

Weak-strong beam-beam simulations for SuperKEKB Phase-2 - Updates

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Acknowledgements:

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Outline

- **Introduction**
- **Tune scan using BBWS**
 - **Weak-strong simulations: Principle investigations, not good for predicting final lum. performance of a collider**
- **Summary**

1. Introduction

► Phase-2 machine parameters

- Full crossing angle: $\theta=0.083$ rad

Parameters can be different from operational ones because of wrong RF voltage

| | HER: 100/4 LER: 200/4 | | HER: 100/4 LER: 100/4 | | HER: 88/1.76 LER: 200/4 | |
|-------------------------|-------------------------|--------|-------------------------|--------|---------------------------|--------|
| | HER | LER | HER | LER | HER | LER |
| E (GeV) | 7.007 | 4 | 7.007 | 4 | 7.007 | 4 |
| I _b (mA) | 285 | 340 | 285 | 340 | 285 | 340 |
| # bunch | 789 | | 789 | | 789 | |
| ϵ_x (nm) | 4.5 | 2.0 | 4.5 | 1.9 | 4.5 | 2.0 |
| ϵ_y (pm) | 45 | 20 | 45 | 19 | 45 | 20 |
| ϵ_z (μ m) | 3.4 | 4.5 | 3.4 | 3.5 | 3.4 | 4.5 |
| β_x (mm) | 100 | 200 | 100 | 100 | 88 | 200 |
| β_y (mm) | 4 | 4 | 4 | 4 | 1.76 | 4 |
| σ_z (mm) | 5.3 | 5.9 | 5.3 | 4.6 | 5.3 | 5.9 |
| v _x | 45.57 | 44.57 | 45.57 | 44.57 | 45.57 | 44.57 |
| v _y | 43.60 | 46.60 | 43.60 | 46.60 | 43.60 | 46.60 |
| v _s | 0.0258 | 0.0176 | 0.0258 | 0.0223 | 0.0258 | 0.0176 |

1. Introduction

► Phase-2 machine parameters

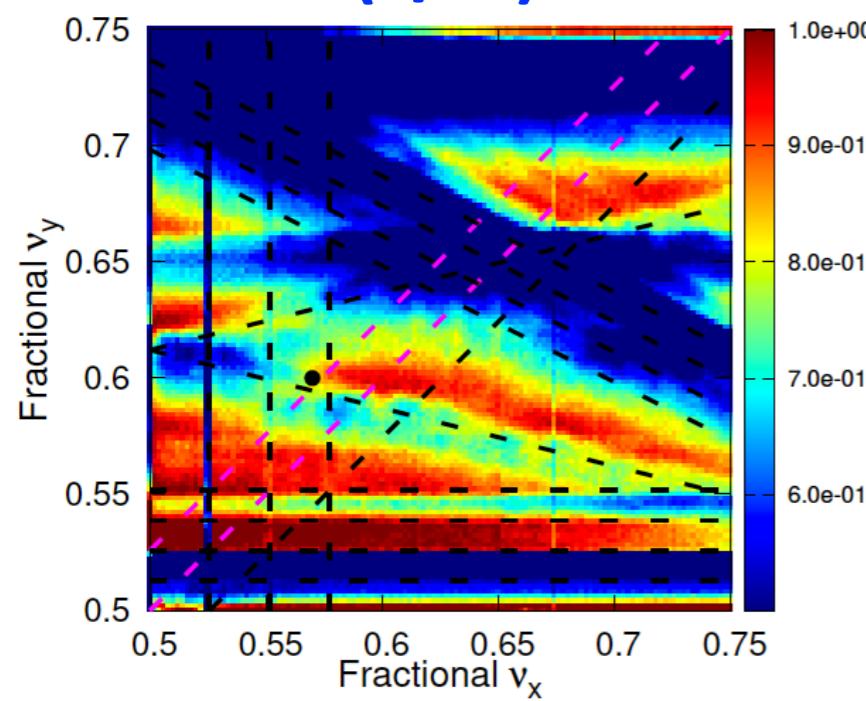
- HER: 100/4 | LER: 200/4 => Current operational parameters
- HER: 100/4 | LER: 100/4 => Idea of squeezing $\beta_{x,y}^*$
- HER: 88/1.76 | LER: 200/4 => Perfect geometric balance, e.g.
 $\sigma_{x+}^* = \sigma_{x-}^*, \sigma_{y+}^* = \sigma_{y-}^*$

2. BBWS simulation

► Optics: HER 100/4 mm and LER 100/4 mm

- Weak beam: HER: plots with normalization

Lum. (L/L_0)



Geometric luminosity:

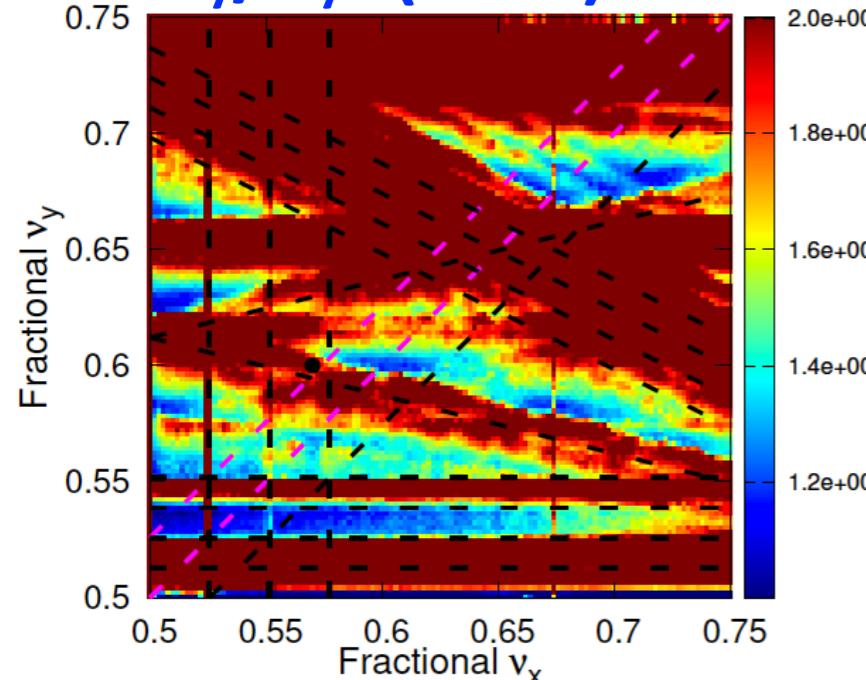
$$L_0 = 5.1 \times 10^{33} \text{ cm}^{-2}\text{s}^{-1}$$

$$\sigma_{x^-}^* = 21.3 \text{ } \mu\text{m}, \sigma_{y^-}^* = 0.43 \text{ } \mu\text{m}$$

$$\sigma_{x^+}^* = 13.9 \text{ } \mu\text{m}, \sigma_{y^+}^* = 0.28 \text{ } \mu\text{m}$$

Beam-beam resonances NOT relaxed...

σ_y/σ_{y0} (RMS)

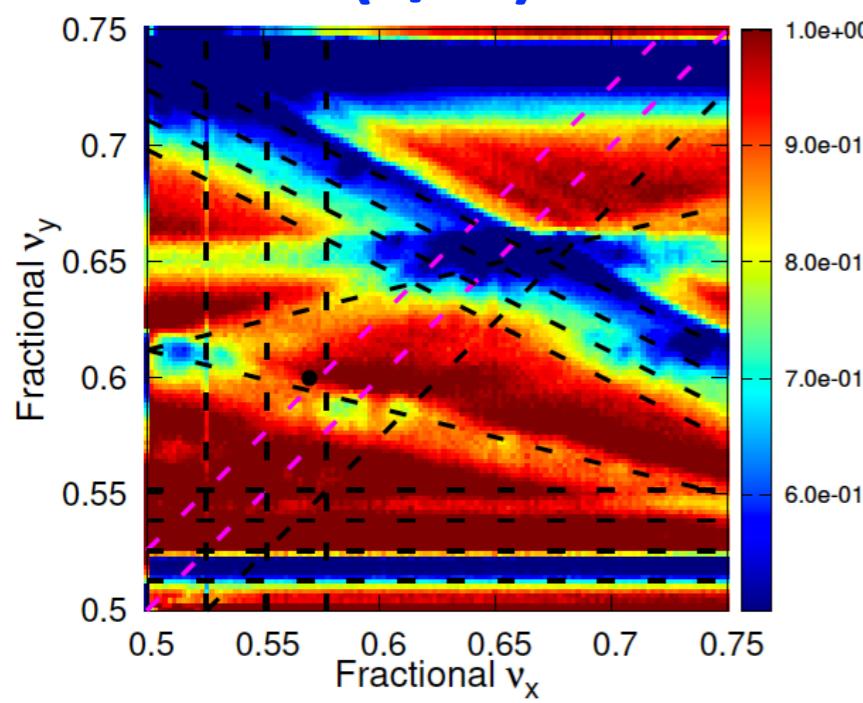


2. BBWS simulation

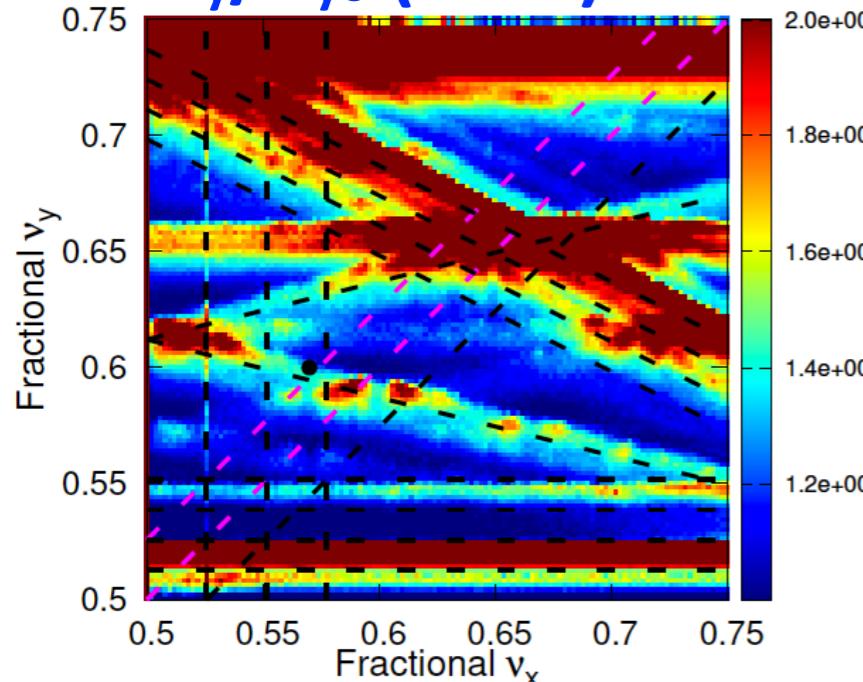
► Optics: HER 100/4 mm and LER 200/4 mm

- Weak beam: HER: plots with normalization

Lum. (L/L_0)



σ_y/σ_{y0} (RMS)



Geometric luminosity:

$$L_0 = 4.5 \times 10^{33} \text{ cm}^{-2}\text{s}^{-1}$$

$$\sigma_{x-}^* = 21.3 \mu\text{m}, \sigma_{y-}^* = 0.43 \mu\text{m}$$

$$\sigma_{x+}^* = 20.0 \mu\text{m}, \sigma_{y+}^* = 0.28 \mu\text{m}$$

(Lum. loss due to bunch length)

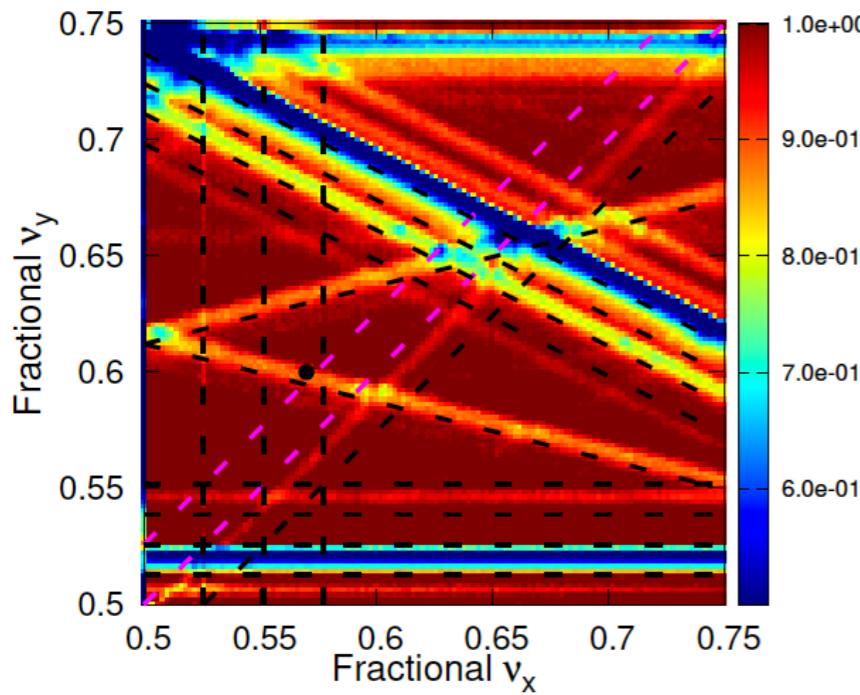
ALL beam-beam resonances relaxed!

2. BBWS simulation

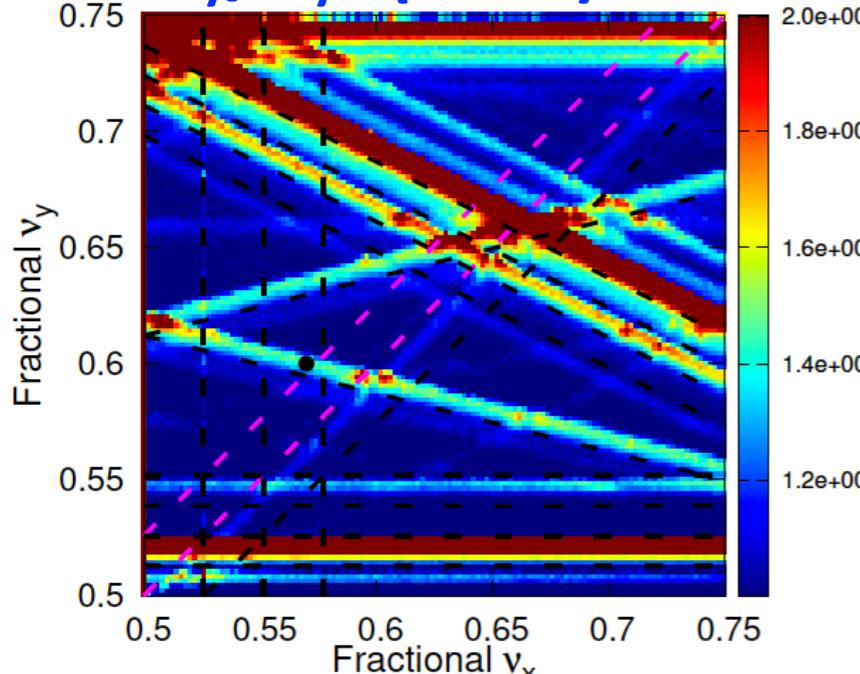
► Optics: HER 88/1.76 mm and LER 200/4 mm

- Weak beam: HER: plots with normalization

Lum. (L/L_0)



σ_y/σ_{y0} (RMS)



Geometric luminosity:

$$L_0 = 5.7 \times 10^{33} \text{ cm}^{-2}\text{s}^{-1}$$

$$\sigma_{x-}^* = 20.0 \mu\text{m}, \sigma_{y-}^* = 0.28 \mu\text{m}$$

$$\sigma_{x+}^* = 20.0 \mu\text{m}, \sigma_{y+}^* = 0.28 \mu\text{m}$$

(Lum. loss due to bunch length)

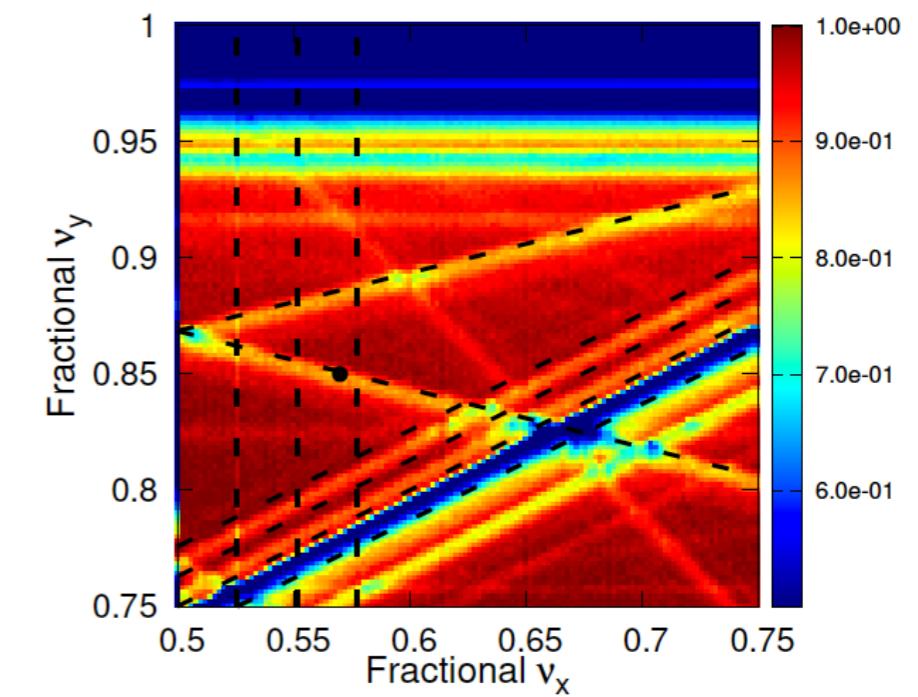
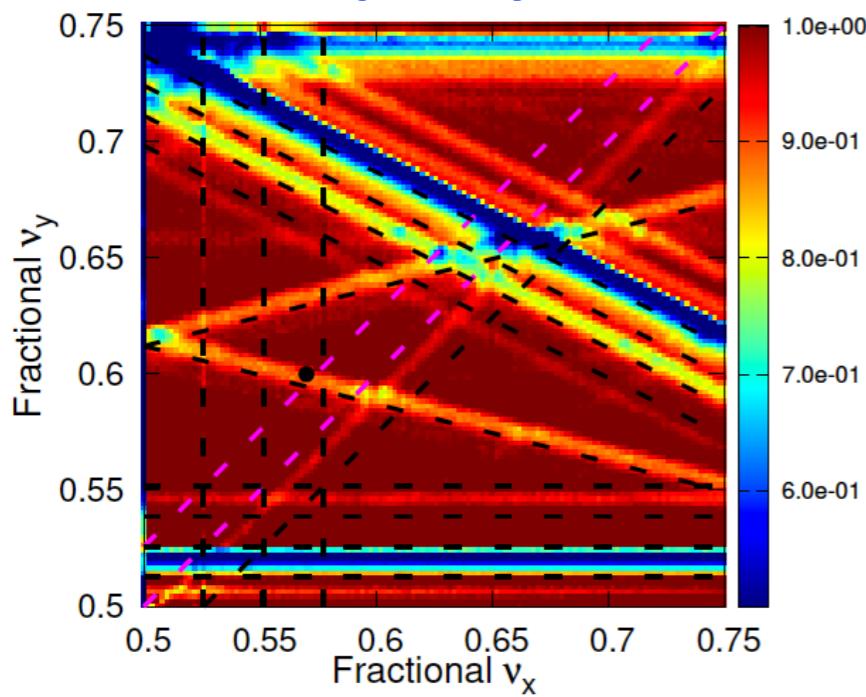
ALL beam-beam resonances
further relaxed!

2. BBWS simulation

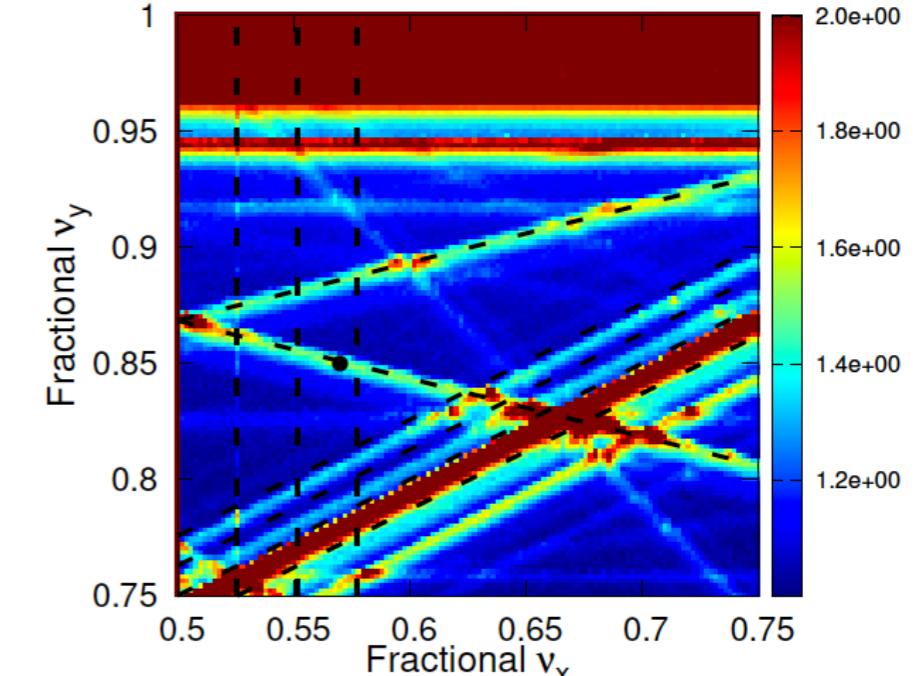
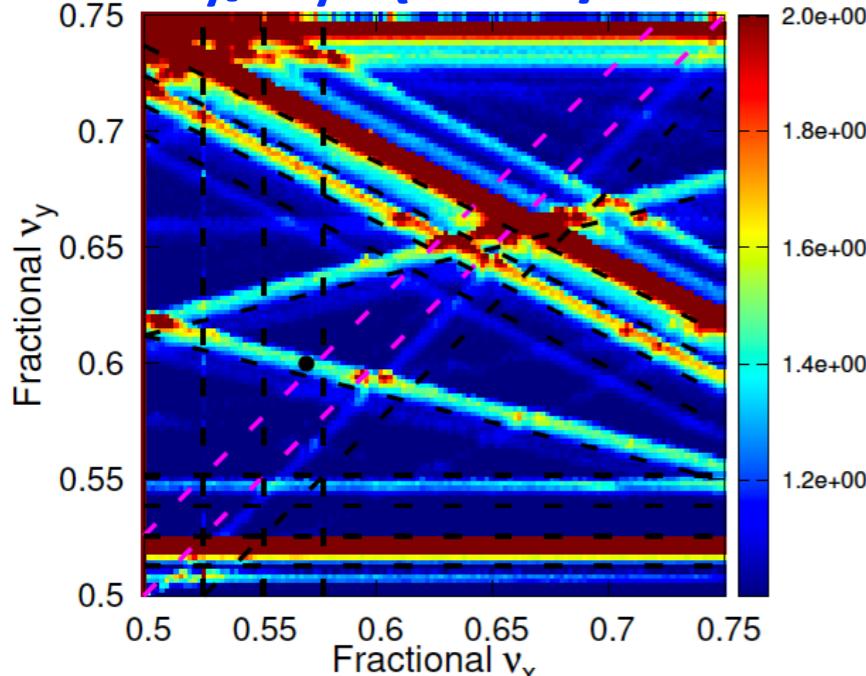
► Optics: HER 88/1.76 mm and LER 200/4 mm

- Weak beam: HER: plots with normalization

Lum. (L/L_0)



σ_y/σ_{y0} (RMS)

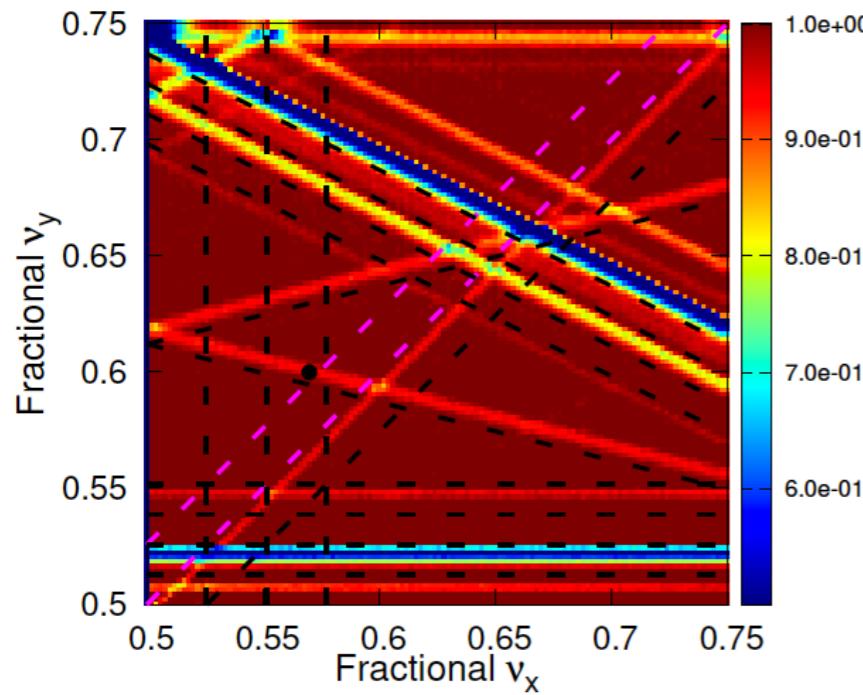


2. BBWS simulation

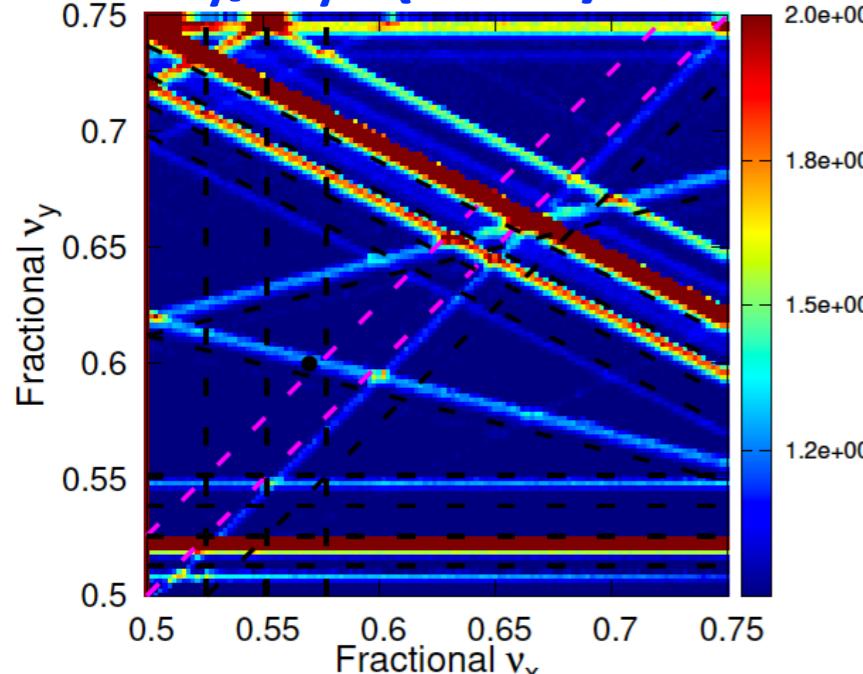
► Optics: HER 50/1 mm and LER 200/4 mm

- Weak beam: HER: plots with normalization

Lum. (L/L_0)



σ_y/σ_{y0} (RMS)



Geometric luminosity:

$$L_0 = 6.4 \times 10^{33} \text{ cm}^{-2}\text{s}^{-1}$$

$$\sigma_{x-}^* = 15.1 \mu\text{m}, \sigma_{y-}^* = 0.21 \mu\text{m}$$

$$\sigma_{x+}^* = 20.0 \mu\text{m}, \sigma_{y+}^* = 0.28 \mu\text{m}$$

(Lum. loss due to bunch length)

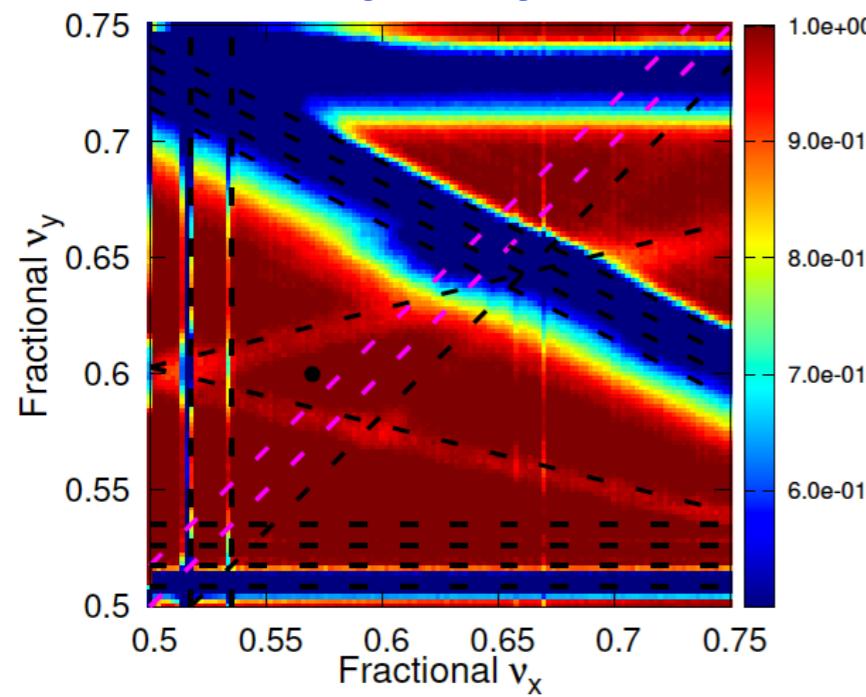
ALL beam-beam resonances
further relaxed!

2. BBWS simulation

► Optics: HER 200/4 mm and LER 200/4 mm

- Weak beam: LER: plots with normalization

Lum. (L/L_0)



Geometric luminosity:

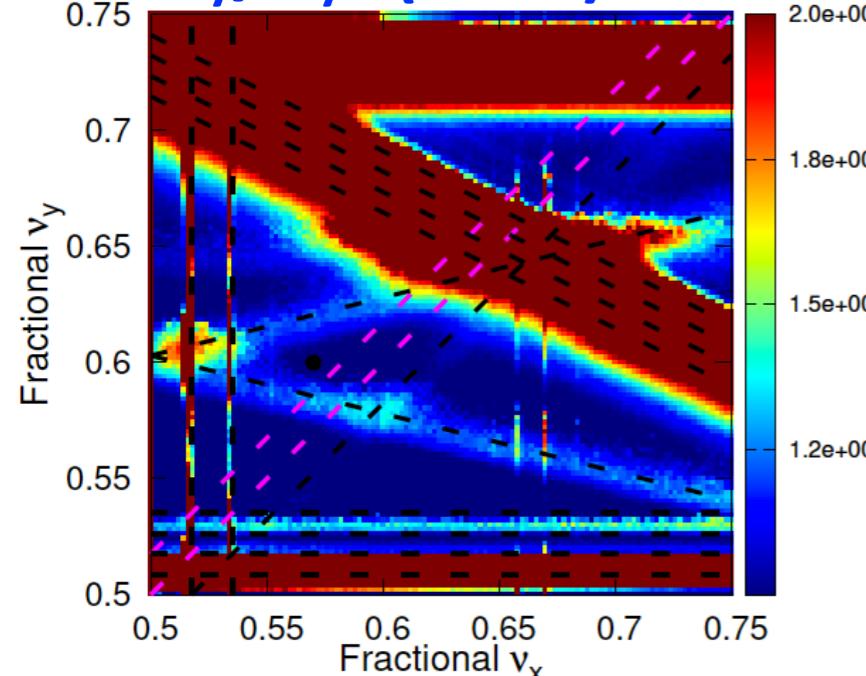
$$L_0 = 4.2 \times 10^{33} \text{ cm}^{-2}\text{s}^{-1}$$

$$\sigma_{x^-}^* = 30.8 \mu\text{m}, \sigma_{y^-}^* = 0.44 \mu\text{m}$$

$$\sigma_{x^+}^* = 20.0 \mu\text{m}, \sigma_{y^+}^* = 0.28 \mu\text{m}$$

(Lum. loss due to bunch length)

σ_y/σ_{y0} (RMS)

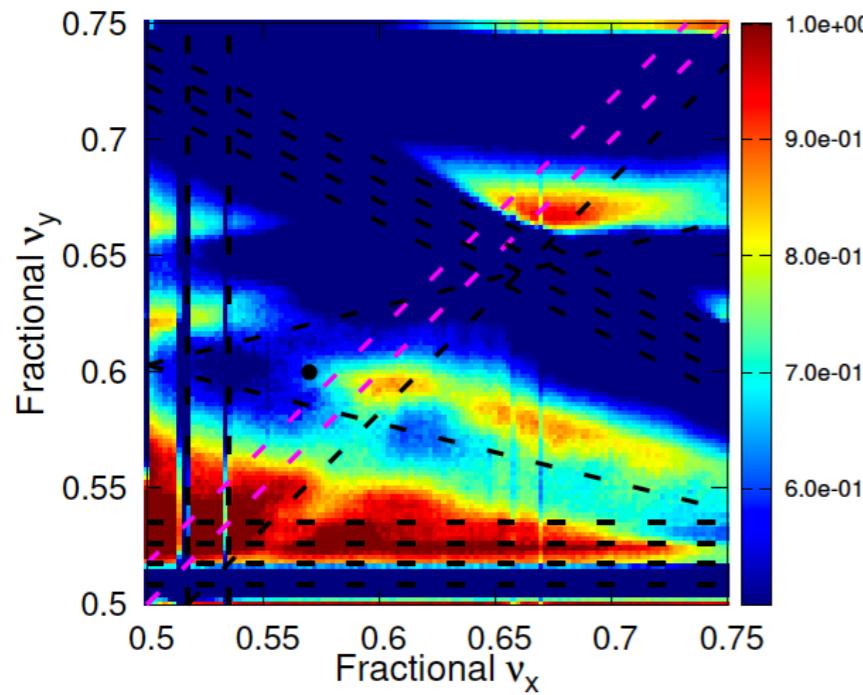


2. BBWS simulation

► Optics: HER 50/1 mm and LER 200/4 mm

- Weak beam: LER: plots with normalization

Lum. (L/L_0)



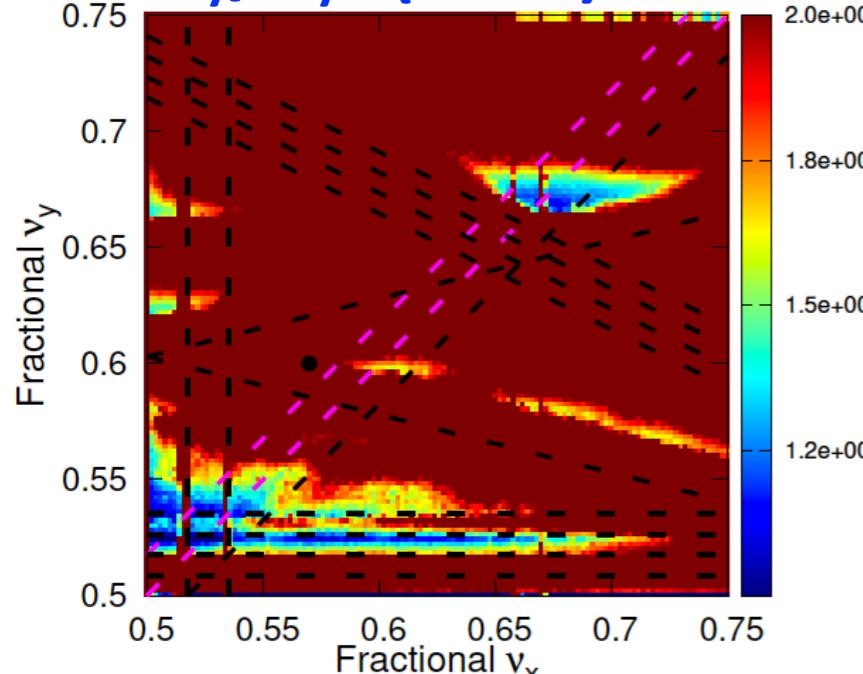
Geometric luminosity:

$$L_0 = 6.4 \times 10^{33} \text{ cm}^{-2}\text{s}^{-1}$$

$$\sigma_{x^-}^* = 15.1 \mu\text{m}, \sigma_{y^-}^* = 0.21 \mu\text{m}$$

$$\sigma_{x^+}^* = 20.0 \mu\text{m}, \sigma_{y^+}^* = 0.28 \mu\text{m}$$

σ_y/σ_{y0} (RMS)



2. BBWS simulation

- On lum. tuning-up strategy (based on beam-beam simulations)
 - Step-1: Optics change (β^* , etc.)
 - Step-2: Optics correction: minimize emittance coupling $\varepsilon_y/\varepsilon_x \Rightarrow$ Leave more space for other collective effects: beam-beam, IBS, space charge, e-cloud, bunch lengthening due to impedance, linear coupling/dispersion, etc.
 - Step-3: Geometric balance and bunch/beam current balance of e+/e- beams
 - Step-4: Select best working point (v_x, v_y) => Move to Step-2, do iterations
 - Step-5: IP knobs, nonlinear optics correction, etc.
 - Iterations: 1 => 2 => 3 => => 4 => 2 => 5 => 1 => 2 ...

3. Summary

➤ Tune scan using BBWS

- Beam-beam resonances are unexpectedly strong
- Various beam-beam resonances observed in tune scan via BBWS
- Near the (.57,.60) working point (current Phase-2 commissioning), the beam-beam resonance $v_x + 4v_y + k^*v_s = N$ is strong
- To relax (ALL) beam-beam resonances, geometric balance is necessary ($\sigma_{x+}^* = \sigma_{x-}^*$, $\sigma_{y+}^* = \sigma_{y-}^*$) for the two beams

➤ Future tuning strategy

- Strong-strong simulation (Ohmi-san and Hirosawa-san)
- Optimizations of key parameters: (I_{bunch} , $\beta_{x,y}^*$, v_x , v_y) for HER and LER => More beam-beam simulations
- Optimizations of linear and nonlinear optics via optics measurements/corrections => Suppress lattice nonlinearity
- Crab waist (?)
- Need balance of e+ and e- bunch currents (Energy transparency)?