Dynamic Aperture Optimization with constraints

for SuperKEKB LER

Hiroshi Sugimoto
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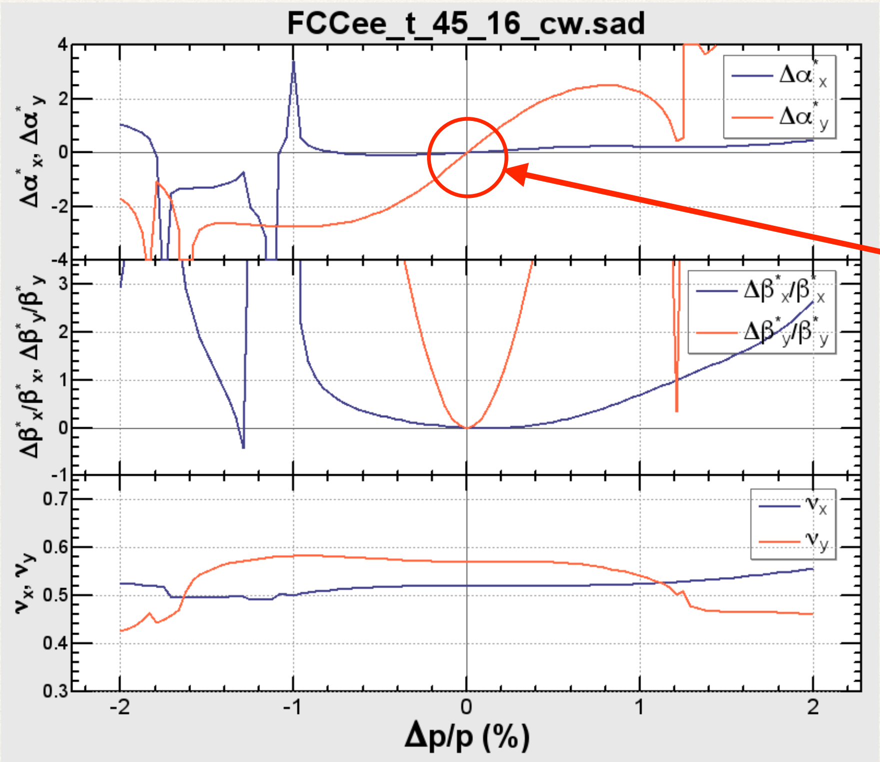
Optimization of dynamic aperture

K. Oide

Since 1986 SAD Strategic Accelerator Design

- Constraints on $\partial\beta^*/\partial\delta$, $\partial\alpha^*/\partial\delta$, $\partial\mu/\partial\delta$ are necessary for operation of a collider maintaining the luminosity.

- $\partial R^*/\partial\delta$ are also important in the case of SuperKEKB.

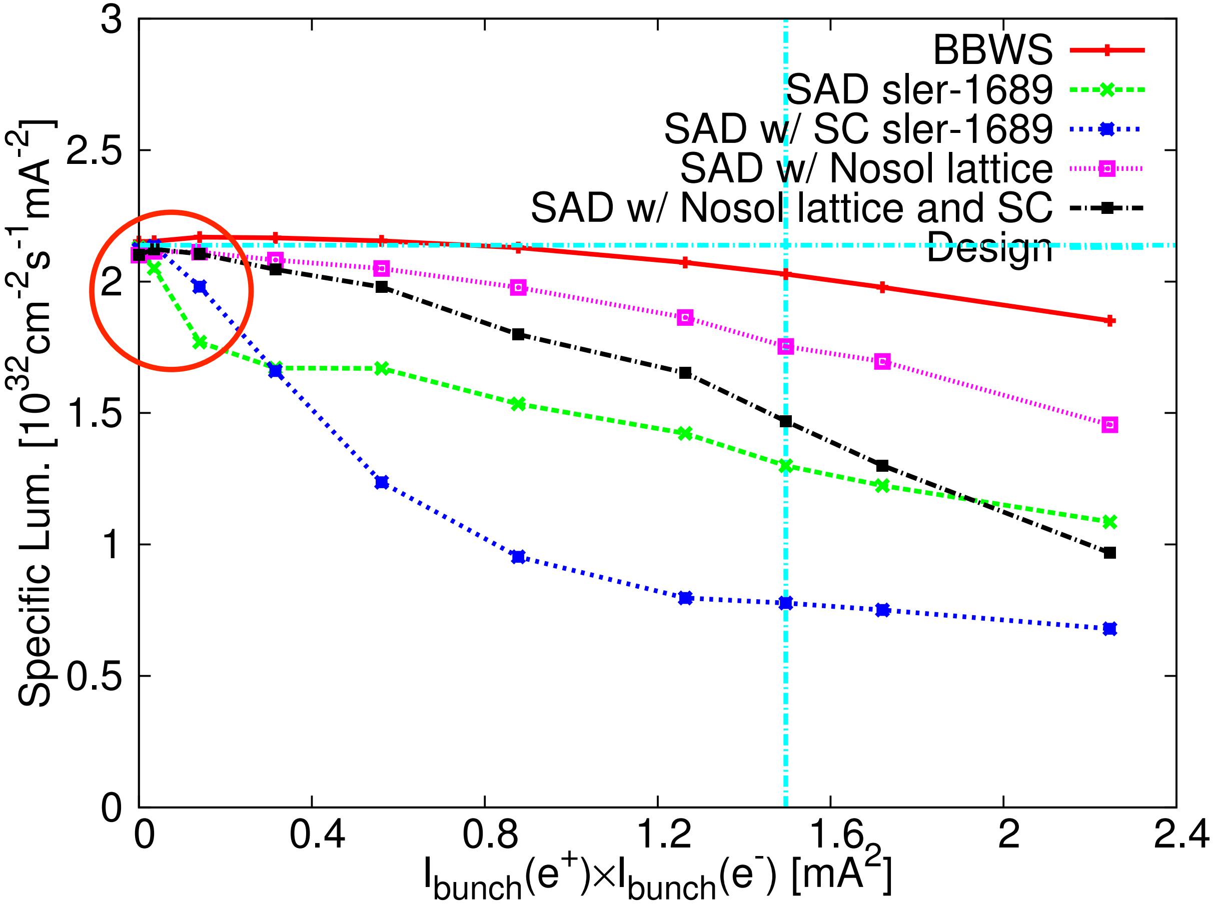


This example causes a shift of vertical waist $\Delta s(\delta) \approx 1$ mm for $\delta = \pm 0.1\%$: Reduction of luminosity may appear even at zero intensity.
It may have something to do with the luminosity observed in the simulation with lattice (D. Zhou).

Optimized DA without constraints at the IP

Luminosity Loss at Low Current

D. Zhou



Constraints at the IP

K. Oide

The momentum dependence of the Twiss parameters at the IP:

$$\frac{1}{\beta^*}\frac{\partial \beta^*}{\partial \delta} \propto \sum_i k_{2i}\beta_i\eta_{xi}\cos(2|\psi_i - \psi^*| - \mu)$$

$$\frac{\partial \alpha^*}{\partial \delta} \propto \sum_i k_{2i}\beta_i\eta_{xi}\sin(2|\psi_i - \psi^*| - \mu)$$

Thus if we keep the condition

$$\sum_i \Delta k_{2i}\beta_i\eta_{xi}\exp(2|\psi_i - \psi^*|) = 0$$

together with tune chromaticity condition

$$\sum_i \Delta k_{2i}\beta_i\eta_{xi} = 0$$

during the optimization of k_{2i}, then the chromatic dependences of β^*, α^* do not change. In other words, the sextupoles must satisfy

$$\sum_i C_{ki}k_{2i} = v_k, (k = 1, 6) \ . \tag{1}$$

Application to SuperKEKB

- Chromatic XY-coupling should also be considered during the optimization of skew sextupole field.
- Assuming $\alpha_x^* = \alpha_y^* = 0$ at the IP.

$$\sqrt{\frac{\beta_x^*}{\beta_y^*}}\frac{\partial R_1^*}{\partial \delta} \propto \sum_{\text{skew}} K_2^{\text{skew}} \eta_x \sqrt{\beta_x \beta_y} \left\{ \frac{\cos(\Delta\phi_- - \pi\nu_-)}{\sin \pi\nu_-} - \frac{\cos(\Delta\phi_+ - \pi\nu_+)}{\sin \pi\nu_+} \right\}$$

$$\frac{1}{\sqrt{\beta_x^* \beta_y^*}}\frac{\partial R_2^*}{\partial \delta} \propto \sum_{\text{skew}} K_2^{\text{skew}} \eta_x \sqrt{\beta_x \beta_y} \left\{ \frac{\sin(\Delta\phi_+ - \pi\nu_+)}{\sin \pi\nu_+} - \frac{\sin(\Delta\phi_- - \pi\nu_-)}{\sin \pi\nu_-} \right\}$$

$$\sqrt{\beta_x^* \beta_y^*}\frac{\partial R_3^*}{\partial \delta} \propto \sum_{\text{skew}} K_2^{\text{skew}} \eta_x \sqrt{\beta_x \beta_y} \left\{ \frac{\sin(\Delta\phi_+ - \pi\nu_+)}{\sin \pi\nu_+} + \frac{\sin(\Delta\phi_- - \pi\nu_-)}{\sin \pi\nu_-} \right\}$$

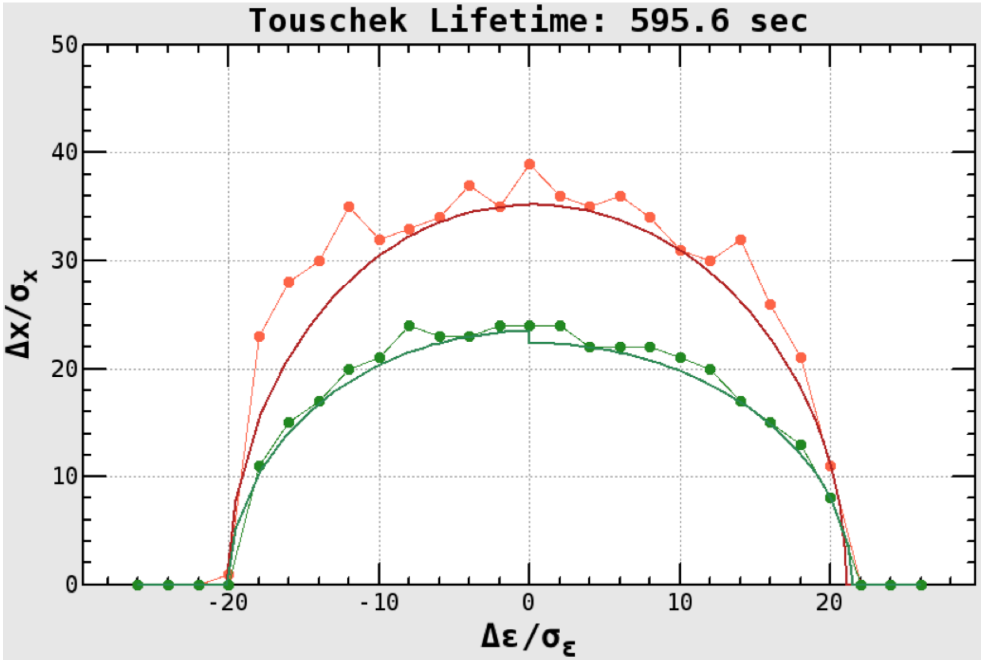
$$\sqrt{\frac{\beta_y^*}{\beta_x^*}}\frac{\partial R_4^*}{\partial \delta} \propto \sum_{\text{skew}} K_2^{\text{skew}} \eta_x \sqrt{\beta_x \beta_y} \left\{ \frac{\cos(\Delta\phi_- - \pi\nu_-)}{\sin \pi\nu_-} + \frac{\cos(\Delta\phi_+ - \pi\nu_+)}{\sin \pi\nu_+} \right\}$$

$$\nu_\pm \equiv \nu_x \pm \nu_y \quad \Delta\phi_\pm \equiv \Delta\phi_x \pm \Delta\phi_y \quad \Delta\phi_{x,y} = |\phi_{x,y}^* - \phi_{x,y}|$$

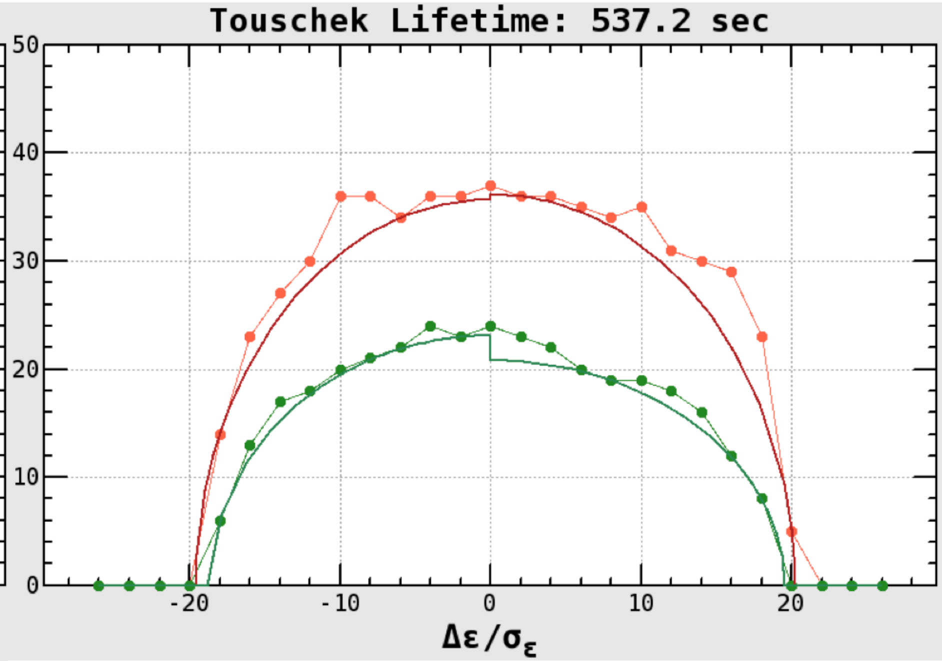
- Using the above expressions,
  we can keep chromatic XY-coupling constant in the same manner.

Dynamic Aperture

sler_1689 W/O constraints

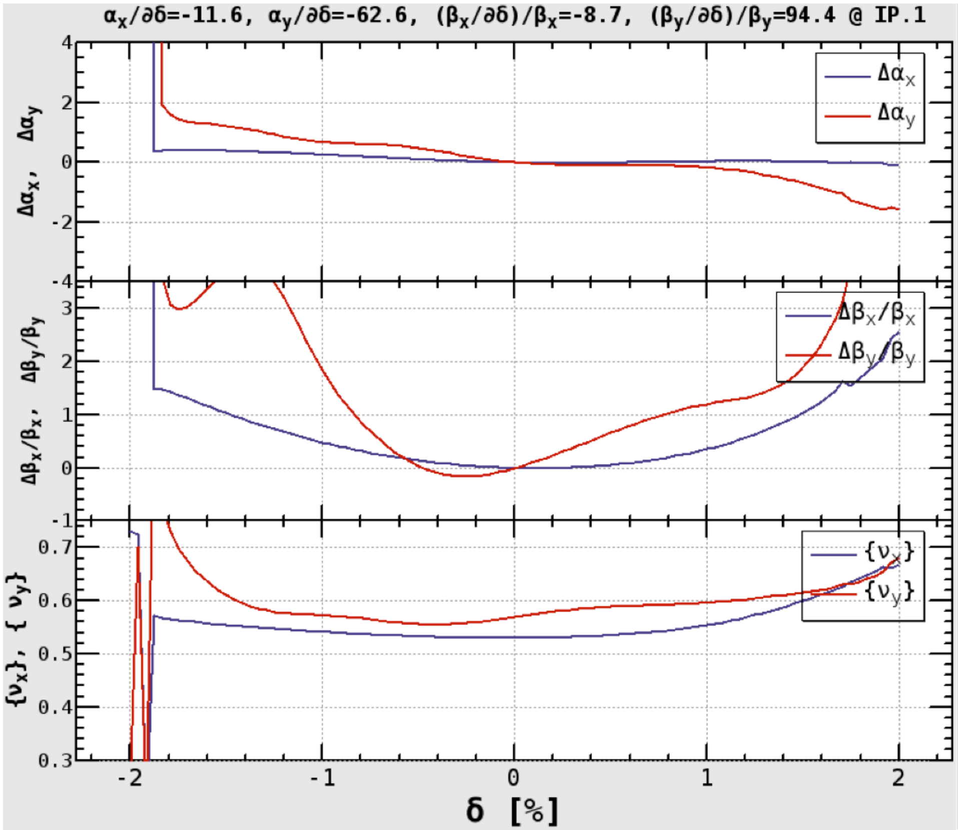


sler_1689 W/ constraints

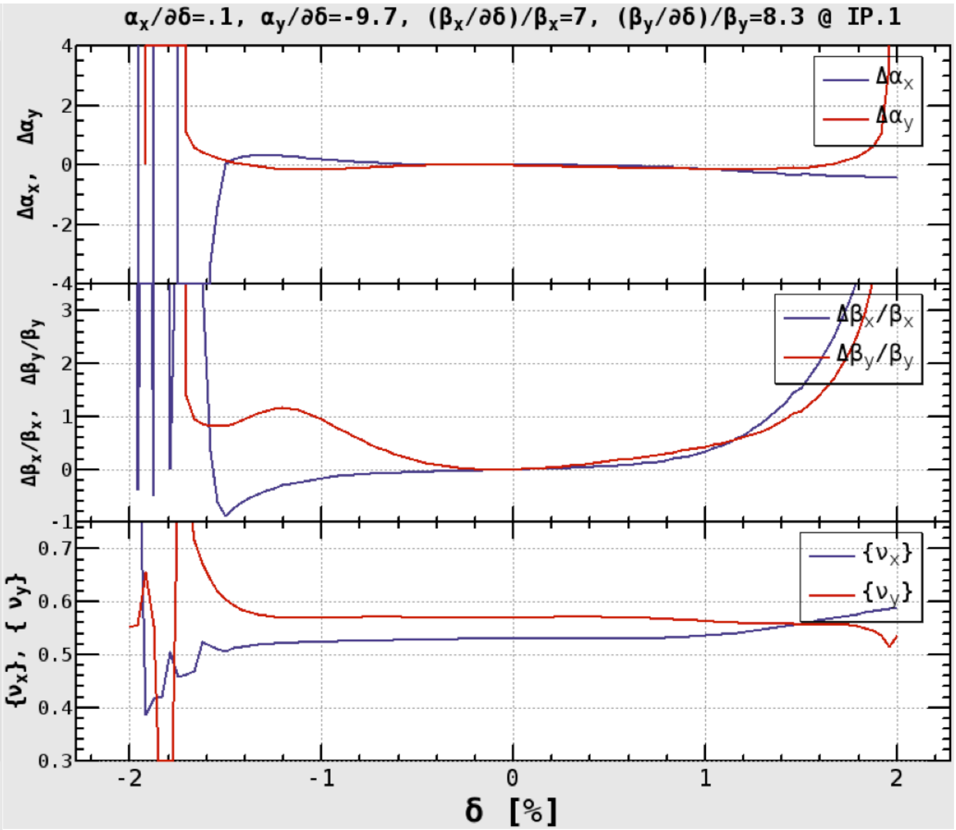


Beta Chromaticity

sler_1689 W/O constraints

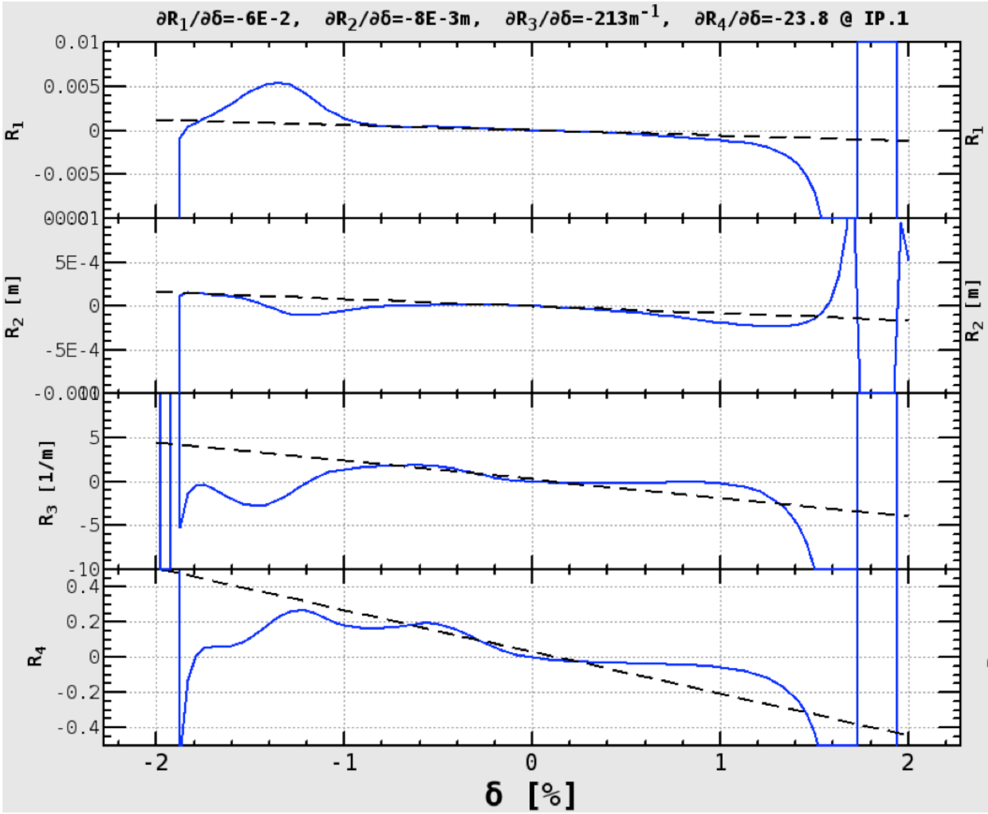


sler_1689 W/ constraints

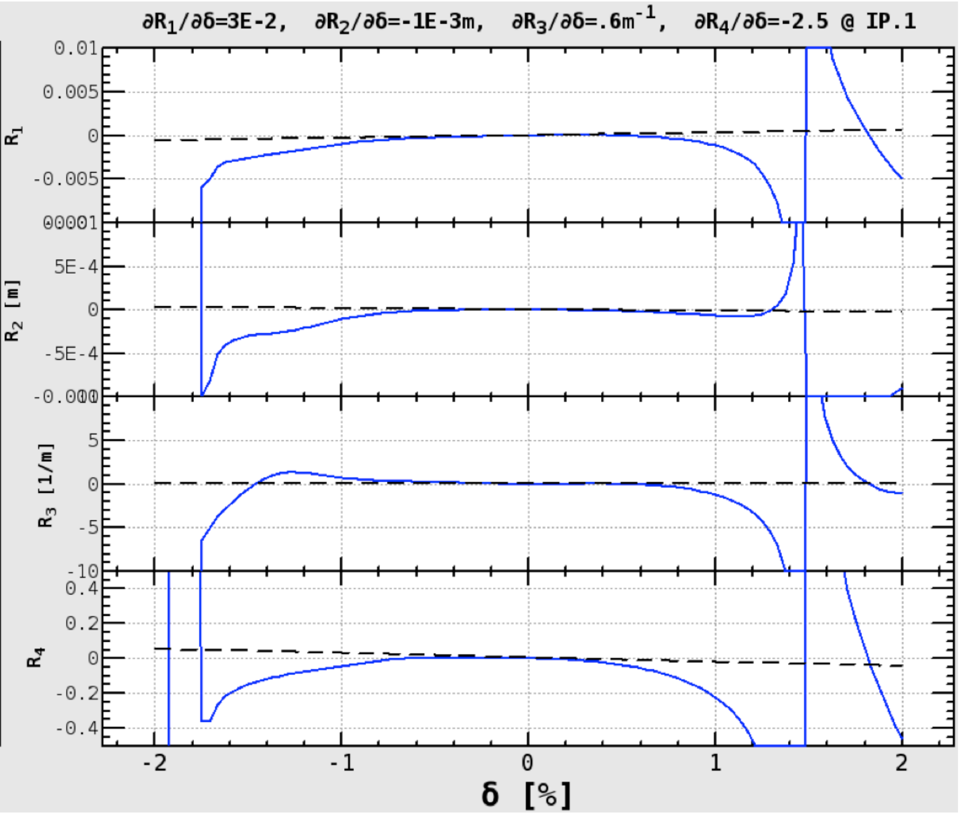


Chromatic XY-coupling

sler_1689 W/O constraints

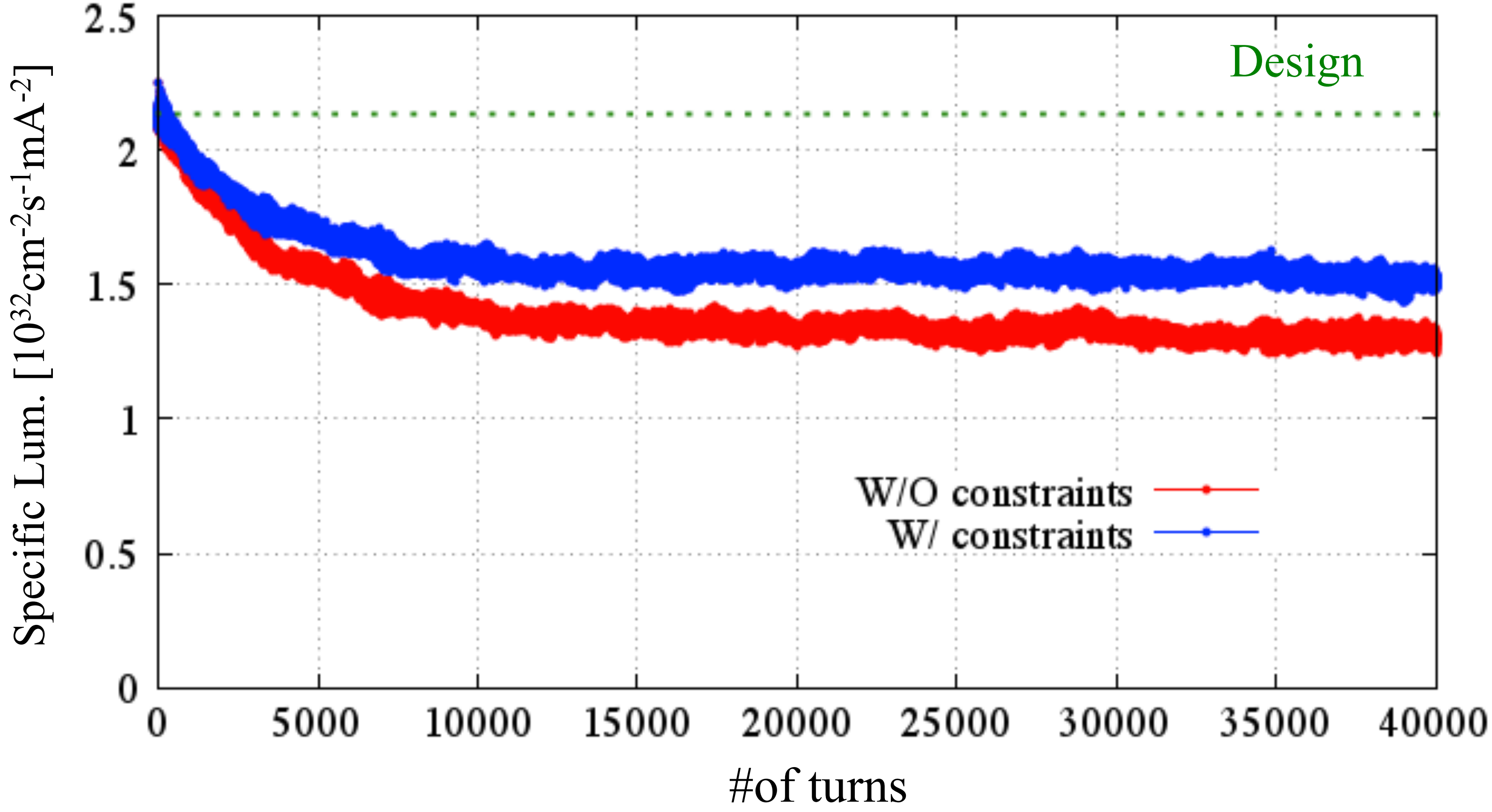


sler_1689 W/ constraints



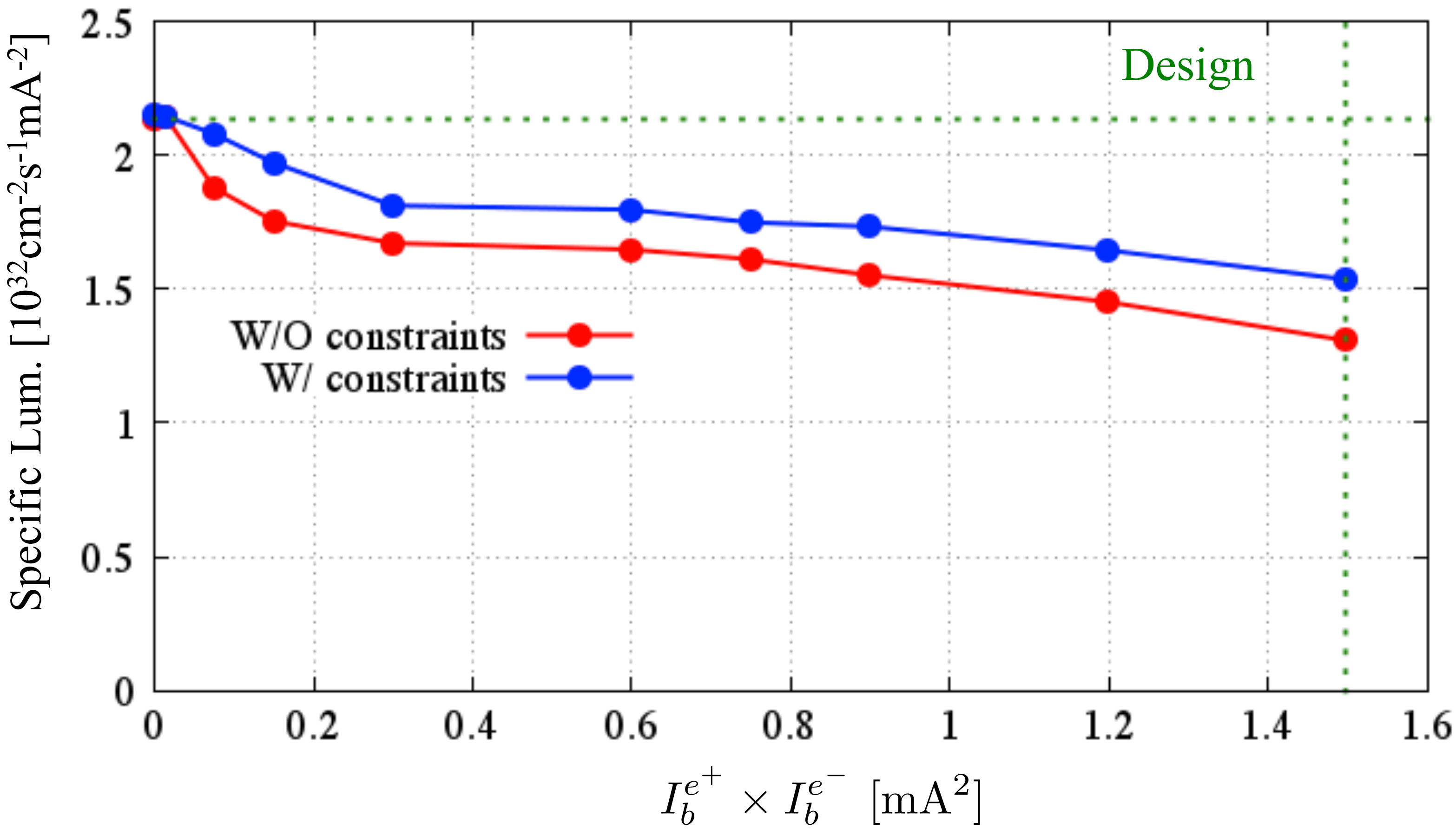
Specific Luminosity (WS simulation)

Design bunch current



- Luminosity performance is improved as expected.

Specific Luminosity (WS simulation)



- The luminosity loss at low current becomes smaller, but still observed.

Summary

- Inspired by Oide-san's work, the SuperKEKB DA is re-optimized with constraints.
- Chromatic XY-coupling should also be considered in the SuperKEKB case.
- Luminosity performance gets better as expected.
- The luminosity loss at low bunch current is improved, but we still observe that luminosity is very sensitive as well as DA.
- Next
  - Study for HER

作業予定

着手済み

- 山本昇氏提唱のベータ関数解析の検討
- ダンピングリングの光学補正の検討、デザインレポート

未着手

- エラー付きモデルラティスによるエミッタンス評価の論文化？
  - 既に類似の論文があるので独自性が低いのでは？
    e.g. PhysRevSTAB.14.034002
- ダンピングリングのコミッショニングツール
- etc.