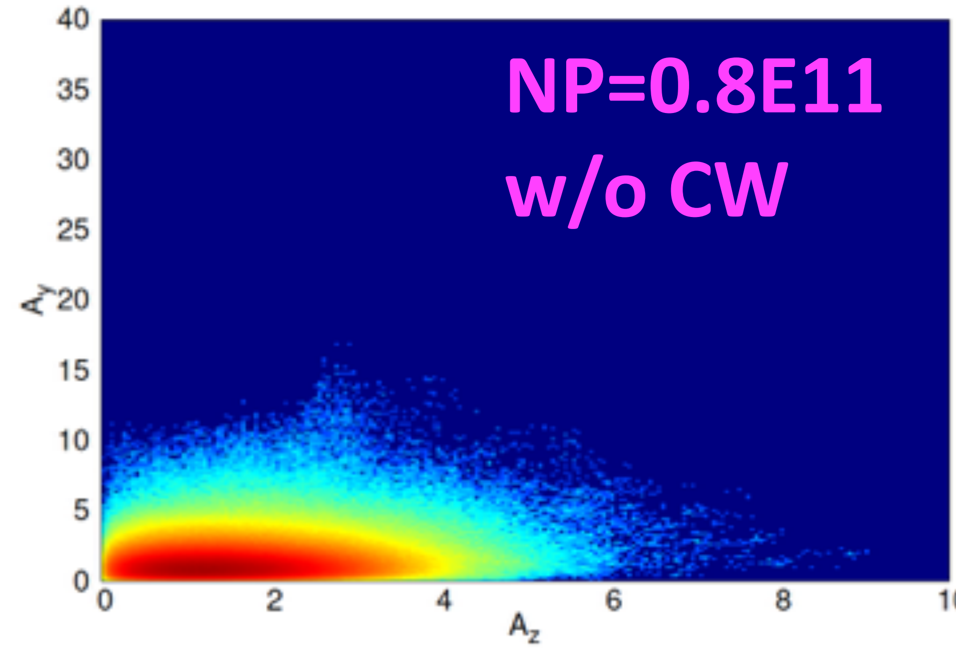


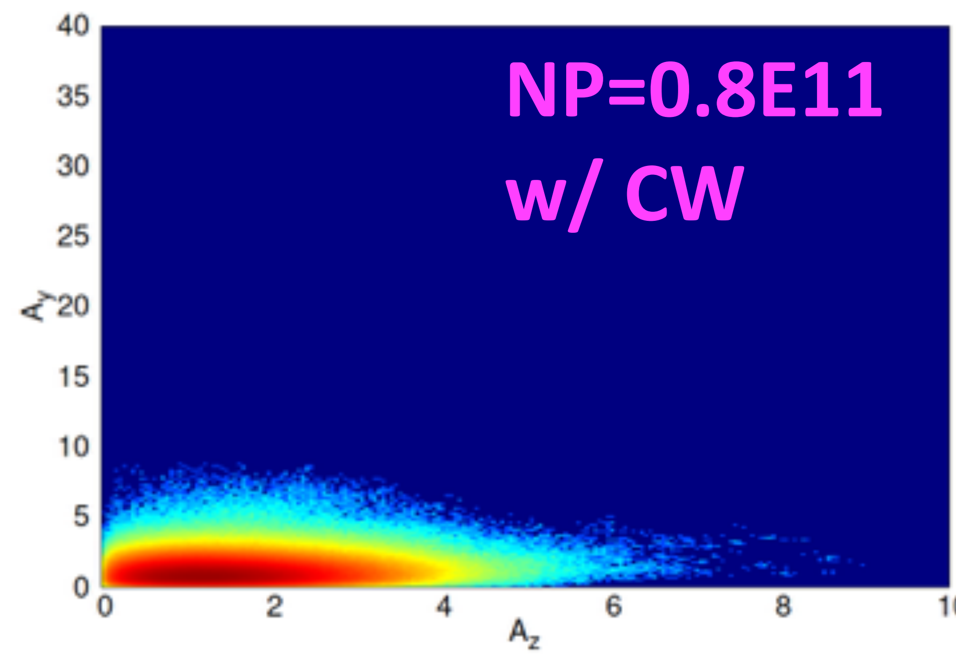


2. BBWS simulations: Beam tail: ZH

➤ w/ BS, [.53,.56]/IP, y-z distribution





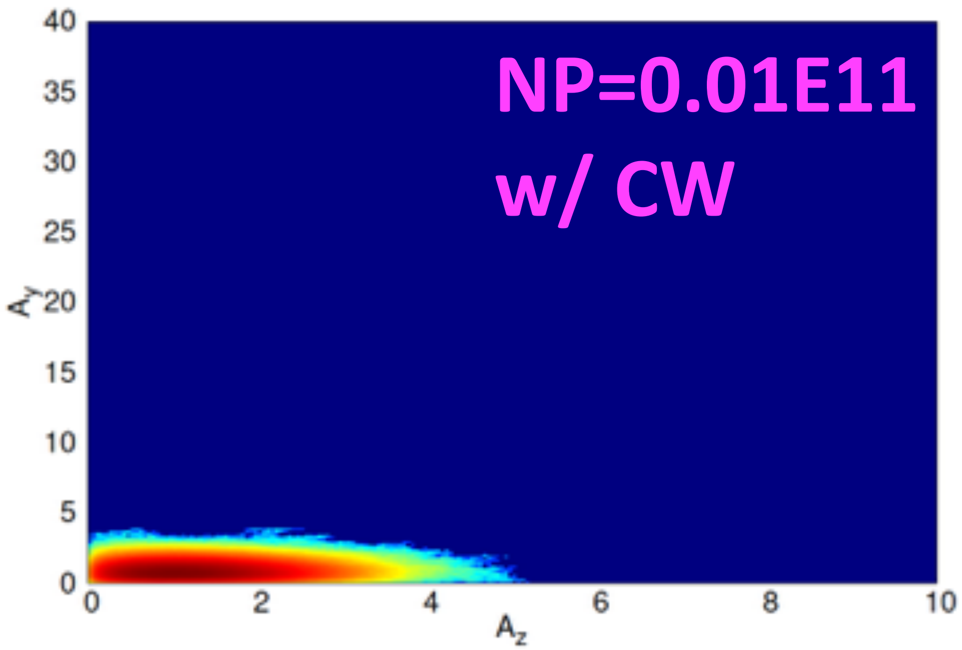


$$A_y = \sqrt{2J_y/\epsilon_y}$$

$$A_z = \sqrt{2J_z/\epsilon_z}$$

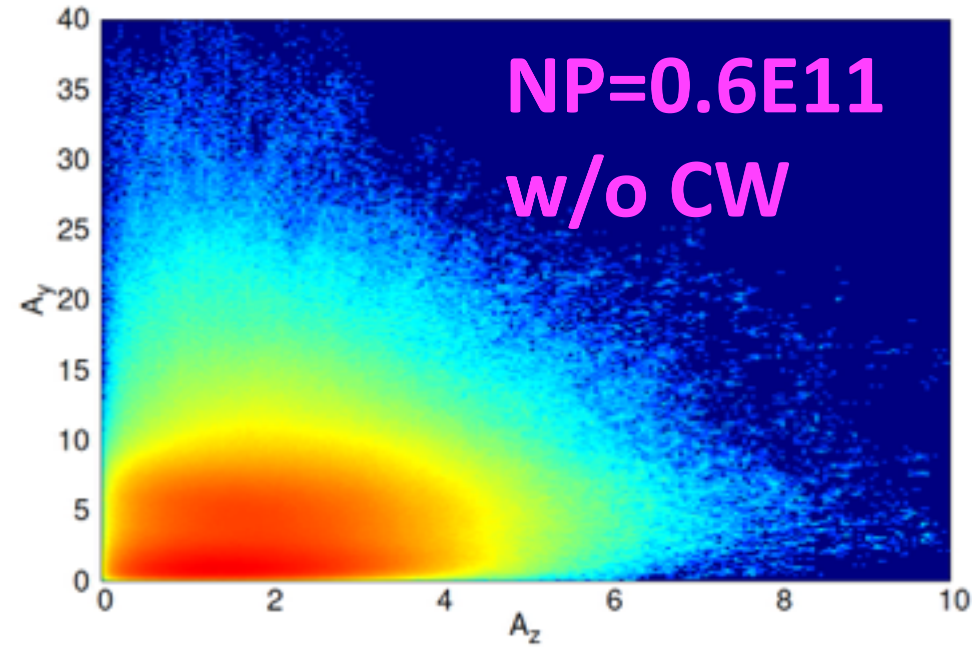
2. BBWS simulations: Beam tail: WW

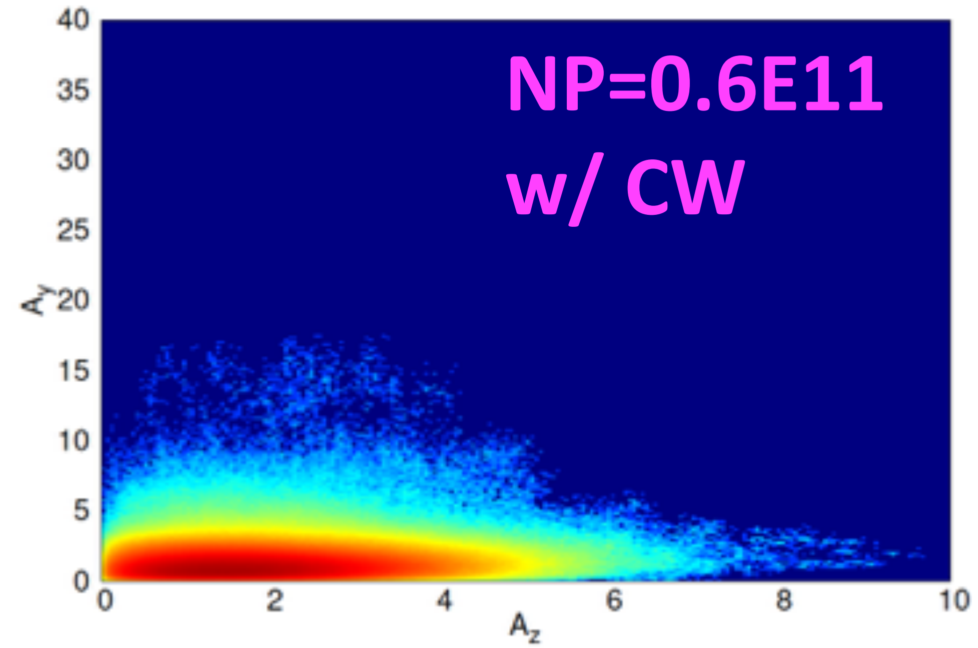
➤ **w/ BS, [.54,.57]/IP, y-z distribution**



$$A_y = \sqrt{2J_y/\epsilon_y}$$

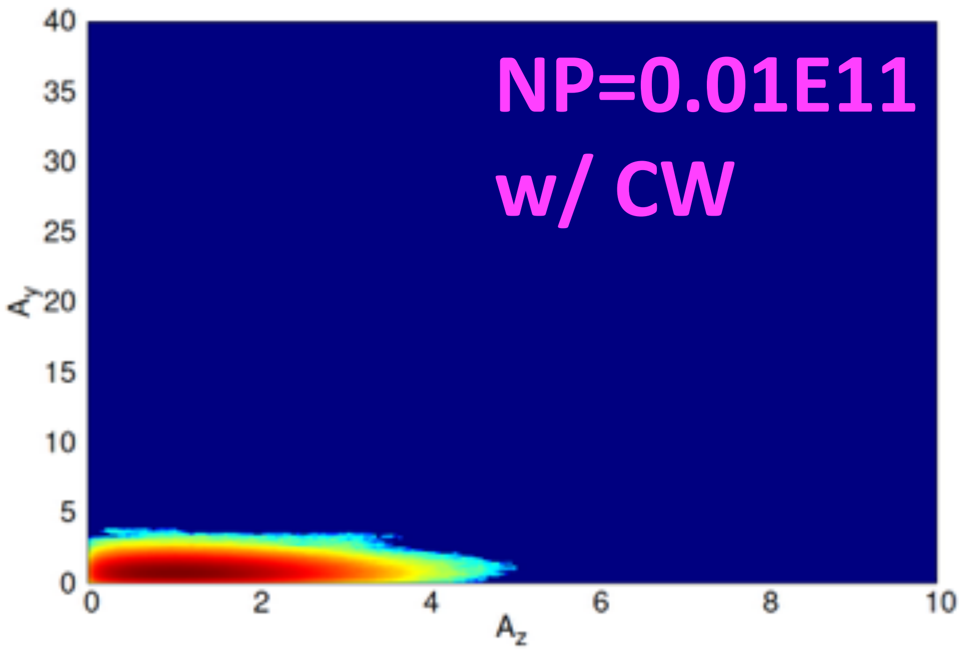
$$A_z = \sqrt{2J_z/\epsilon_z}$$

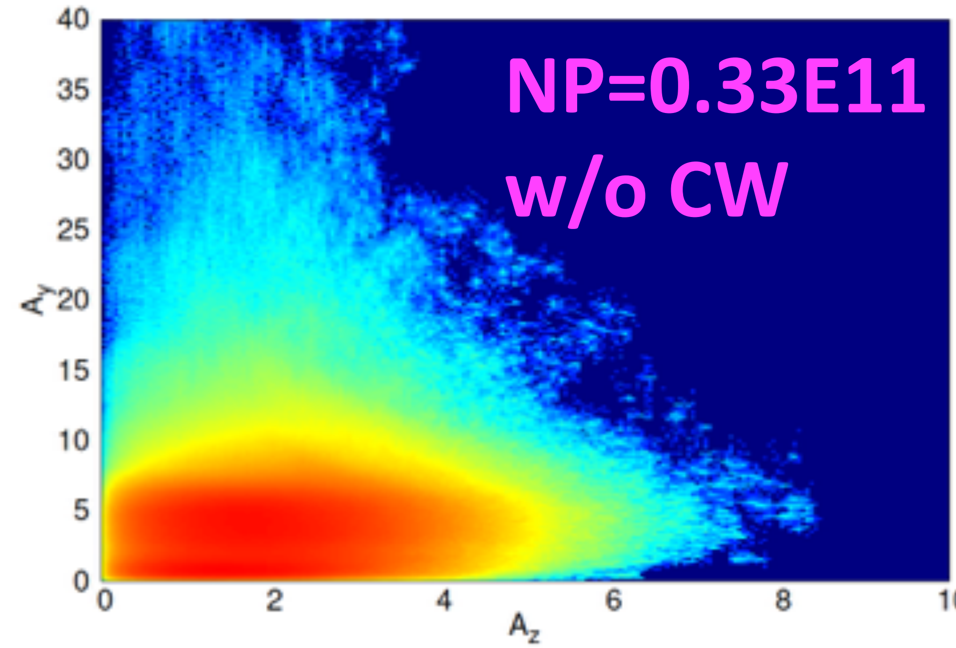




2. BBWS simulations: Beam tail: Z

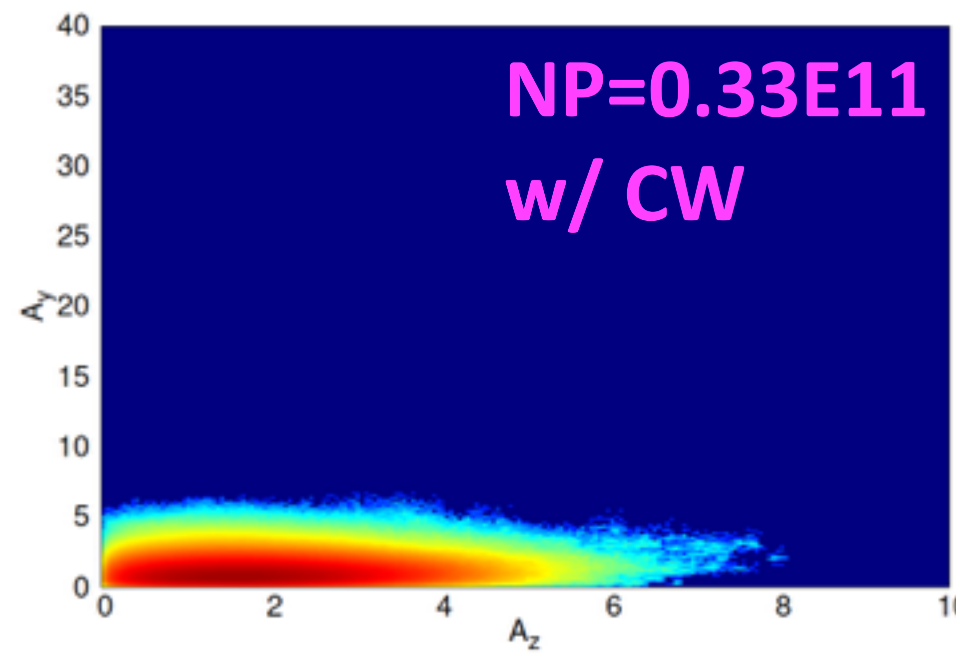
➤ **w/ BS, [.54,.57]/IP, y-z distribution**





$$A_y = \sqrt{2J_y/\epsilon_y}$$

$$A_z = \sqrt{2J_z/\epsilon_z}$$



3. Summary and discussions

➤ Simulated parameters by BBWS with input of baseline parameters - v2: w/ BS w/ CW

- General agreements besides ZZ [Need double-check]

	Z[1)]	WW[1)]	ZH[2)]	tt[1)]
rms $\sigma_{z,tot}$ [mm]	3.96	2.83	2.39	2.56
rms $\sigma_{\delta,tot}$ [%]	0.054	0.093	0.12	0.17
rms $\sigma_{x,\ tot}$ [μm]	10.7	21.7	28.0	34.4
rms $\sigma_{y,\ tot}$ [nm]	42.8	47.2	49.6	77.7
L/IP [$10^{34}cm^{-2}s^{-1}$]	91.4	22.0	5.48	1.34
Achievable L/IP[3)]	97.1	23.9	5.64	1.46

[1)]Working point: [.54, .57]
[2)]Working point: [.53, .56]
[3)]Maximum lum. from the tune scan

3. Summary and discussions

➤ Simulated parameters by BBWS with input of baseline parameters - v2: w/ BS w/o CW

- [.54, .57] might not be the best choice for WW and ZZ

	Z[1)]	WW[1)]	ZH[2)]	tt[1)]
rms $\sigma_{z,tot}$ [mm]	4.31	3.07	2.42	2.56
rms $\sigma_{\delta,tot}$ [%]	0.059	0.10	0.12	0.17
rms $\sigma_{x,\ tot}$ [μm]	9.4	20.9	28.3	34.4
rms $\sigma_{y,\ tot}$ [nm]	183	204.5	66.7	79.5
L/IP [$10^{34}cm^{-2}s^{-1}$]	35.6	10.2	4.98	1.35
Achievable L/IP[3)]	89.3	22.5	5.51	1.45

[1)]Working point: [.54, .57]
[2)]Working point: [.53, .56]
[3)]Maximum lum. from the tune scan

3. Summary and discussions

➤ **BBWS simulations**

- **Lum. tune scan => Determine working point**
- **Choose [.54, .57] for WW and Z not for optimal lum.**

[Reason: Working point blow ν_x-ν_y=Integer not good if assumed tune footprint of the beam spreads into the up-right side like SuperKEKB.]

- **The effectiveness of CW [Good lum. area in tune space, suppression of beam tail, lum. gain, etc.] increases from tt, ZH, WW to Z.**

➤ **Discussions**

- **Effectiveness of CW [with wise choice of working point] strongly depend on the lattice nonlinearity [both amplitude- and momentum-dependent nonlinearity] of the IR region => The study of "Interplay of beam-beam and lattice nonlinearity" might be more important in Z/WW (lattice available?) than in tt/ZH collider.**