

Summary of machine studies

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Acknowledgements:

SuperKEKB KCG and BCG

SuperKEKB commissioning meeting

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Outline

- **2019.06.22: Beam-beam tune shift study**
- **2019.06.20: V-angle change during collision tuning**
- **2019.06.23: Tune scan study [To be done]**

1. 2019.06.22: Beam-beam tune shift study

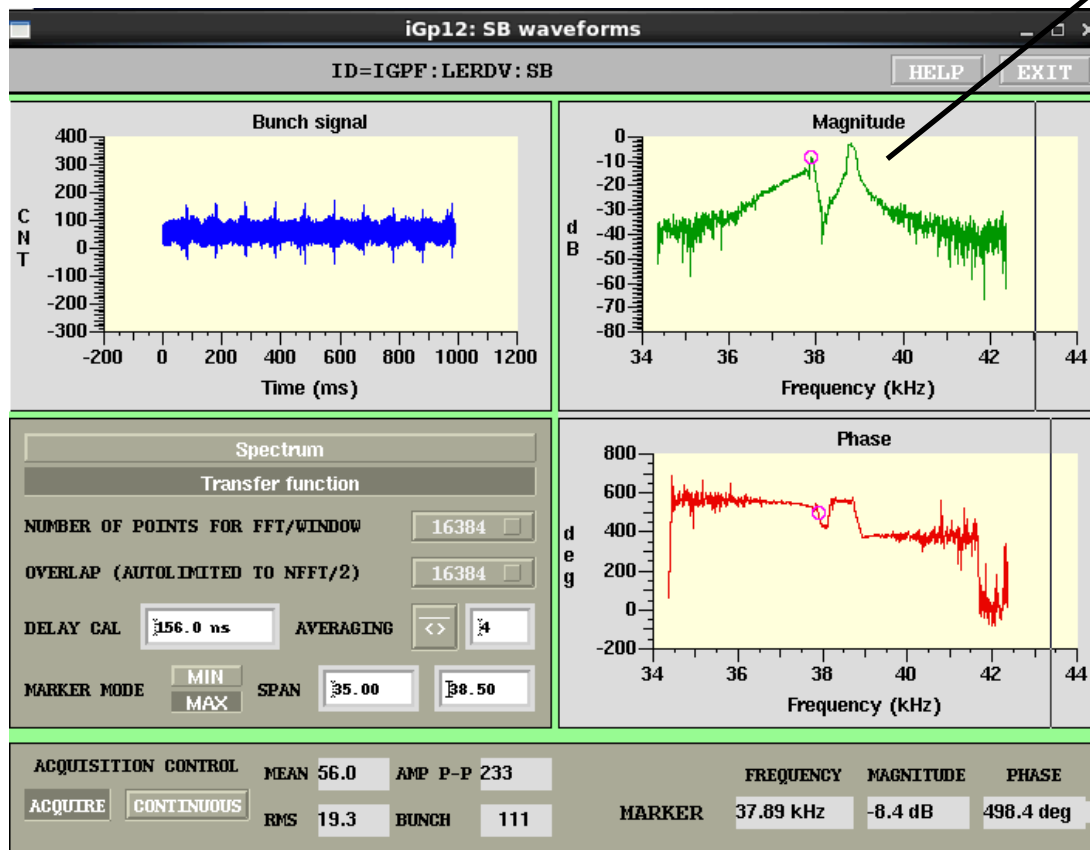
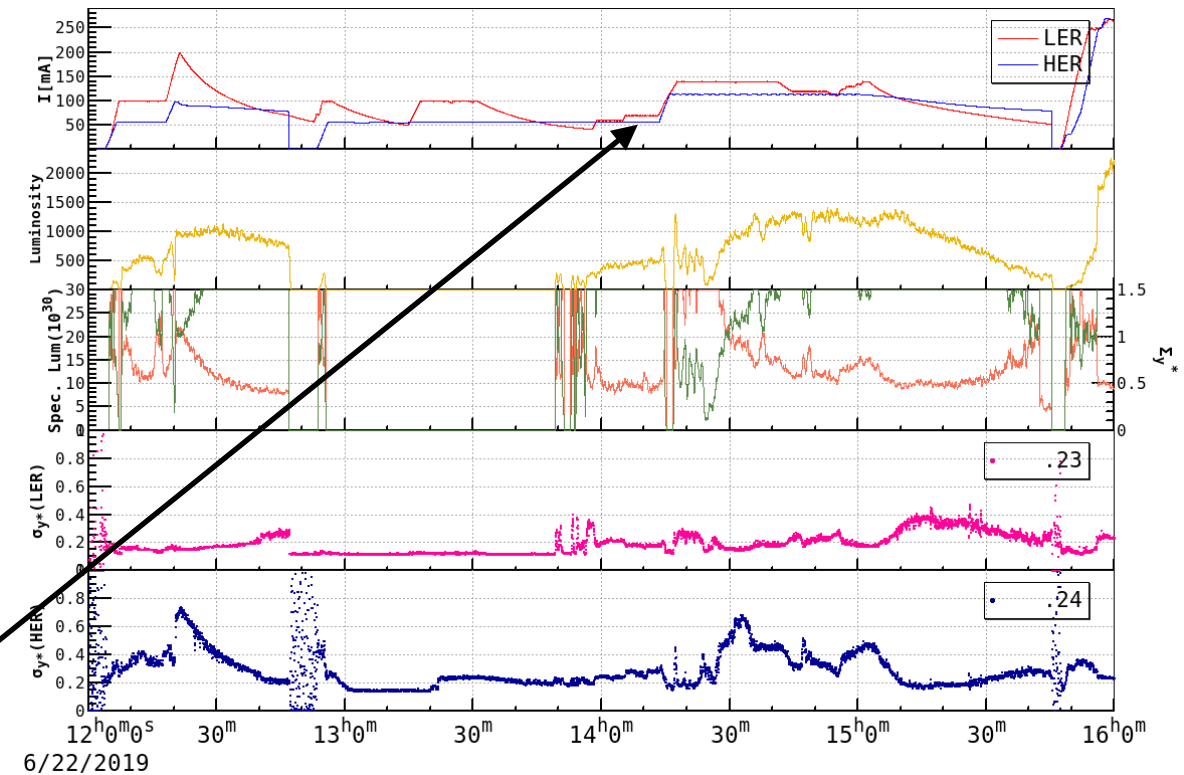
➤ Machine study set-up (expected)

- Filling pattern: #bunch=398, 12 bucket spacing
- Beam currents (consider energy transparency 4 GeV: 7 GeV):
 - * 100 mA (e+) x 57 mA (e-), $I_+ * I_- = 0.036 \text{ mA}^2$
 - * 200 mA (e+) x 114 mA (e-), $I_+ * I_- = 0.144 \text{ mA}^2$
- Feedback system (Thanks to M. Tobiyama)
Log: <http://kekbbpmddev5.kek.jp>
- Fractional $\nu_y = .6075$

1. 2019.06.22: Beam-beam tune shift study

► Experimental observations

- First observation: **14:13 PM**
 - **70 mA (e+) x 57 mA (e-)**
 - $\sigma_y^*(e+) = 0.18 \mu\text{m}$, $\sigma_y^*(e-) = 0.29 \mu\text{m}$ [XRM]
 - Lum. $\sim 5 \cdot 10^{32} \text{ cm}^{-2}\text{s}^{-1}$
 - Beam-beam parameter estimated from lum.:
 $\xi_{y-} \sim 0.022$, $\xi_{y+} \sim 0.011$
 - From feedback system:
 $\xi_{y+} \sim (38.79 - 37.89) \text{ kHz} / 99.39 \text{ kHz} \sim 0.009$
- Fairly good consistency?**



$$\mathcal{L} = \mathcal{L}_0 \cdot R_\theta \quad \mathcal{L}_0 = \frac{N_p N_e f N_b}{2\pi \sqrt{\sigma_{xp}^{*2} + \sigma_{xe}^{*2}} \sqrt{\sigma_{yp}^{*2} + \sigma_{ye}^{*2}}}$$

$$R_\theta \approx \frac{1}{\sqrt{1 + \frac{\sigma_{zp}^{*2} + \sigma_{ze}^{*2}}{\sigma_{xp}^{*2} + \sigma_{xe}^{*2}} \tan^2 \frac{\theta}{2}}}$$

$$\xi_{ye0} = \frac{N_p r_e \beta_{ye}^*}{2\pi \gamma_e \sigma_{xp}^* \sigma_{yp}^*} \frac{1}{\sqrt{\left(\frac{\sigma_{zp}^*}{\sigma_{xp}^*} \tan \frac{\theta}{2}\right)^2 + 1 + \frac{\sigma_{yp}^*}{\sigma_{xp}^*}}}$$

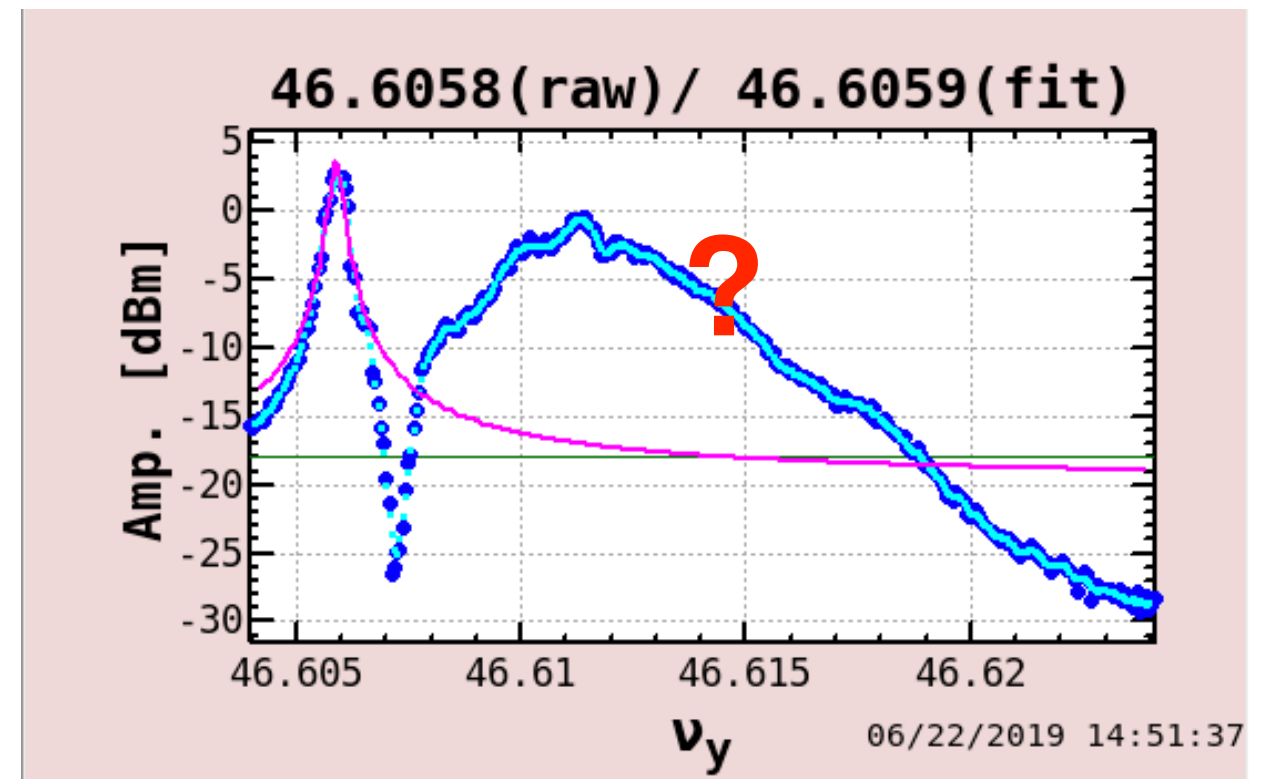
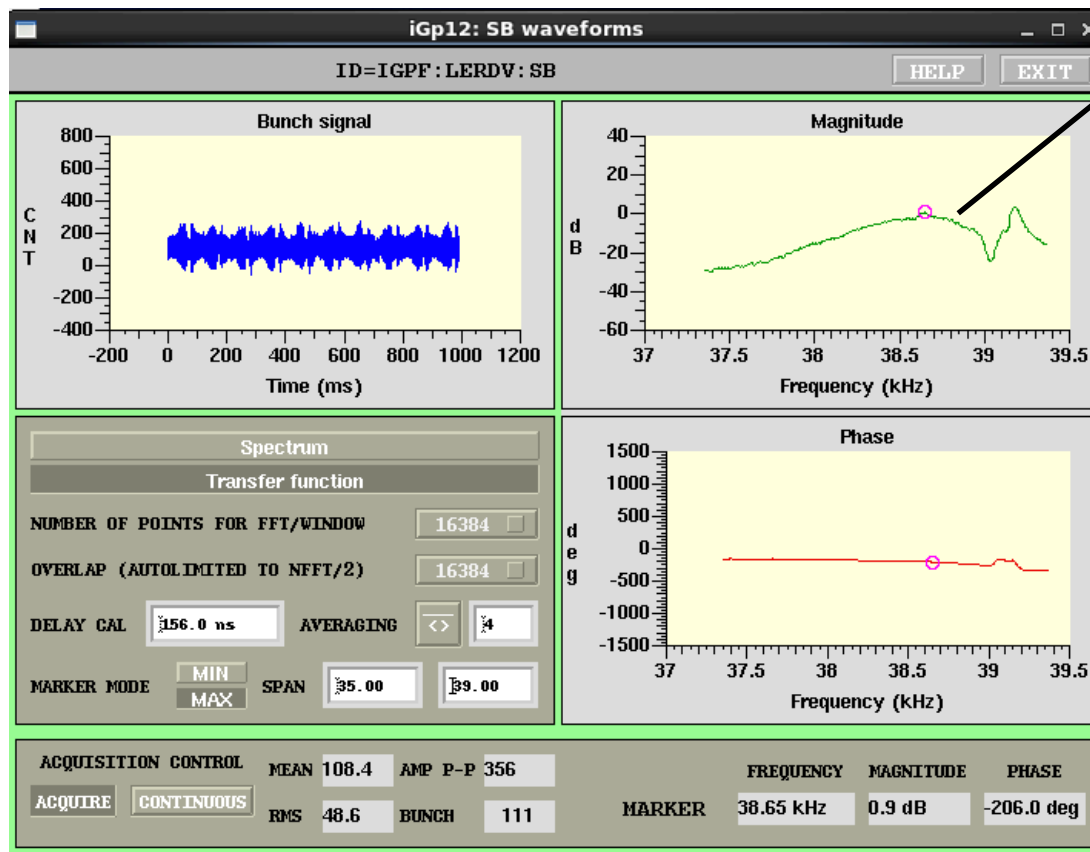
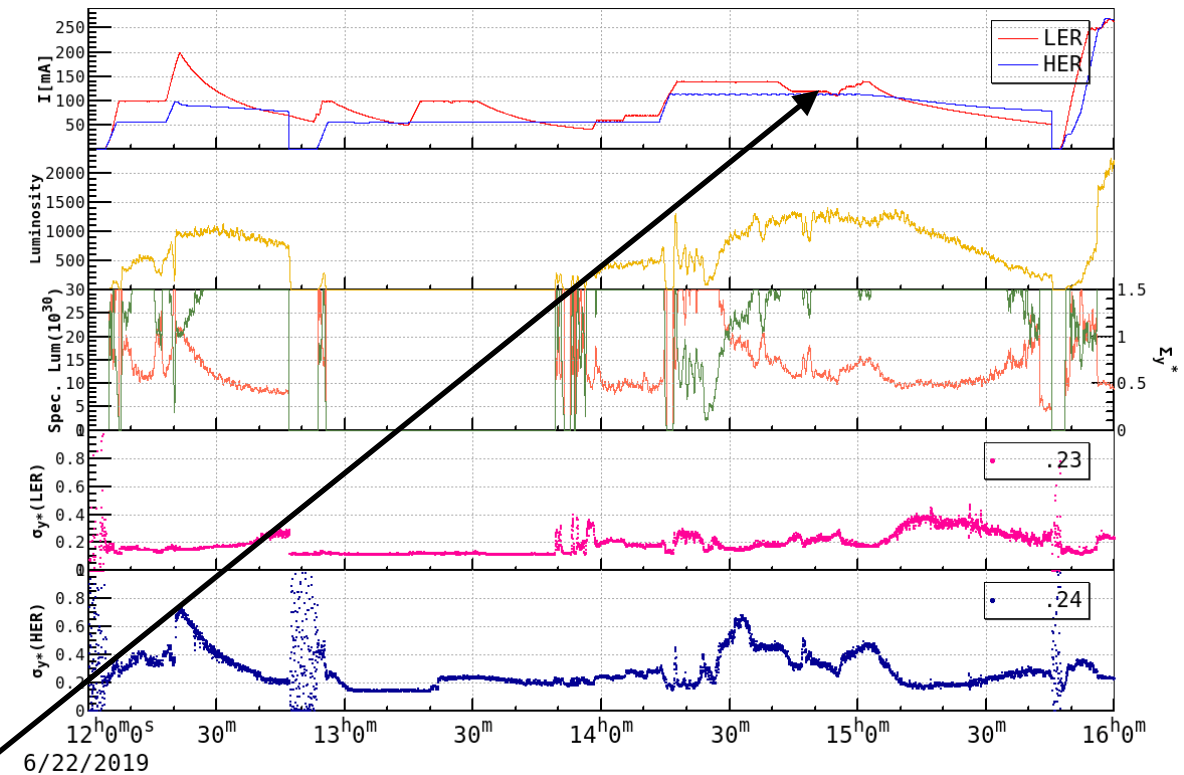
$$\mathcal{L} = \frac{\gamma_{\pm}}{2e r_e} \frac{I_{\pm} \xi_{\pm}}{\beta_{y\pm}^*} \frac{2\sigma_{x\mp}^* \sigma_{y\mp}^*}{\sqrt{\sigma_{x+}^{*2} + \sigma_{x-}^{*2}} \sqrt{\sigma_{y+}^{*2} + \sigma_{y-}^{*2}}}$$

Correct formula?

1. 2019.06.22: Beam-beam tune shift study

► Experimental observations

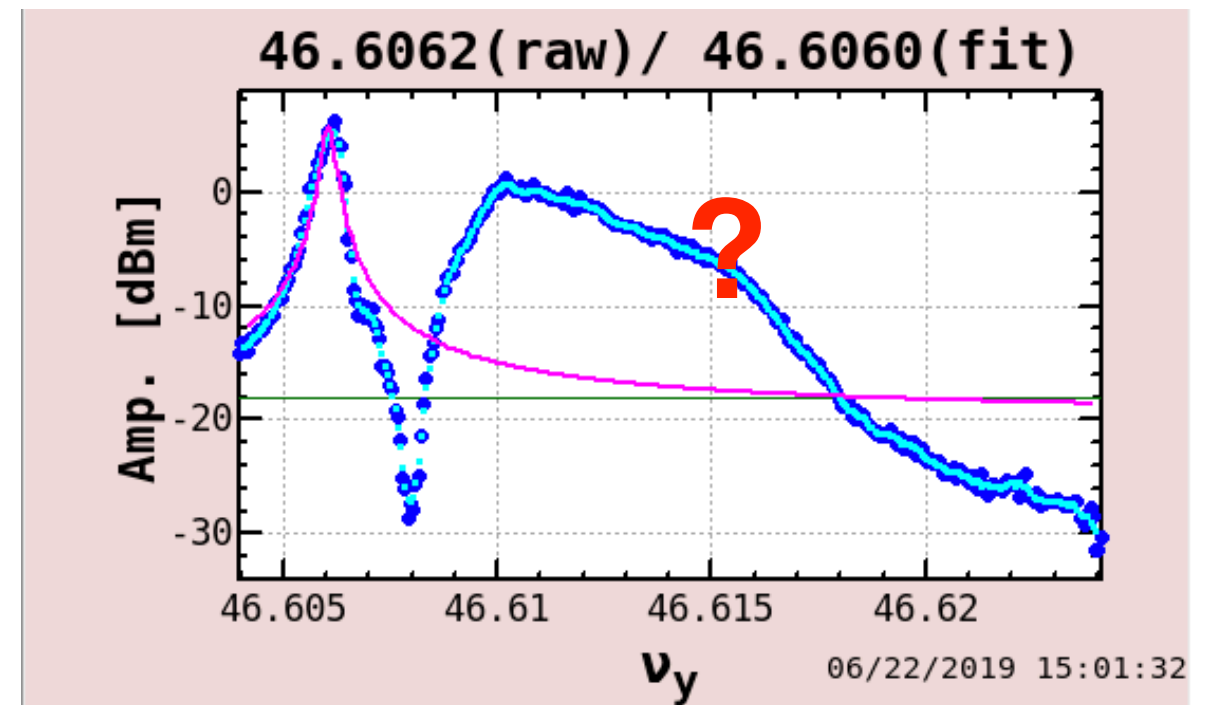
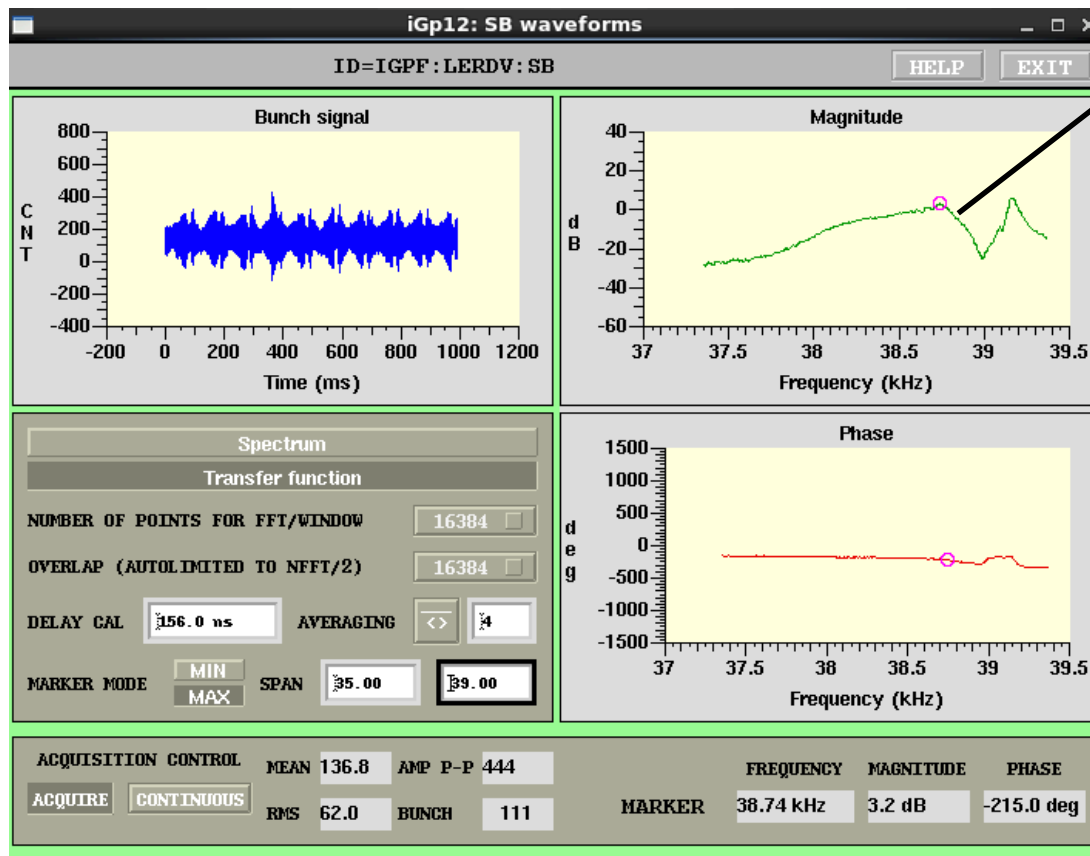
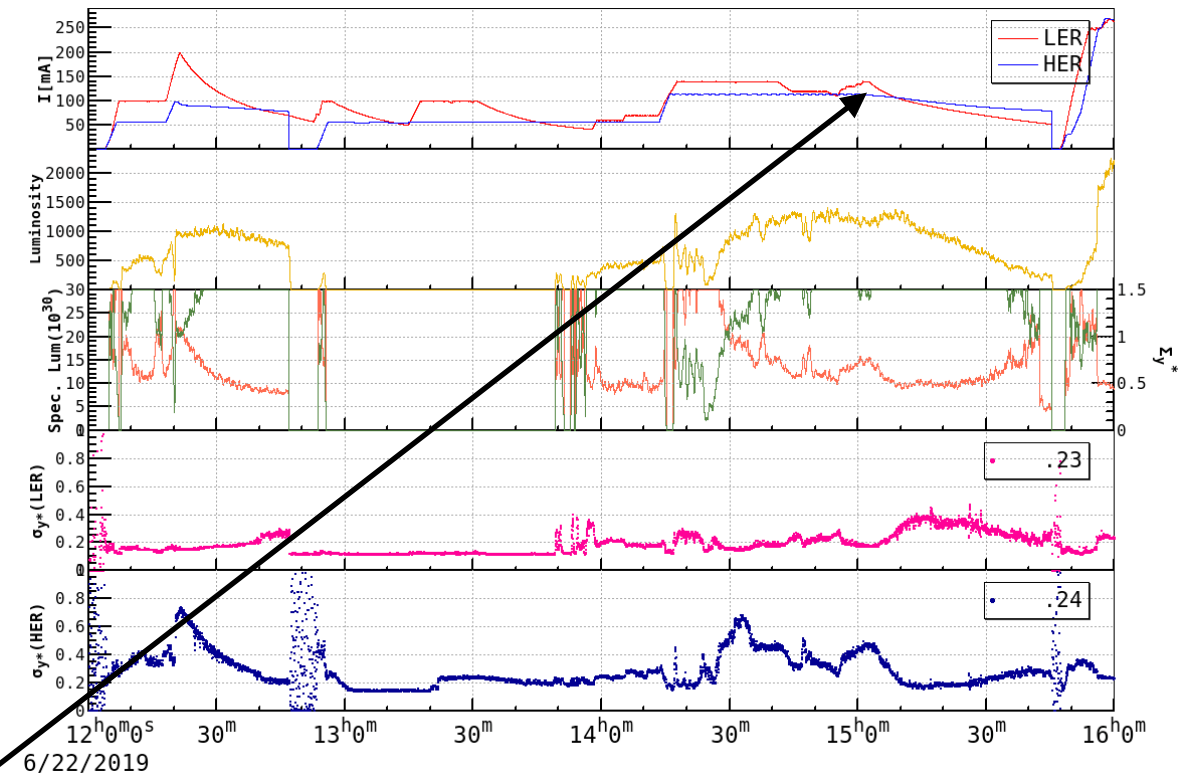
- Second observation: **14:51 PM**
- **119 mA (e+) x 113 mA (e-)**
- $\sigma_y^*(e^+) = 0.23 \mu\text{m}$, $\sigma_y^*(e^-) = 0.33 \mu\text{m}$ [XRM]
- Lum. $\sim 12.5 \cdot 10^{32} \text{ cm}^{-2}\text{s}^{-1}$
- Beam-beam parameter estimated from lum.:
 $\xi_{y-} \sim 0.024$, $\xi_{y+} \sim 0.018$
- From feedback system:
 $\xi_{y+} \sim ? \text{ kHz} / 99.39 \text{ kHz} \sim ?$



1. 2019.06.22: Beam-beam tune shift study

► Experimental observations

- Third observation: **15:02 PM**
- **140 mA (e+) x 113 mA (e-)**
- $\sigma_y^*(e+) = 0.17 \mu\text{m}$, $\sigma_y^*(e-) = 0.46 \mu\text{m}$ [XRM]
- Lum. $\sim 11.5 \cdot 10^{32} \text{ cm}^{-2}\text{s}^{-1}$
- Beam-beam parameter estimated from lum.:
 $\xi_{y-} \sim 0.031$, $\xi_{y+} \sim 0.015$
- From feedback system:
 $\xi_{y+} \sim ? \text{ kHz} / 99.39 \text{ kHz} \sim ?$



1. 2019.06.22: Beam-beam tune shift study

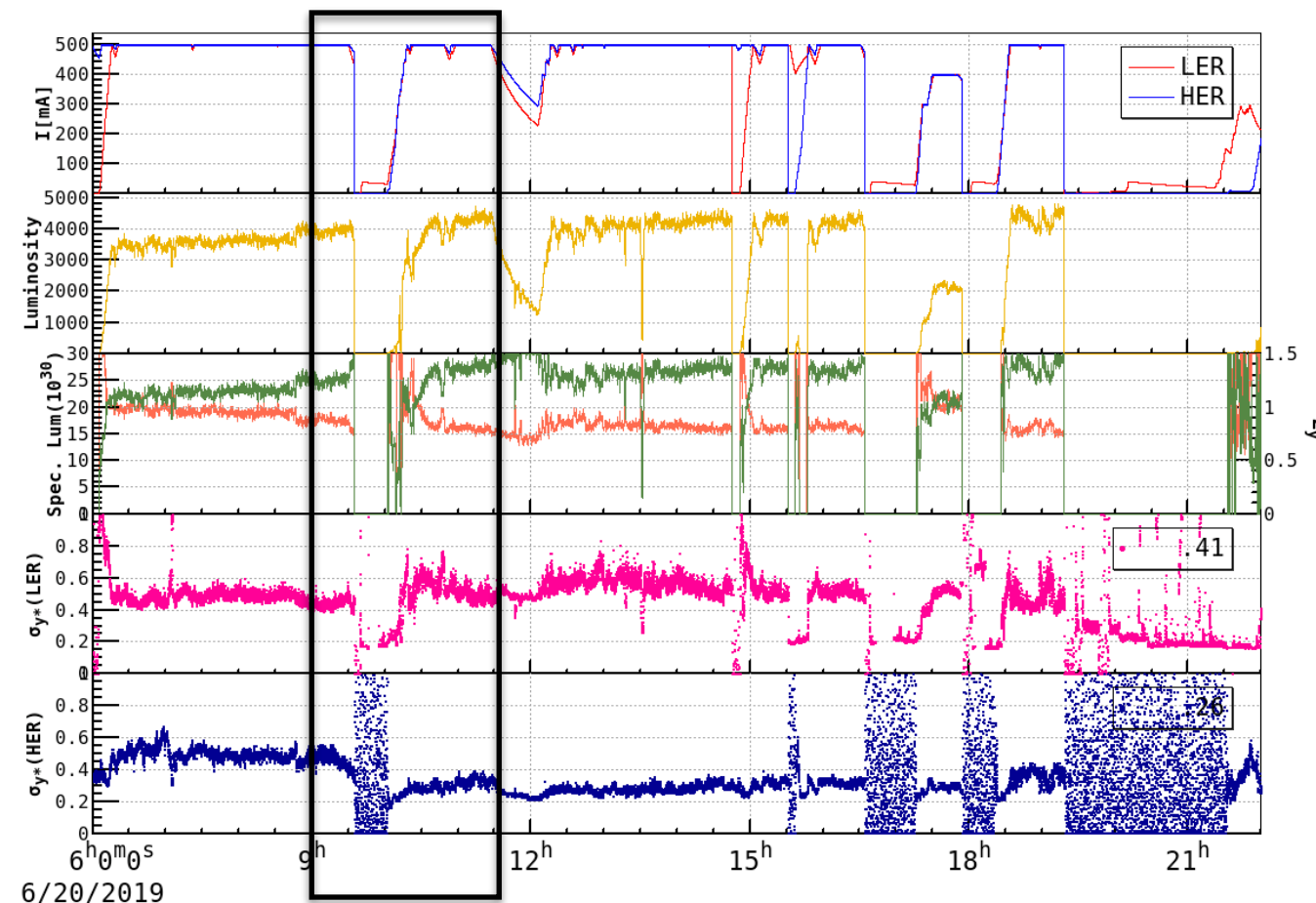
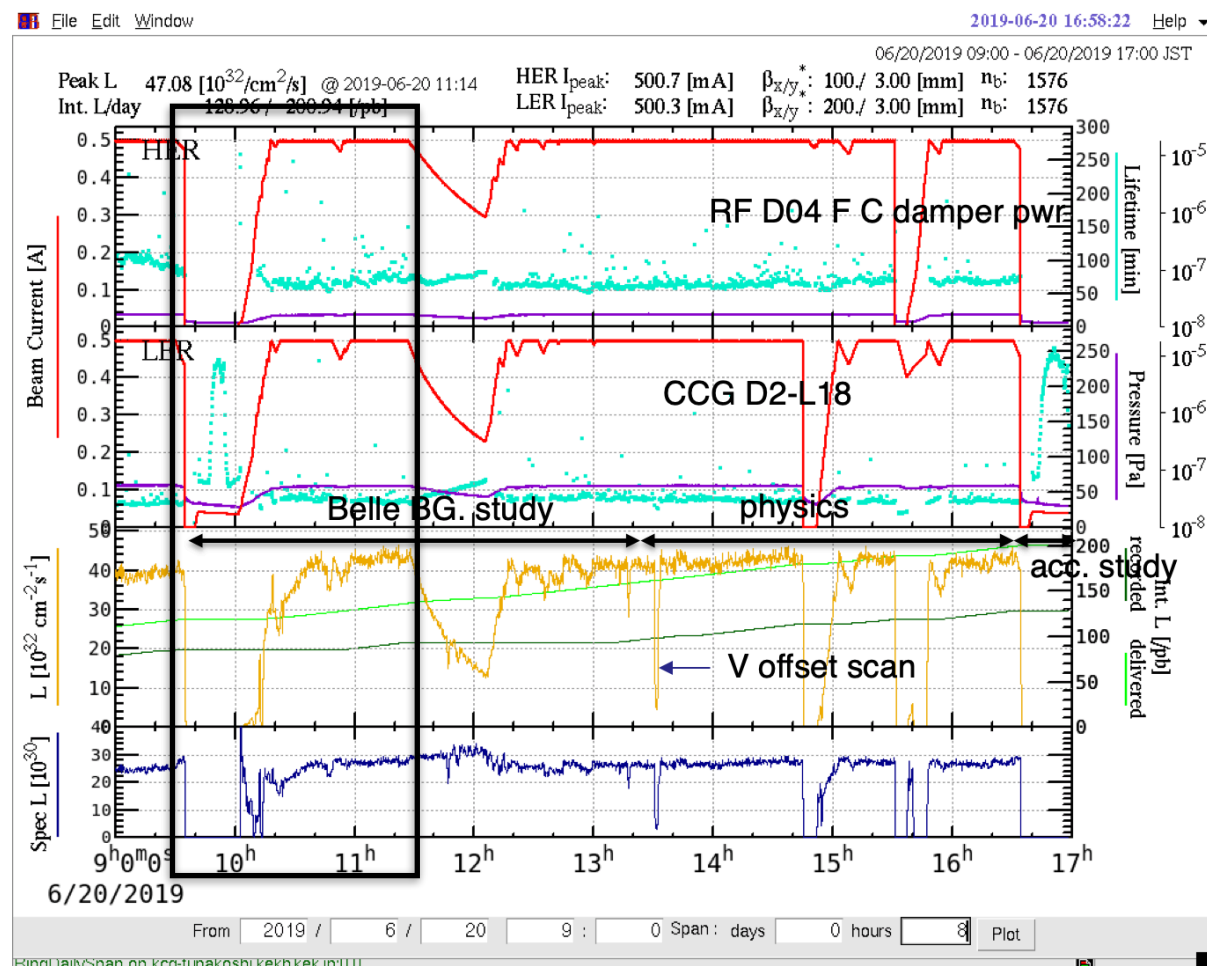
➤ Future study

- Better balanced beam
- Adjust excitation force of feedback system
- Better collision condition (IP knobs optimized, such as iBump V-offset, stabilized vertical beam sizes, equalized beam-beam tune shift for two beams, etc.)
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2. 2019.06.20: V-angle change during collision tuning

➤ Experimental observations

- Remarkable improvement in luminosity by adjusting V-angle during background study
- Vertical size of e- beam reduced significantly



Day shift report on 2019.06.20 (Fukuma-san)

2. 2019.06.20: V-angle change during collision tuning

➤ BBWS simulations to explain the experimental observations

- BBWS: Beam-Beam Weak-Strong simulation code by K. Ohmi
- ζ_y as the input parameter to model the V-angle
- $\varepsilon_{y-}=7.5$ pm, $\varepsilon_{y+}=18$ pm: Estimated from XRM data for single beams (without collision)

	2019.06.20 (case 1)		2019.06.20 (case 2)		2019.06.20 (case 3)	
	HER	LER	HER	LER	HER	LER
I_b (A)	0.5	0.5	0.5	0.5	0.5	0.5
# bunch	1576		1576		1576	
ε_x (nm)	4.537	1.64	4.537	1.64	4.537	1.64
ε_y (pm)	7.5	18	50	18	50	80
β_x (mm)	100	200	100	200	100	200
β_y (mm)	3	3	3	3	3	3
σ_z (mm)	5.5	5.0	5.5	5.0	5.5	5.0
σ_y (nm)	150	232	387	232	387	490
v_x	45.5439	44.559	45.5439	44.559	45.5439	44.559
v_y	43.6082	46.618	43.6082	46.618	43.6082	46.618
v_s	0.02718	0.023	0.02718	0.023	0.02718	0.023
ξ_y (Geom.)	0.041	0.1	0.041	0.039	0.019	0.039
$\mathcal{L}$ (Geom.)	1.16E+34		7.1E+33		5.1E+33	

2. 2019.06.20: V-angle change during collision tuning

► BBWS simulations to explain the experimental observations

- The observed lum. improvement was mainly from the reduced vertical e- beam size
- Vertical angle can cause luminosity loss: just geometric loss if there is no instability
- BUT, if two beams with small vertical emittance collide and there is beam-beam instability, the beam instability is also sensitive to vertical crossing angle (see the red line) => Then curing vertical crossing angle will create additional again

Somehow consistent with experimental observations?

