Comparison of resonance driving terms for SuperKEKB before and after optimizations - Updates

Demin Zhou

Acknowledgements:

K. Ohmi, K. Hirosawa, H. Sugimoto, K. Oide, E. Forest, D. Sagan (Cornell)

Study memo, Mar. 13, 2018

Outline

- ➢ Introduction
  - Lattice:
    sler_1689.sad
    sler_1689_w_const001.sad (by H. Sugimoto)
- ➢ Theory for resonance driving terms
- ➢ Results by PTC (updates)
  - 3rd and 4th order RDTs
  - Momentum-dependent RDTs
- ➢ Other updates
  - Ohmi-Hirosawa method compared with PTC
  - Luminosity calculation
- ➢ Summary

1. Introduction

➤ **Relates presentations in past SuperKEKB mini-optics meetings**

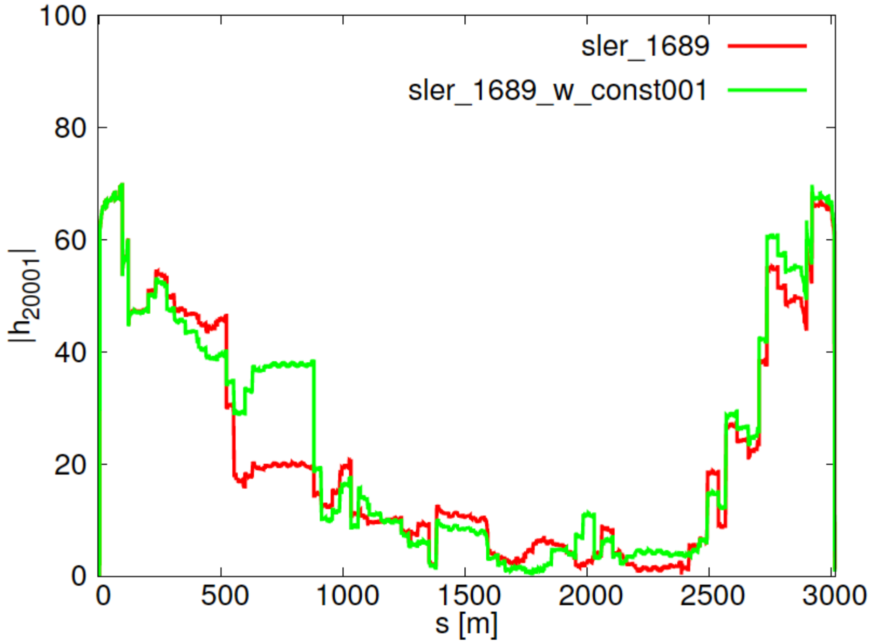
- **H. Sugimoto, Sep. 8, 2016**
- **D. Zhou, Dec. 8, 2016 (There were mistakes in my slides, thanks to H. Sugimoto)**
- **H. Sugimoto, Apr. 6, 2017**
- **K. Hirosawa, Jul. 6, 2017**
- **K. Ohmi, Sep. 21, 2017**
- **H. Sugimoto, Oct. 12, 2017**
- **D. Zhou, Feb. 15, 2018**

3. Results by PTC: Chromatic β and ν

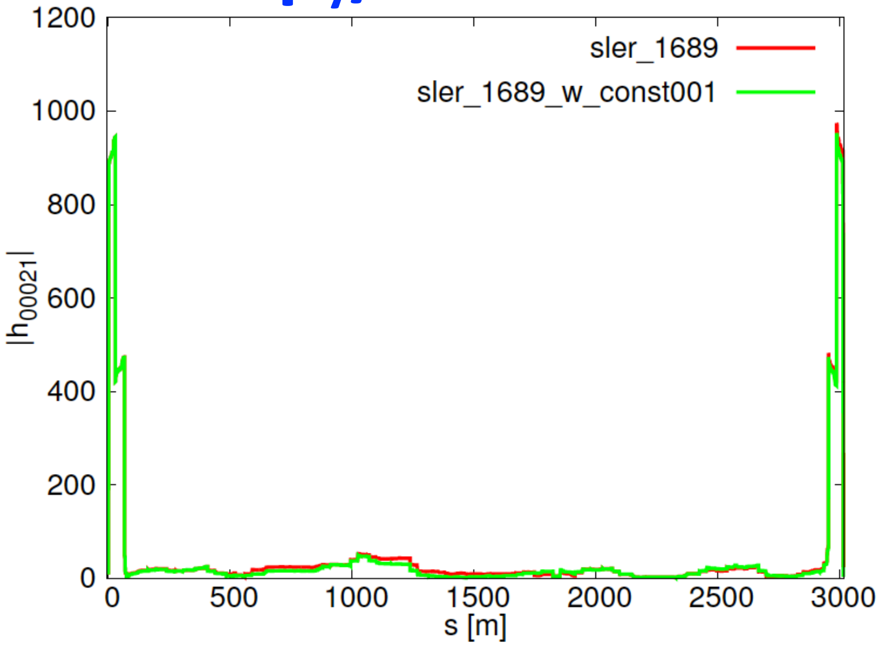
➤ **Detuning along the whole ring**

- **w/ constraints: chromatic correction**

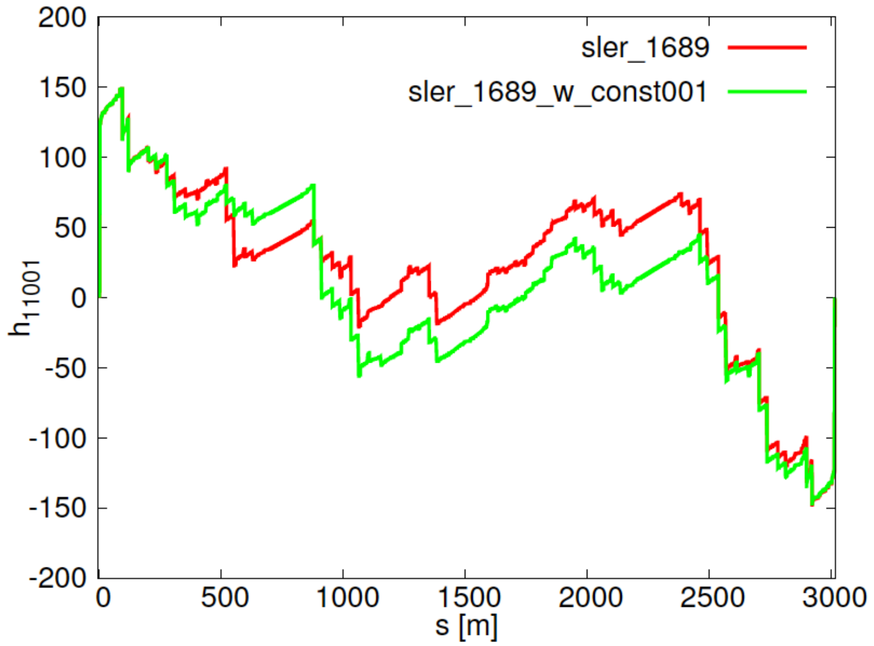
$d\beta_x/d\delta$



$d\beta_y/d\delta$



$d\nu_x/d\delta$



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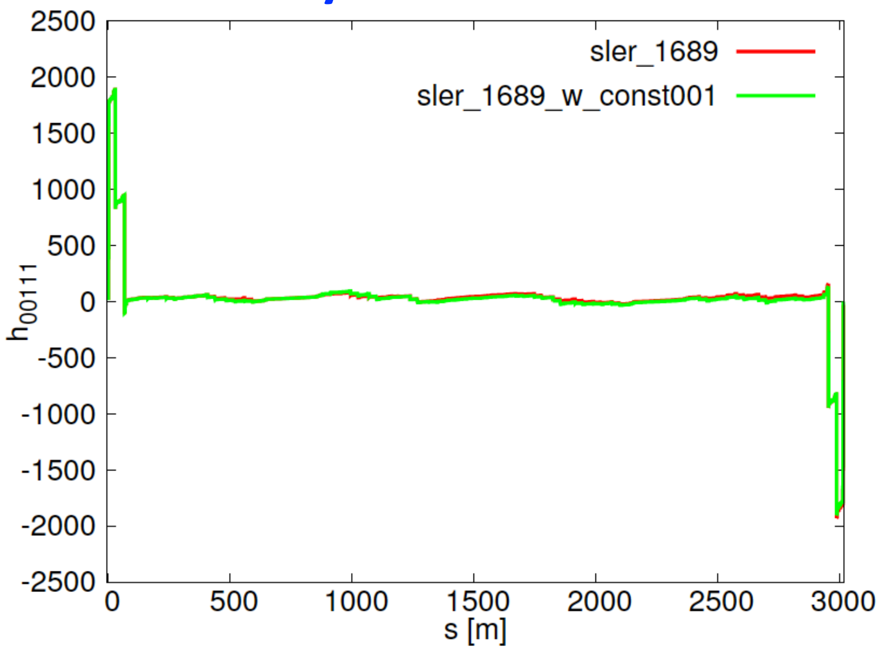

3. Results by PTC: Chromatic β and ν (IR)

➤ **Detuning along the whole ring**

- **w/ constraints: chromatic correction**

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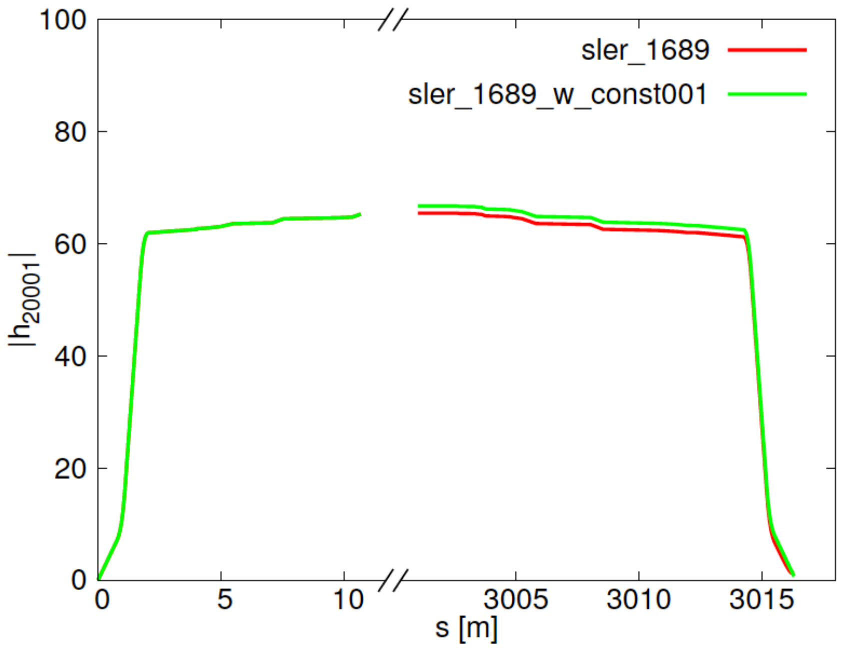
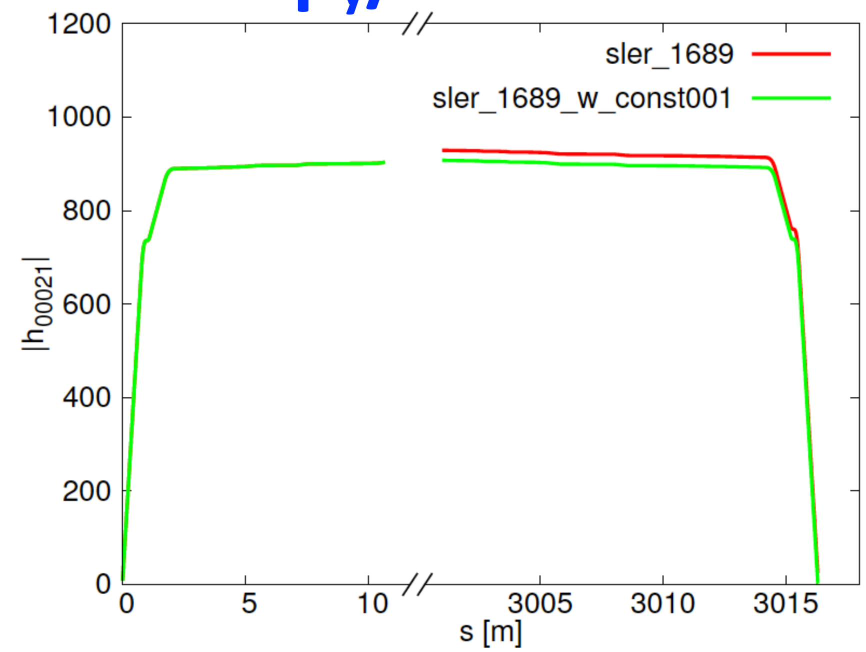
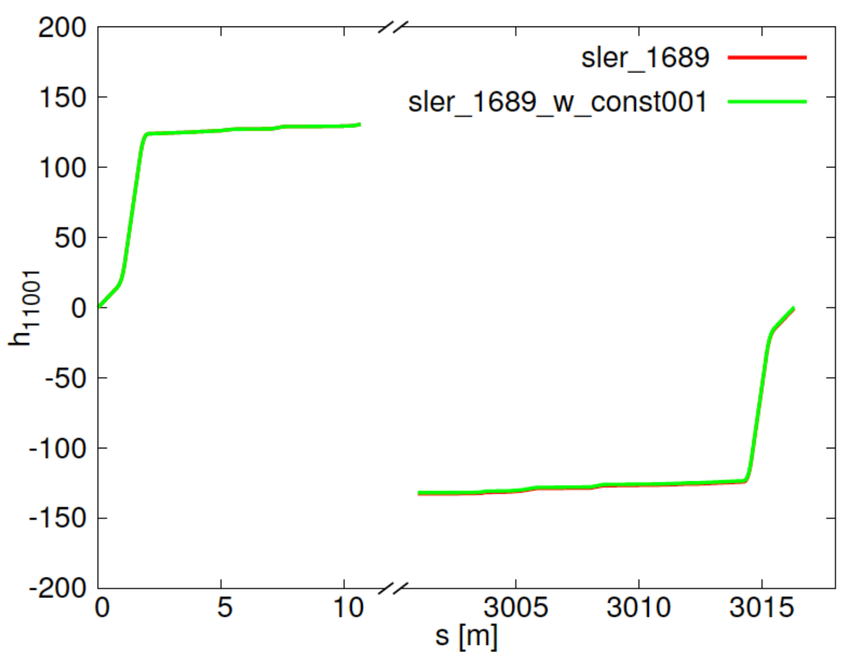


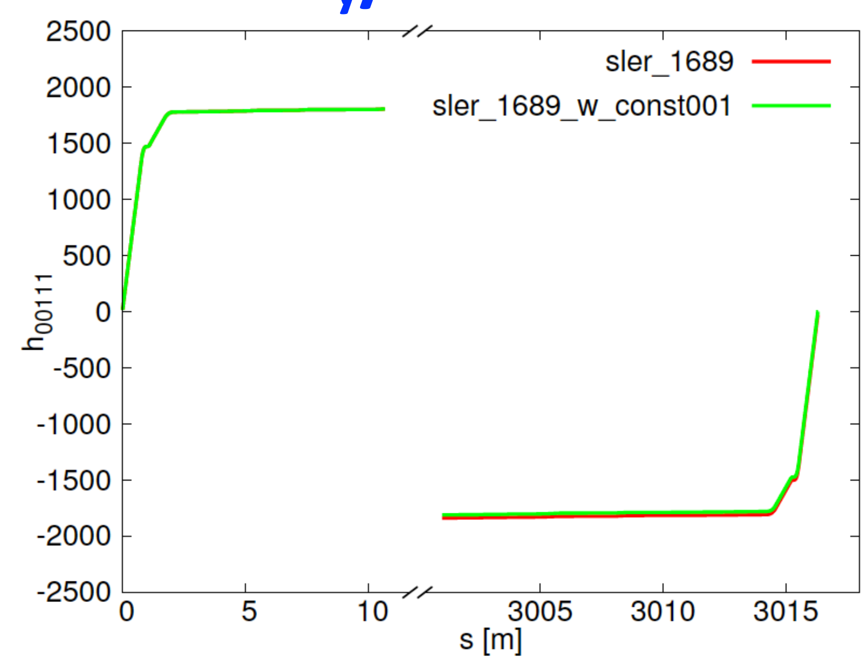
$d\beta_y/d\delta$



$d\nu_x/d\delta$



$d\nu_y/d\delta$

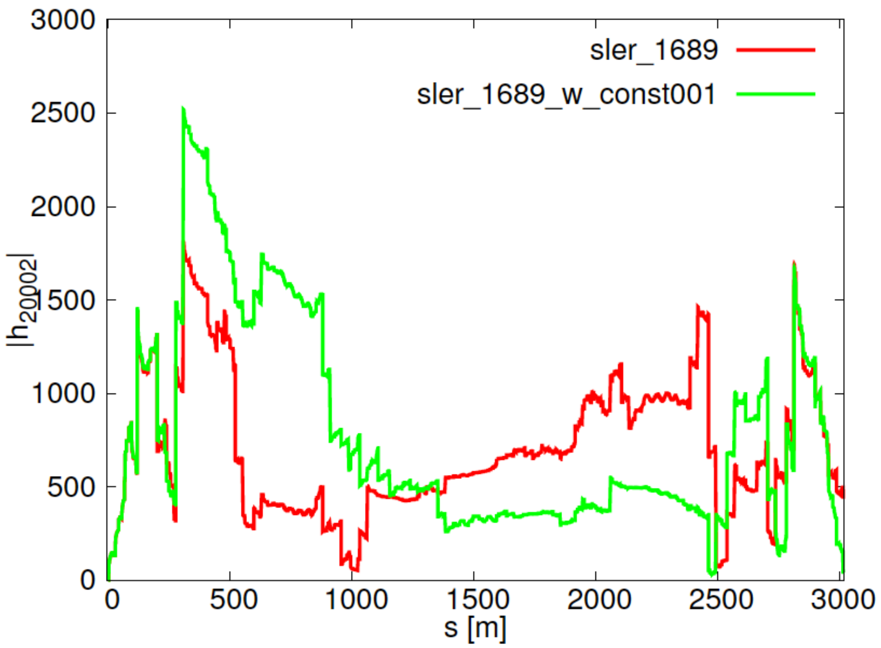


3. Results by PTC: Chromatic β and ν

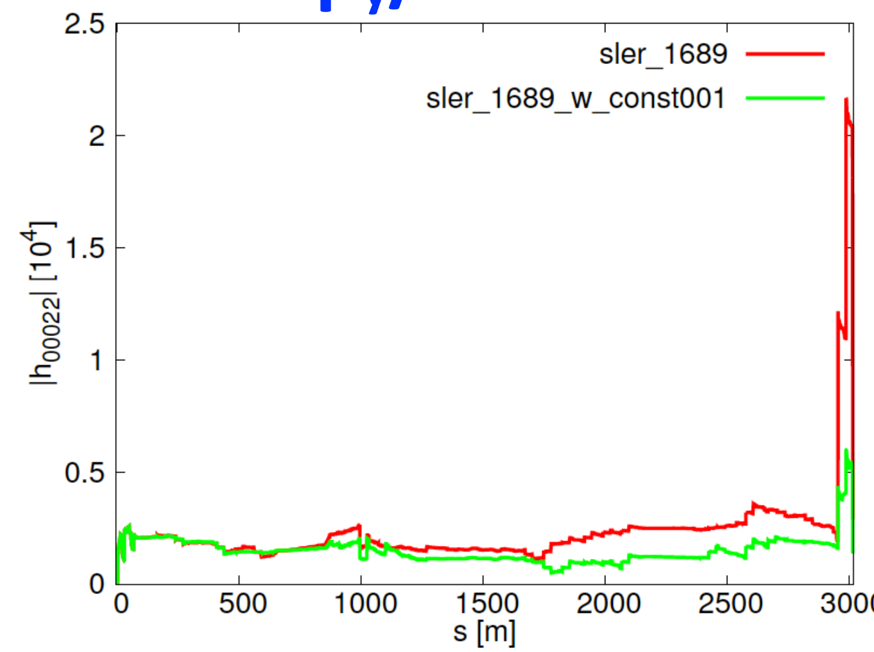
➤ Detuning along the whole ring - second order

- **w/ constraints: chromatic correction**

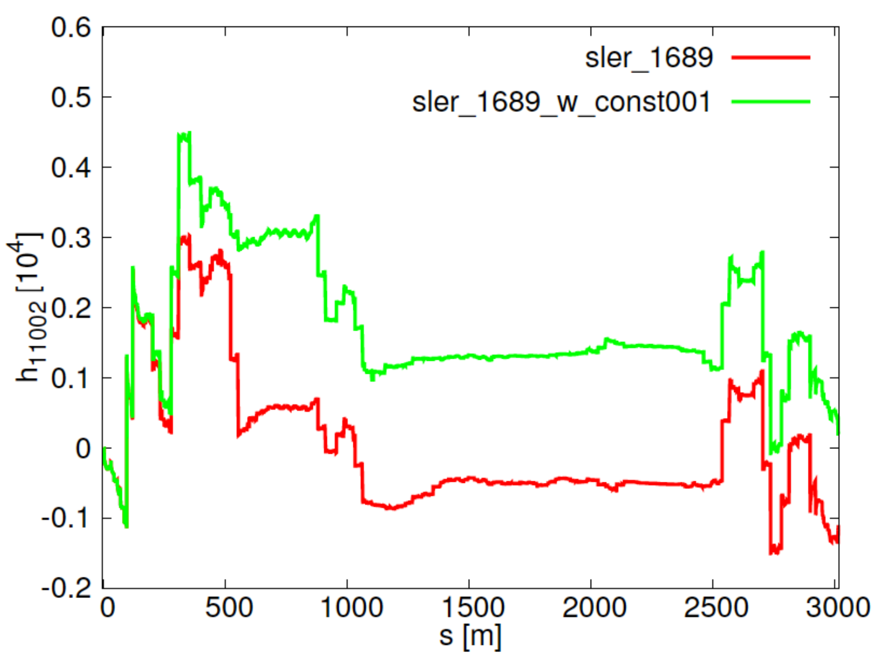
$d^2\beta_x/d\delta^2$



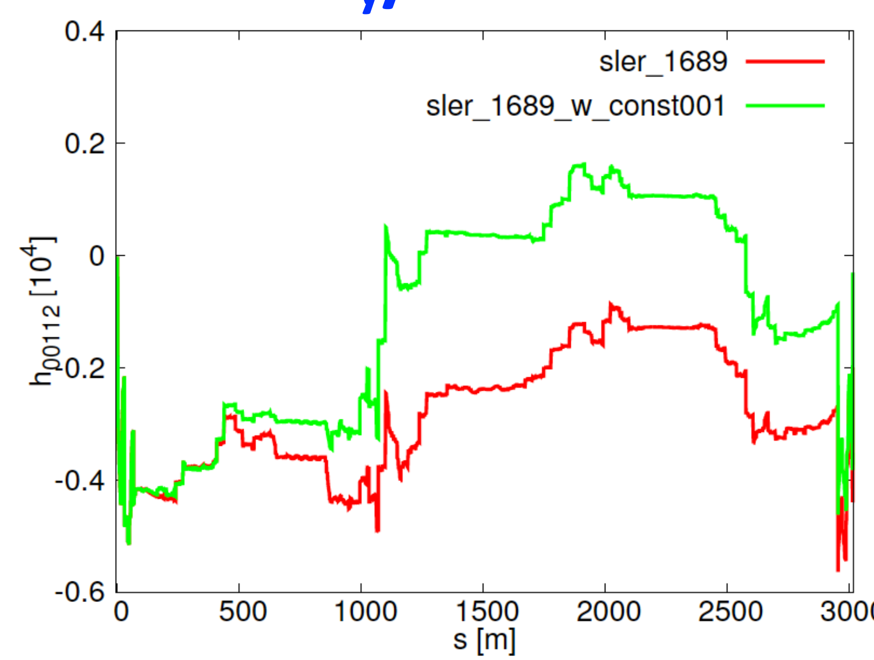
$d^2\beta_y/d\delta^2$



$d^2\nu_x/d\delta^2$



$d^2\nu_y/d\delta^2$

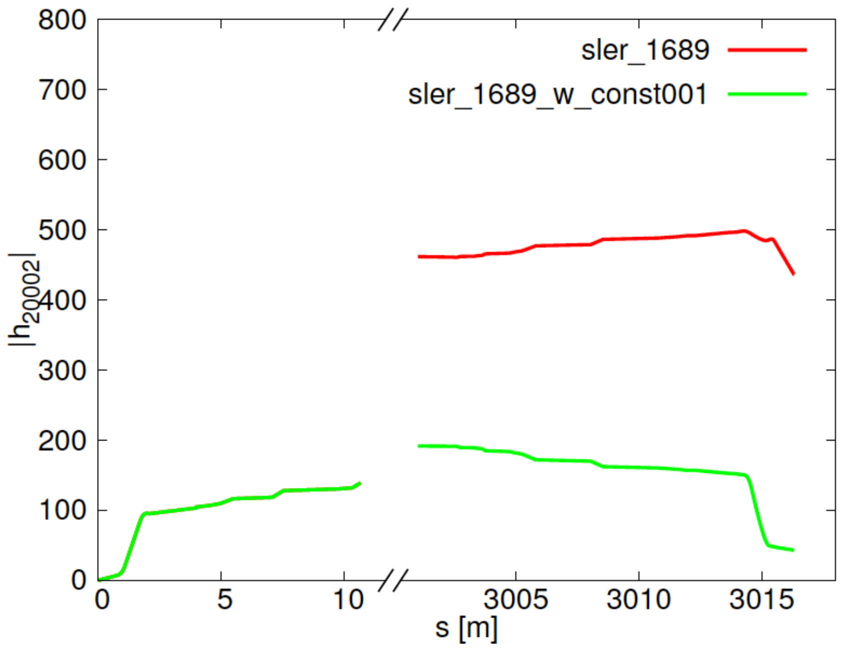


3. Results by PTC: Chromatic β and ν (IR)

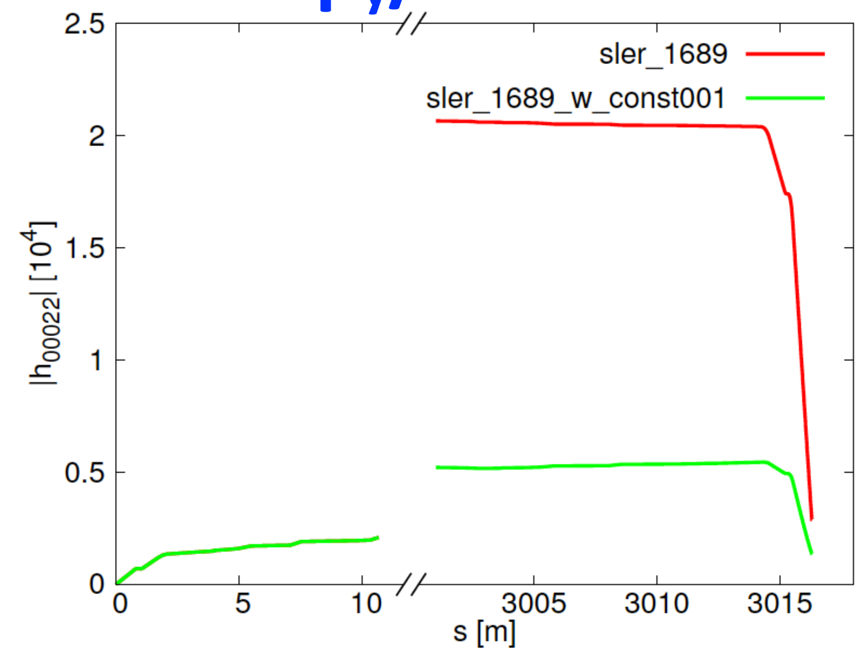
➤ **Detuning along the whole ring - second order**

- **w/ constraints: chromatic correction**

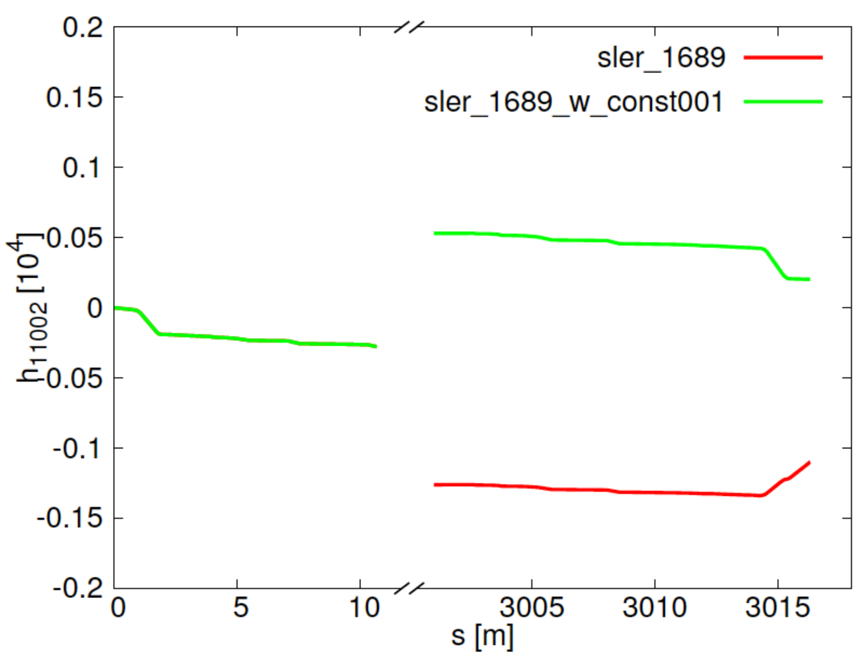
$d^2\beta_x/d\delta^2$



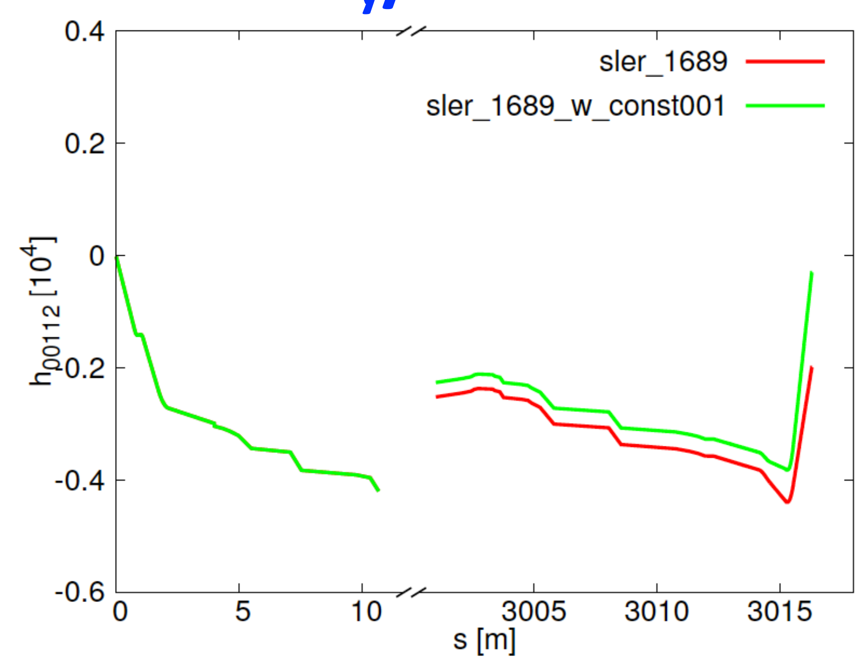
$d^2\beta_y/d\delta^2$



$d^2\nu_x/d\delta^2$



$d^2\nu_y/d\delta^2$

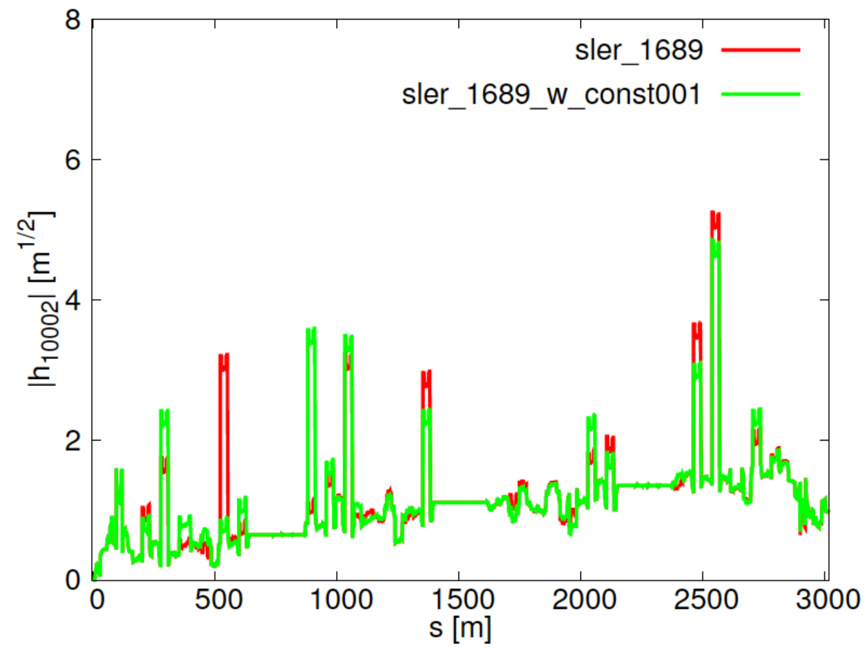


3. Results by PTC: Chromatic dispersion

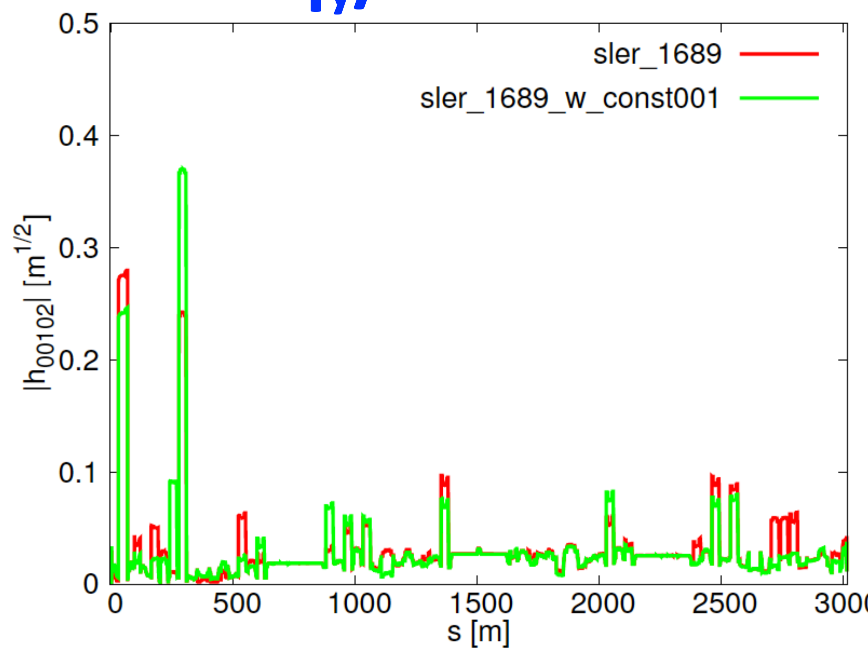
➤ Dispersion along the whole ring

- **w/ constraints: No special control on chromatic dispersions?**

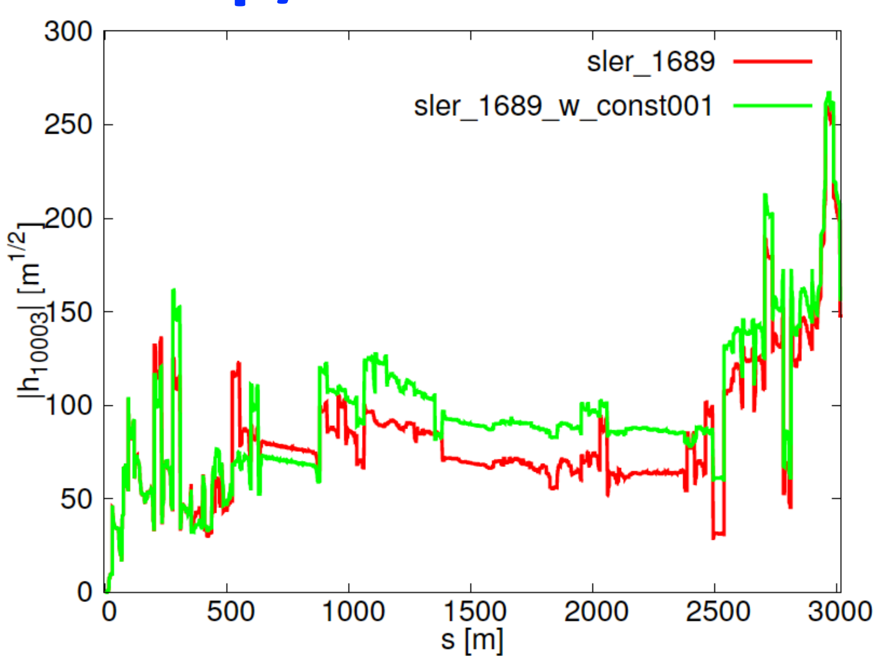
$d\eta_x/d\delta$



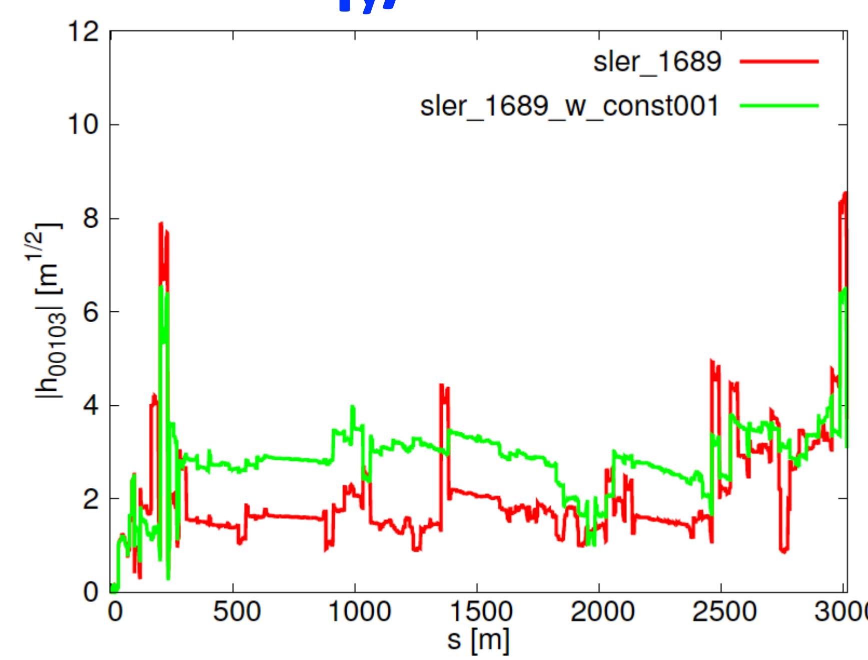
$d\eta_y/d\delta$



$d^2\eta_x/d\delta^2$



$d^2\eta_y/d\delta^2$

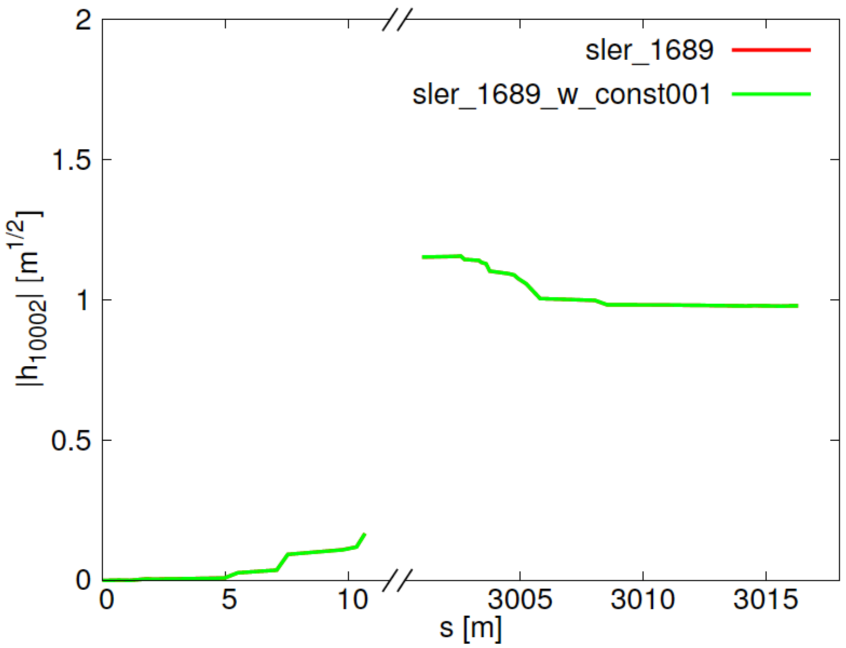


3. Results by PTC: Chromatic dispersion (IR)

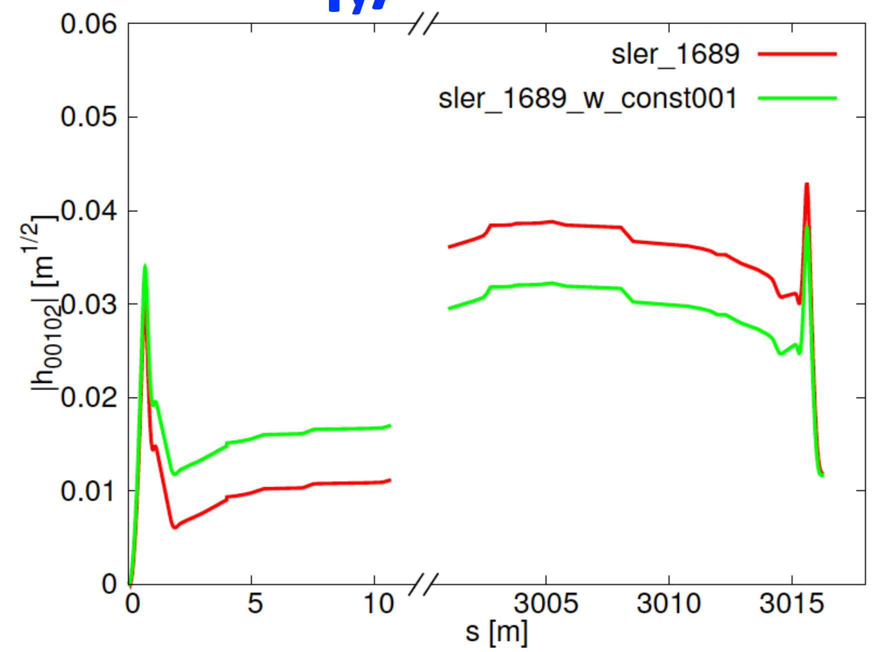
➤ Dispersion along the whole ring

- **w/ constraints: No special control on chromatic dispersions?**

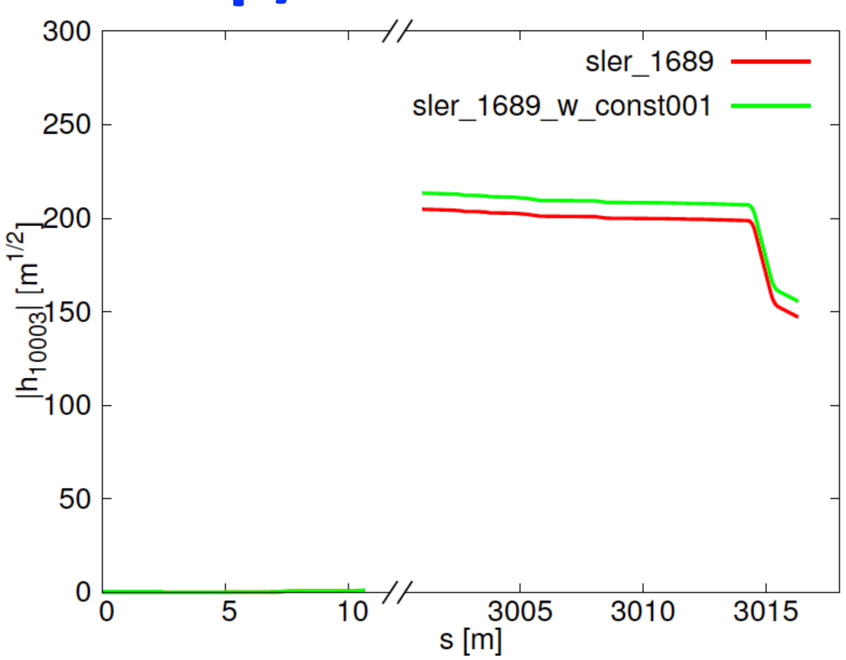
$d\eta_x/d\delta$



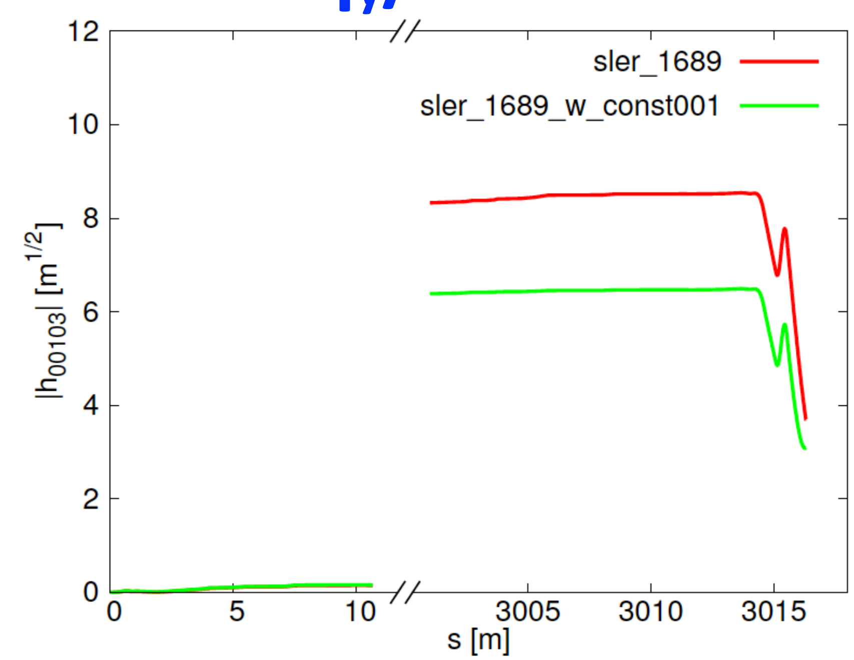
$d\eta_y/d\delta$



$d^2\eta_x/d\delta^2$



$d^2\eta_y/d\delta^2$

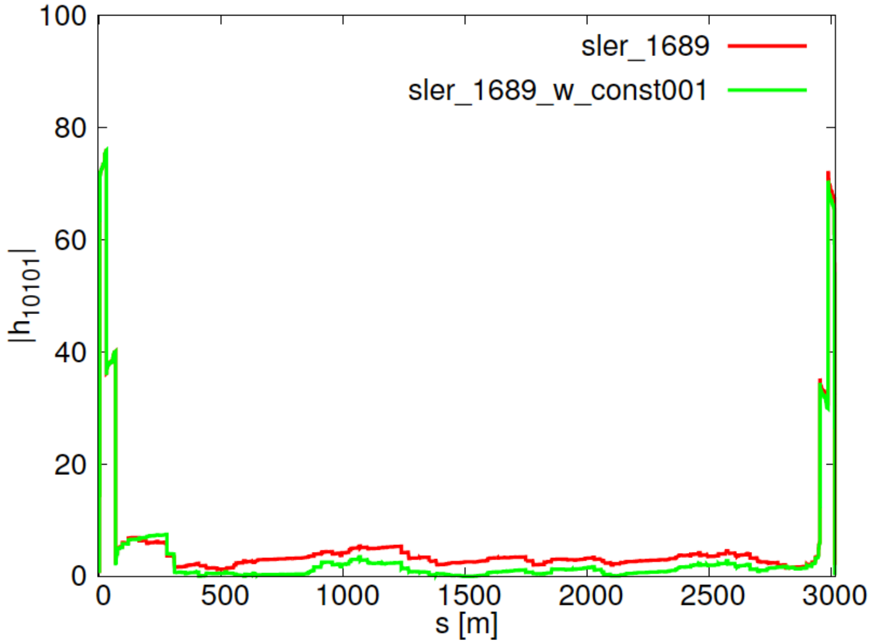


3. Results by PTC: Chromatic coupling

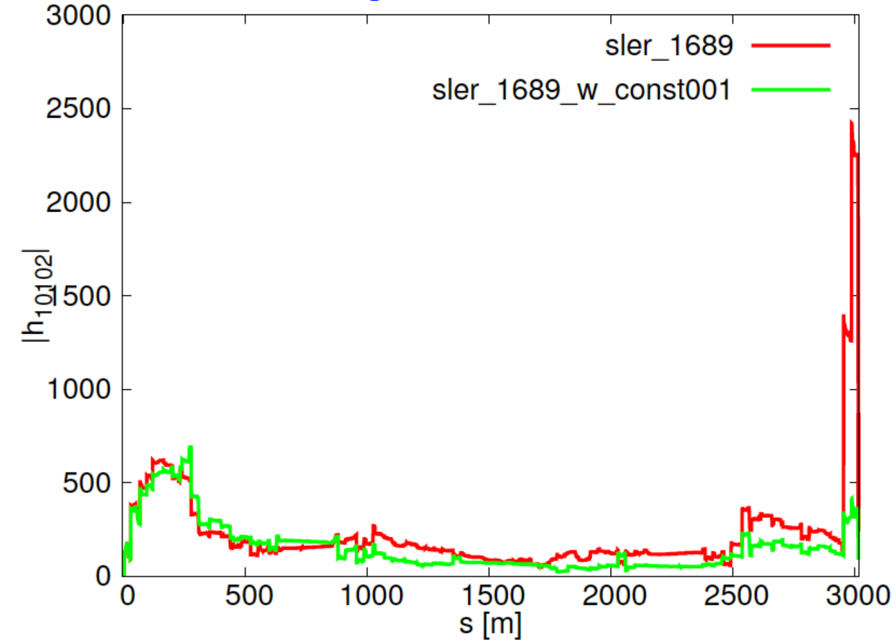
➤ **Chromatic coupling along the whole ring**

- **w/ constraints: Chromatic coupling controlled**

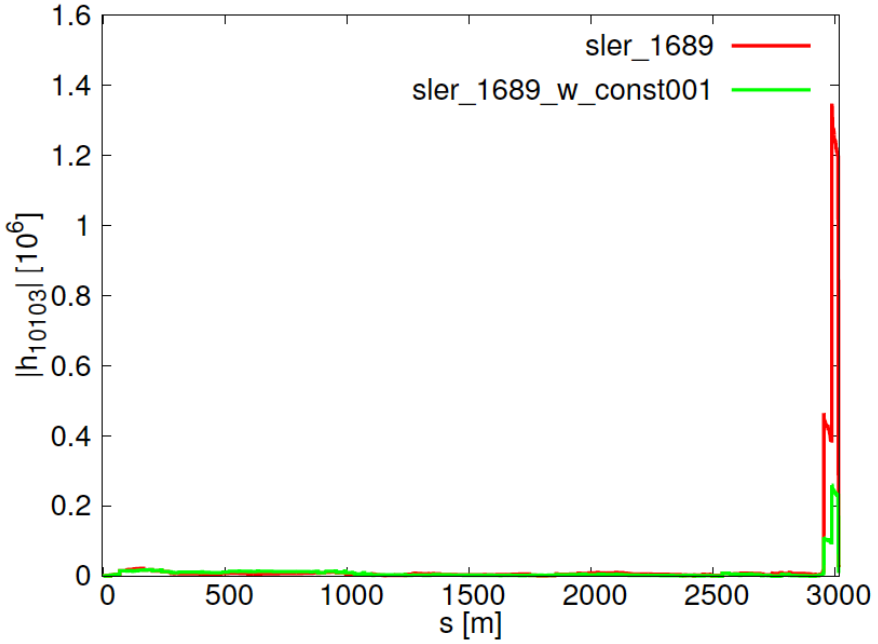
dR/dδ



d²R/dδ²



d³R/dδ³

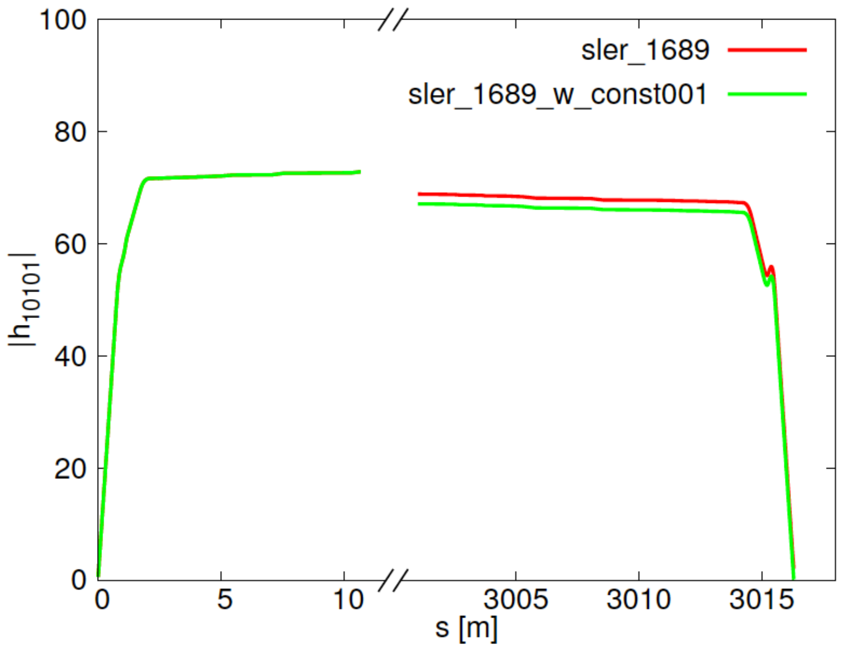


3. Results by PTC: Chromatic coupling (IR)

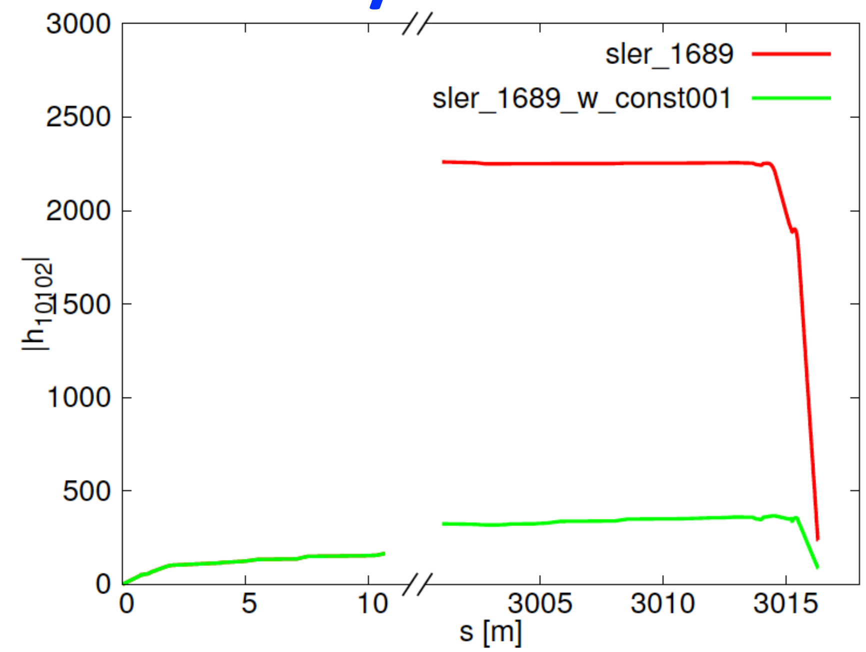
➤ **Chromatic coupling along the whole ring**

- **w/ constraints: Chromatic coupling controlled**

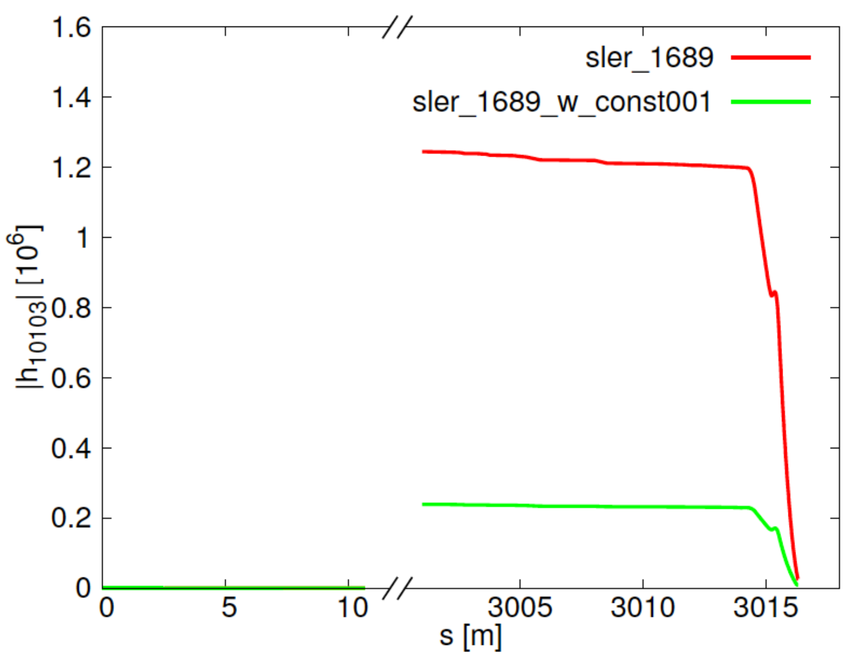
$dR/d\delta$



$d^2R/d\delta^2$



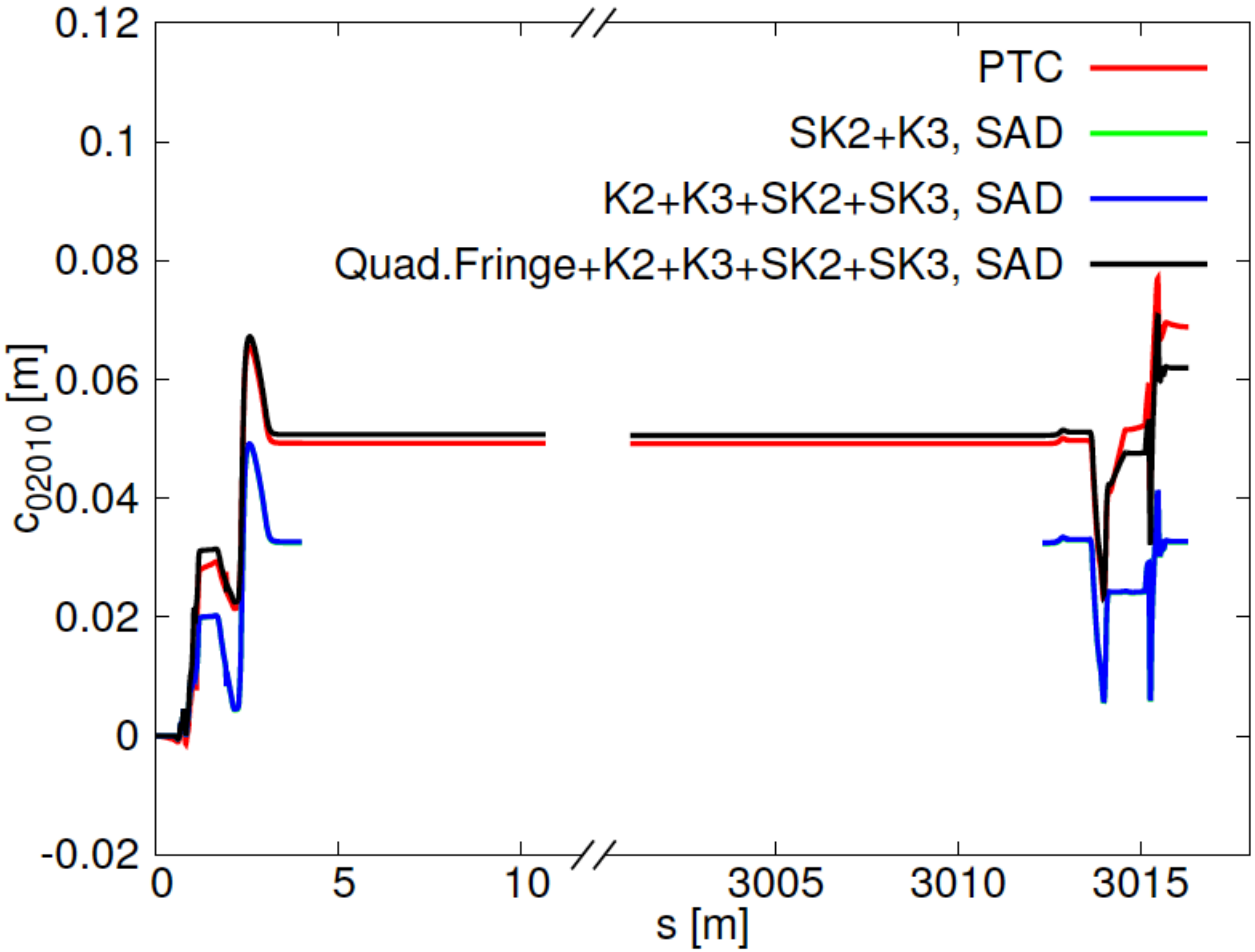
$d^3R/d\delta^3$



4. Compare with SAD

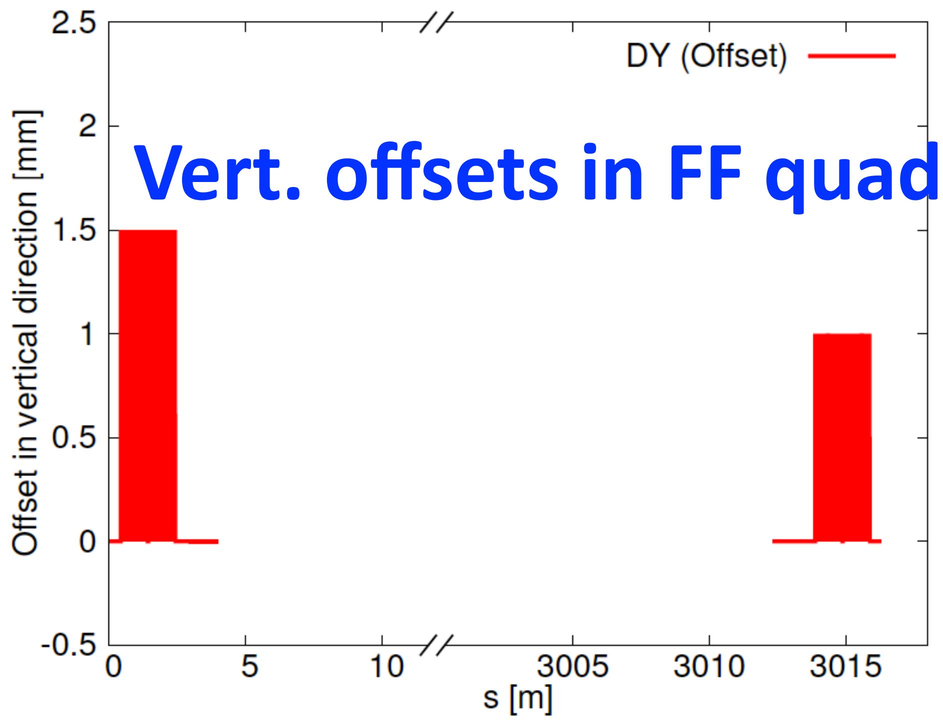
➤ **$p_x^2 p_y$ term**

- Hard-edge fringe fields of final focus quads are important sources



4. Compare with SAD

- $p_x^2 p_y$ term
  - How quad. hard-edge fringes contribute?



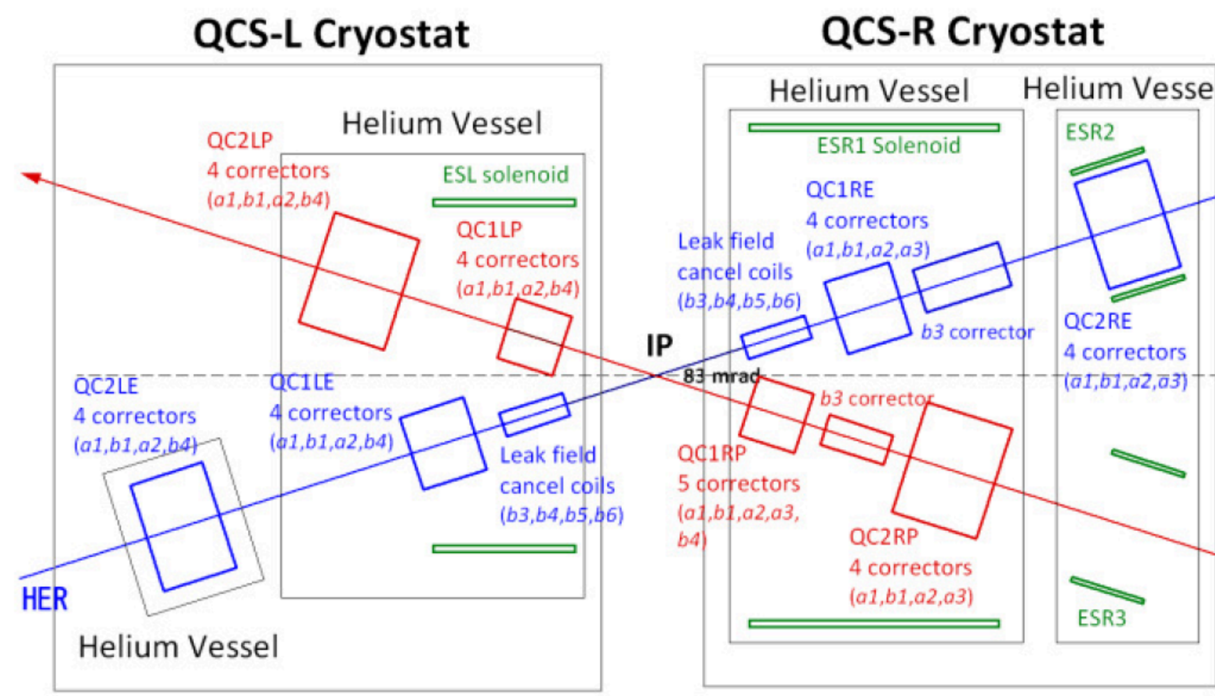
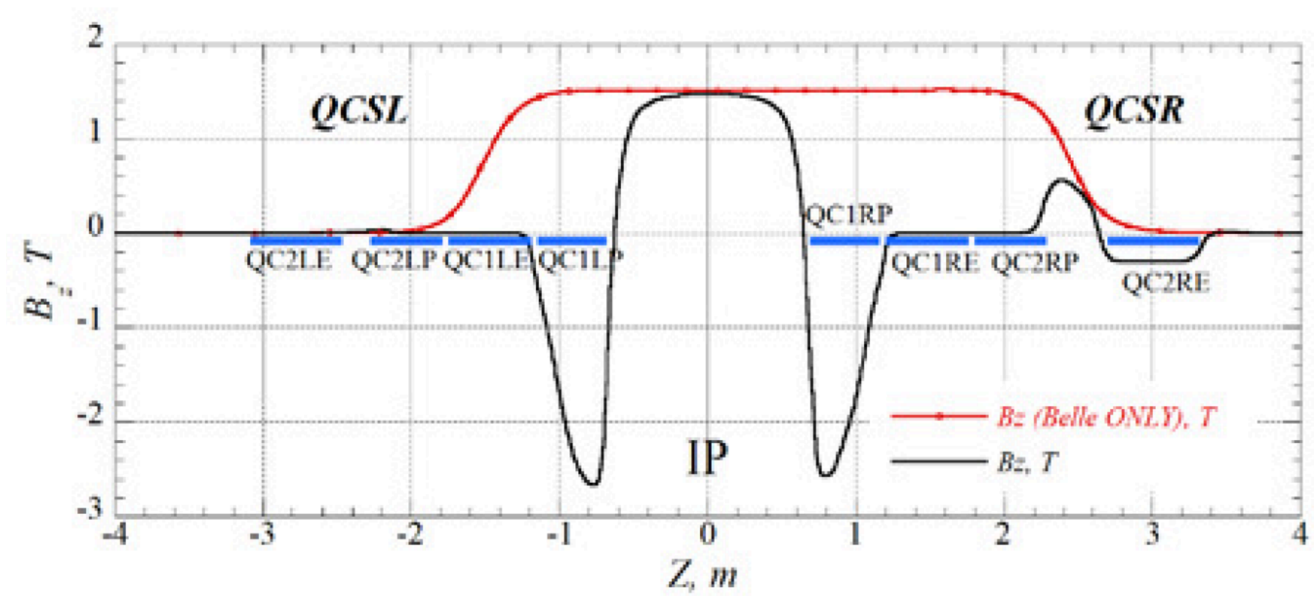


Table 2: Shift Amount of Magnet Axis

Magnet	ΔY	Magnet	ΔX
QC1RP	-1.0 mm	QC1RE	-0.7 mm
QC2RP	-1.0 mm	QC2RE	-0.7 mm
QC1LP	-1.5 mm	QC1LE	+0.7 mm
QC2LP	-1.5 mm	QC2LE	+0.7 mm

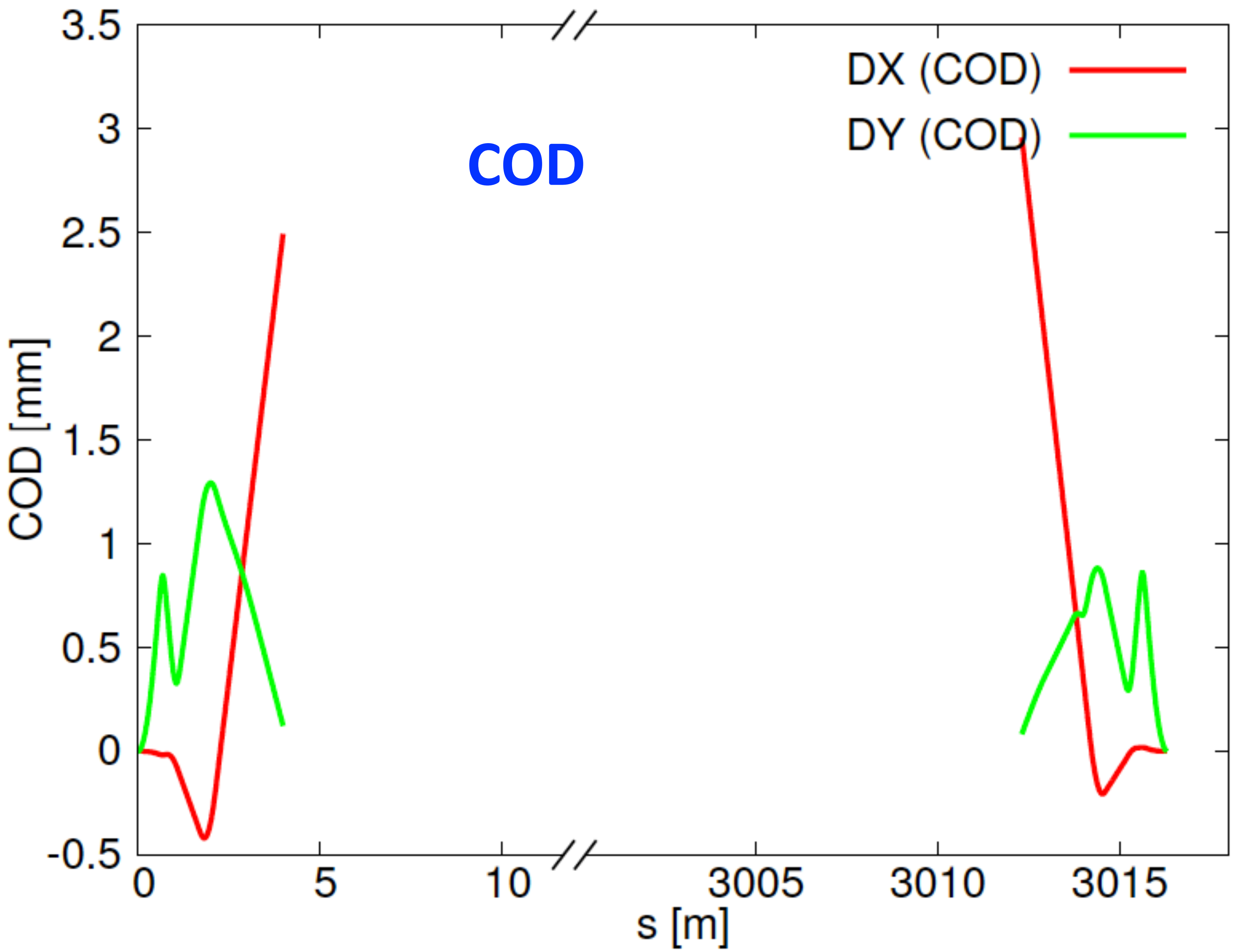


N. Ohuchi et al., IPAC'13

4. Compare with SAD

➤ **$p_x^2 p_y$ term**

- **How quad. hard-edge fringes contribute?**



4. Compare with SAD

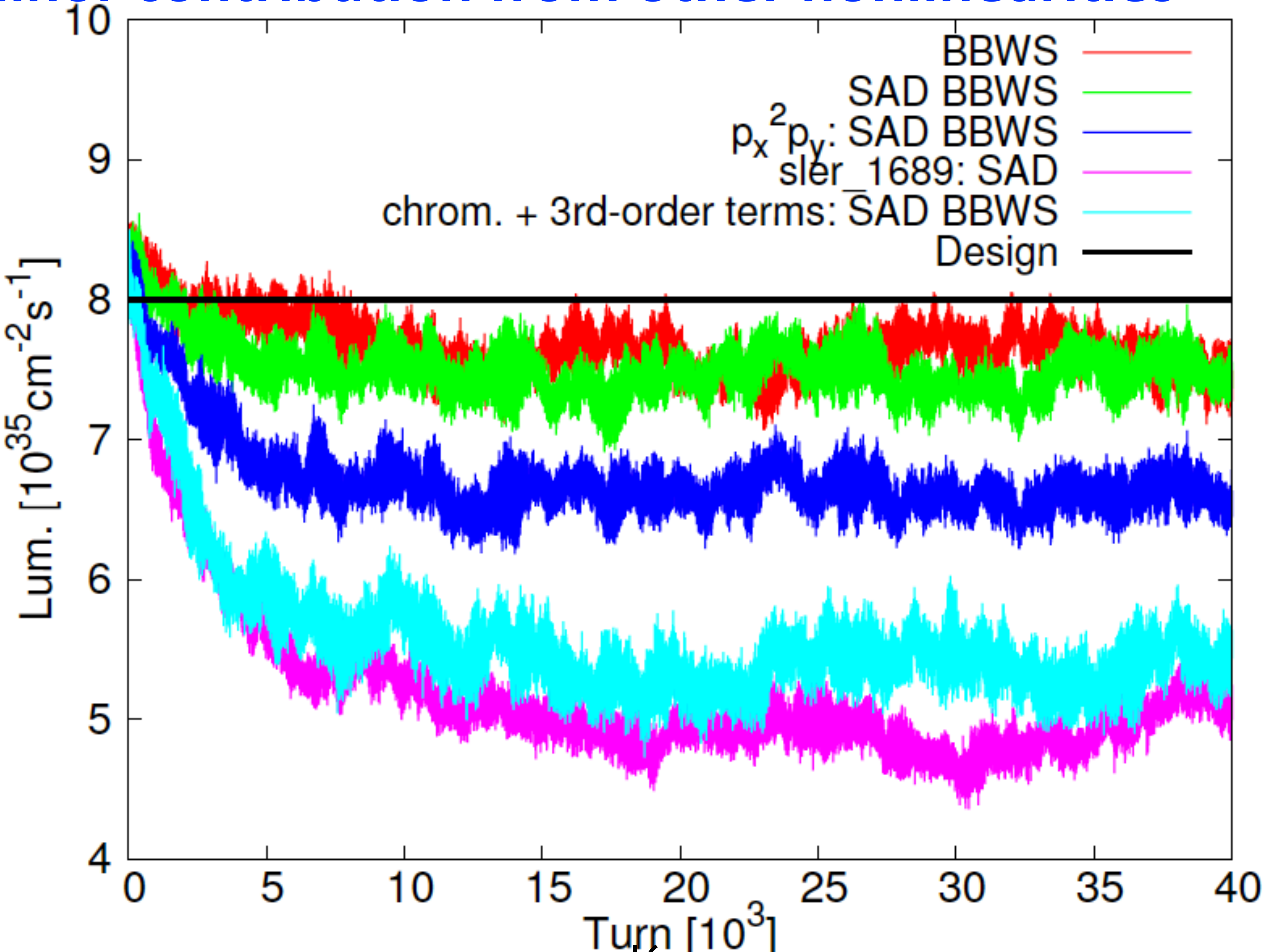
- $p_x^2 p_y$ term
  - How quad. hard-edge fringes contribute?
    + Magnet offsets + COD => 3rd geometric terms

```
In[1]:= (*f1=K1/(12(1+δ)L)*)
        HQfr = f1*((x^3 + 3 x*y^2) px - (y^3 + 3 x^2 y) py);
        D[HQfr, x]*ΔX
        D[HQfr, px]*ΔPX
        D[HQfr, y]*ΔY
        D[HQfr, py]*ΔPY
Out[2]= f1 (-6 py x y + px (3 x^2 + 3 y^2)) ΔX
Out[3]= f1 (x^3 + 3 x y^2) ΔPX
Out[4]= f1 (6 px x y - py (3 x^2 + 3 y^2)) ΔY
Out[5]= f1 (-3 x^2 y - y^3) ΔPY
```

4. Compare with SAD

➤ **Luminosity calculations**

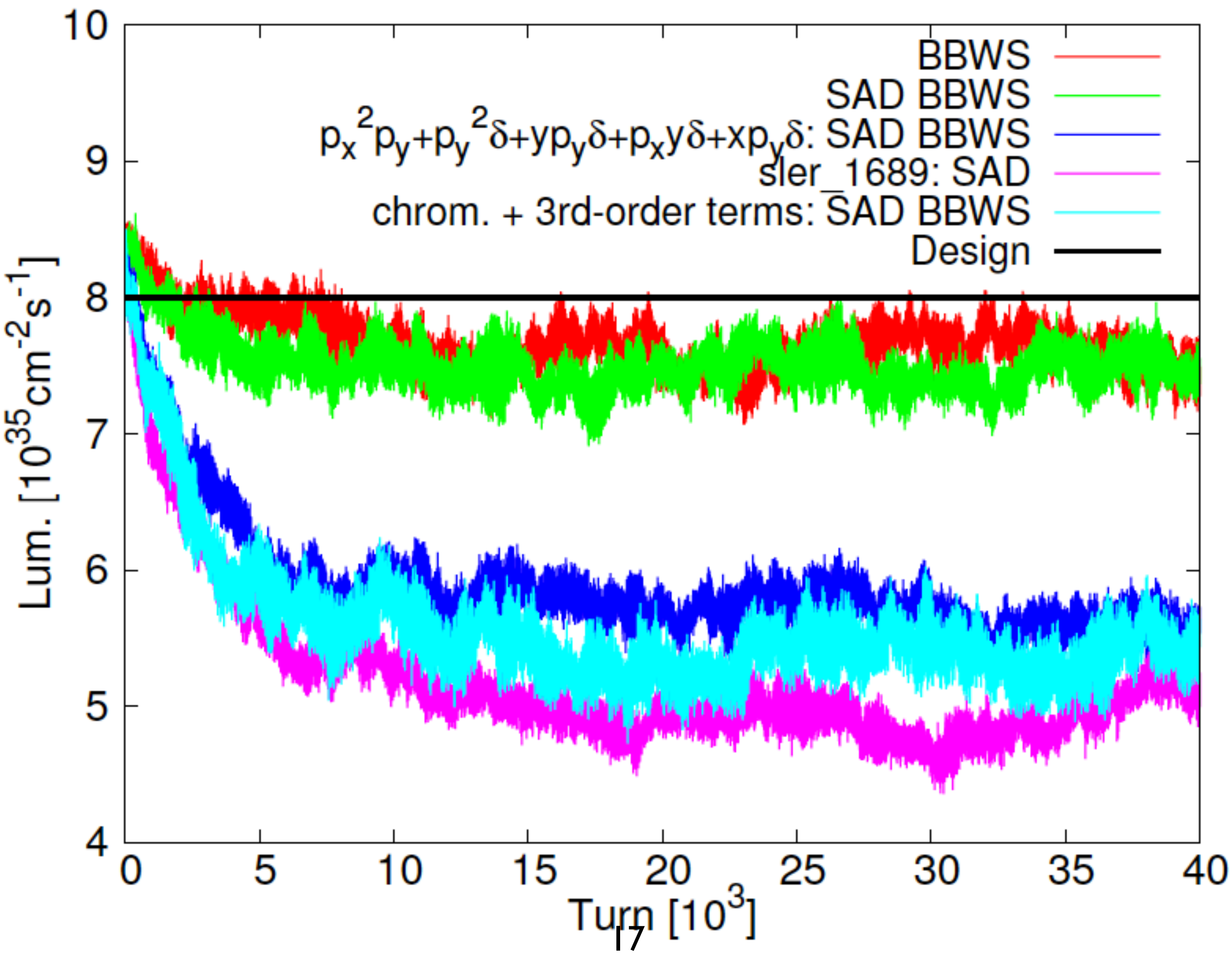
- **~1/3 caused by $p_x^2 py$ term (from FFS, strength calculated by PTC)**
- **~1/2 caused by chromatic effects (including interplay with geometric nonlinearities?)**
- **~1/6 minor contribution from other nonlinearities**



4. Compare with SAD

➤ **Luminosity calculations**

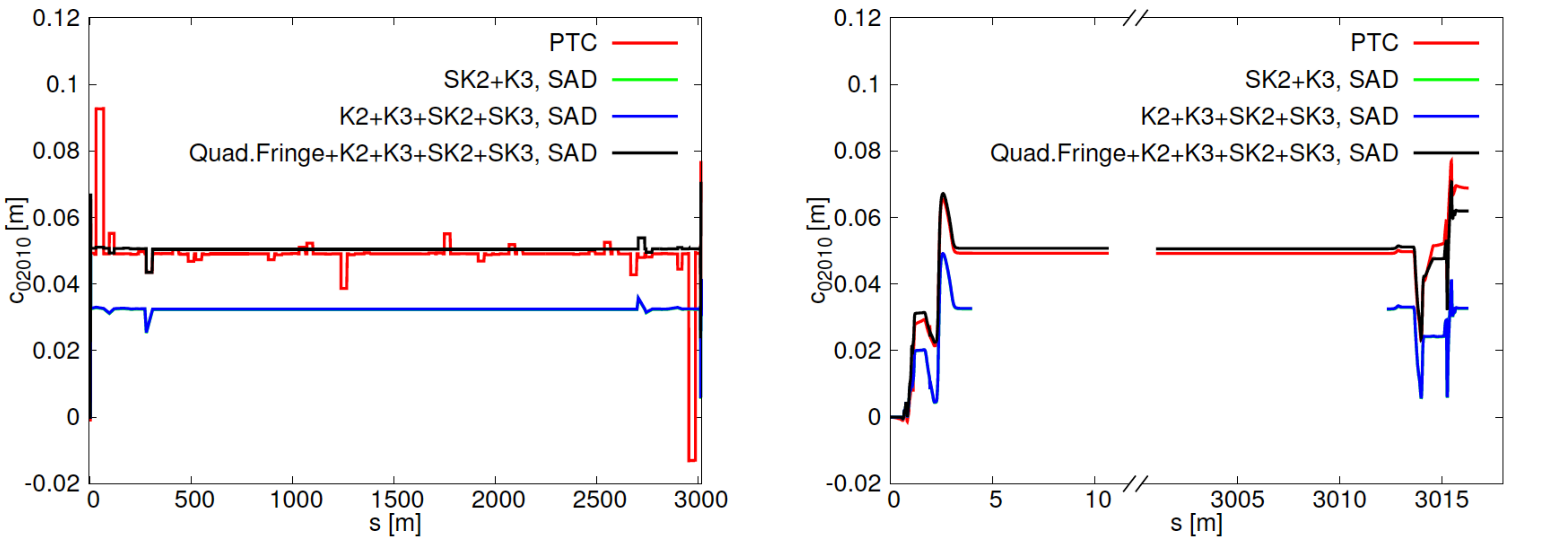
- **Important chromatic nonlinear terms (specific to sler_1689.sad): $p_y^2\delta$, $yp_y\delta$, $p_xy\delta$, $xp_y\delta$**



4. Compare with SAD

➤ Important nonlinear terms (sler_1689)

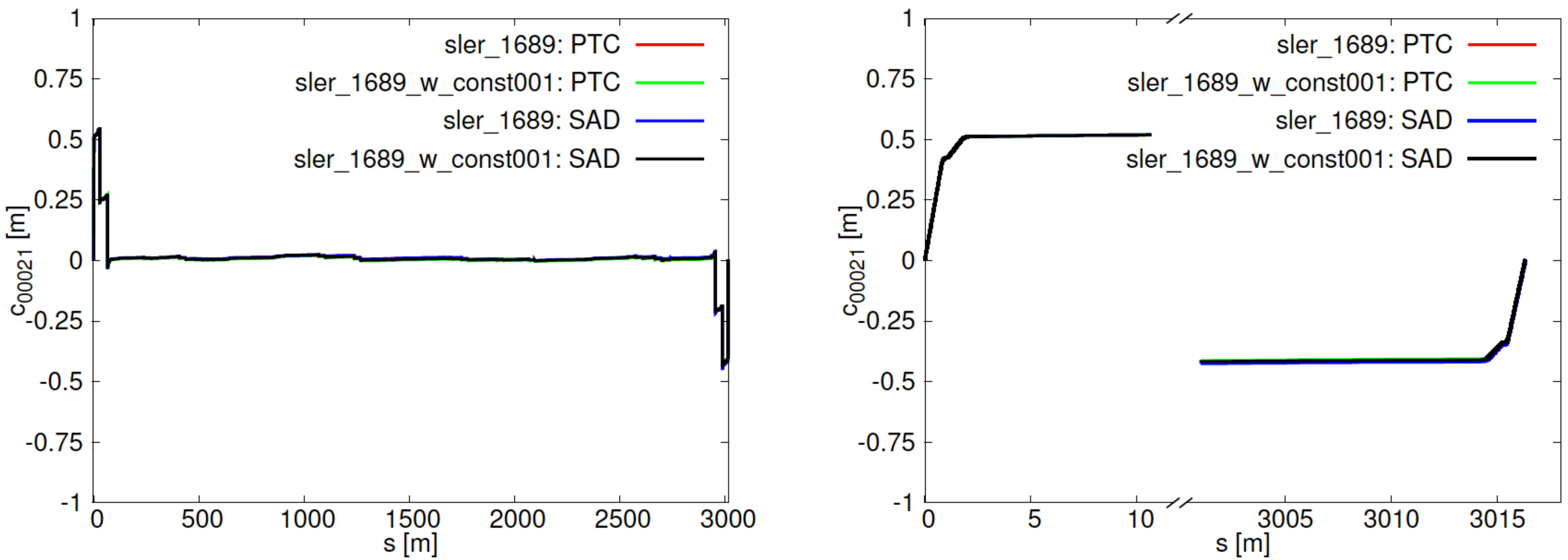
- $p_x^2 p_y$



4. Compare with SAD

➤ Important nonlinear terms (sler_1689)

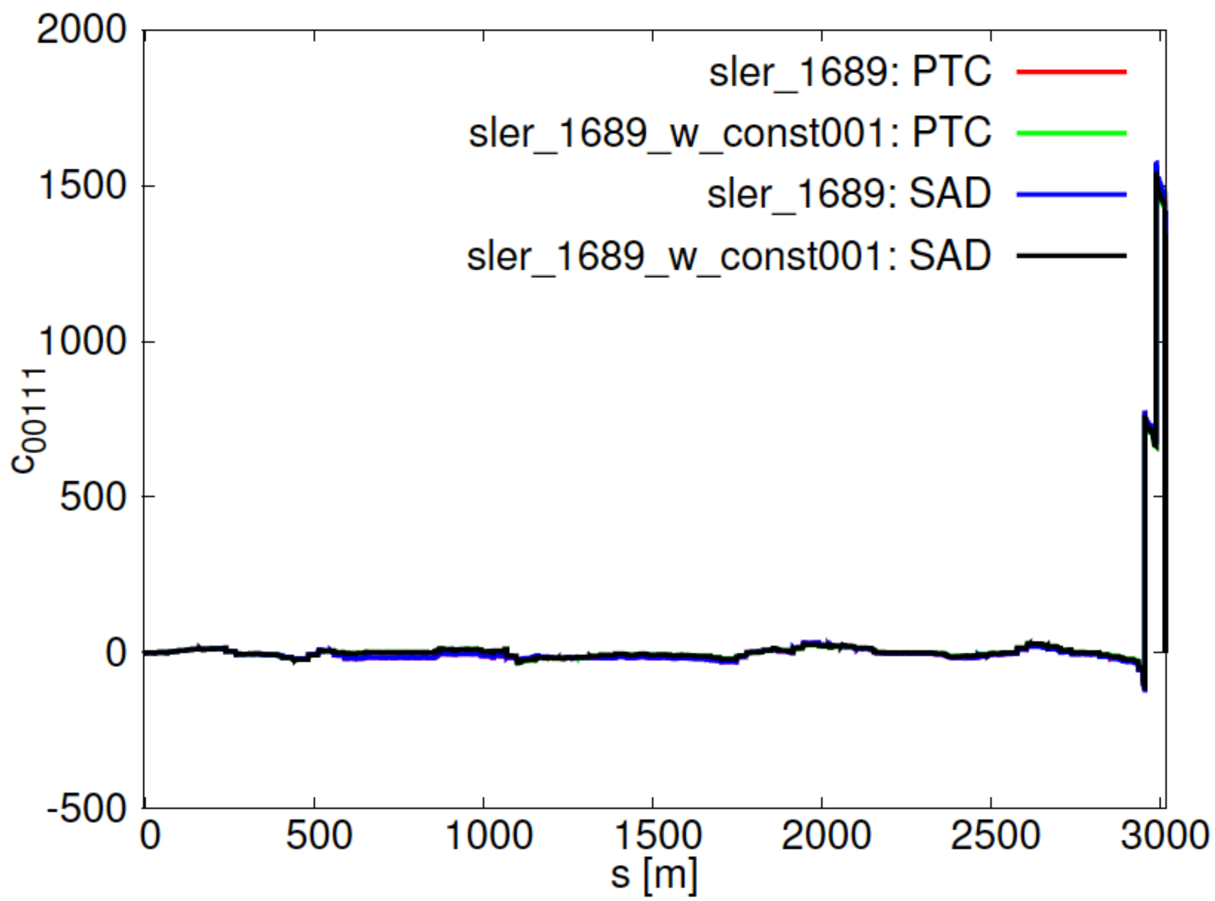
- $p_y^2\delta$

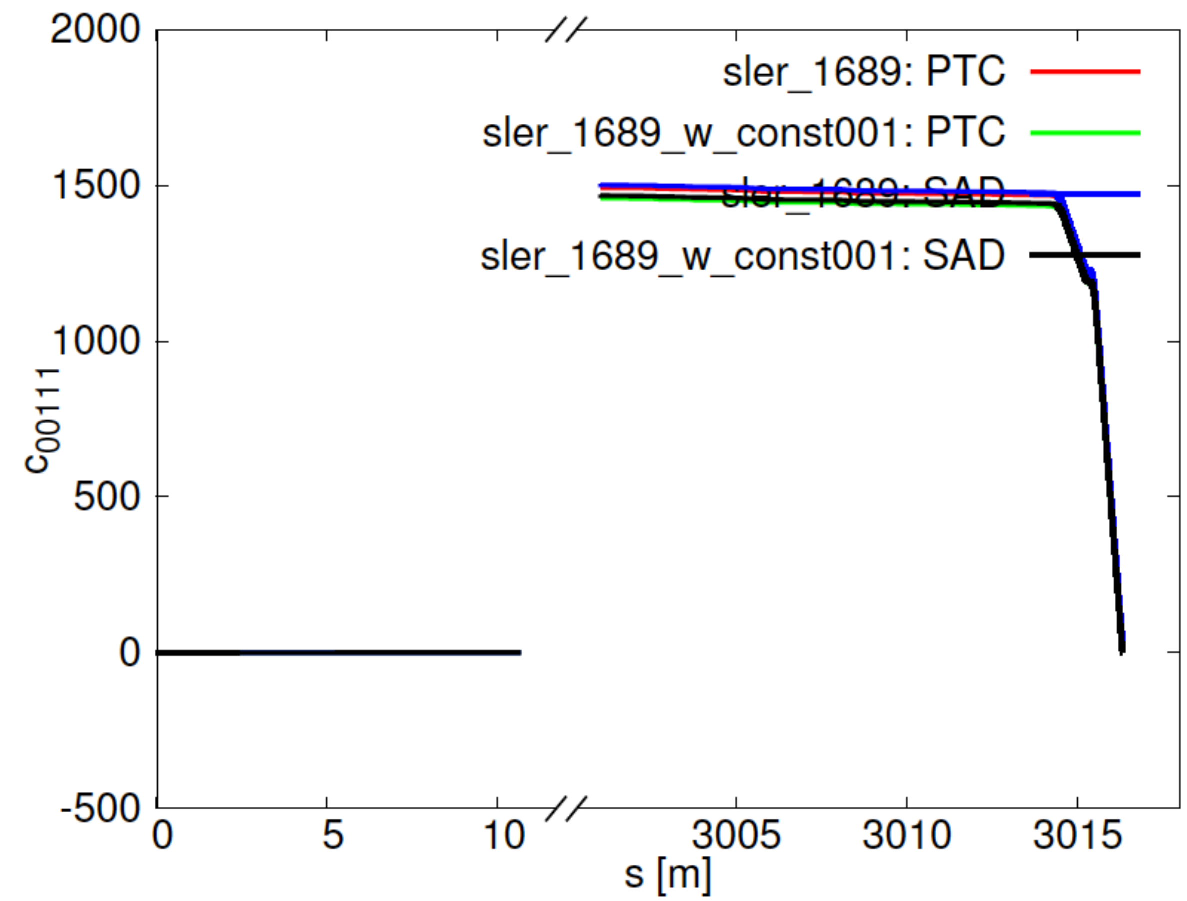


4. Compare with SAD

➤ Important nonlinear terms (sler_1689)

- $yp_y\delta$

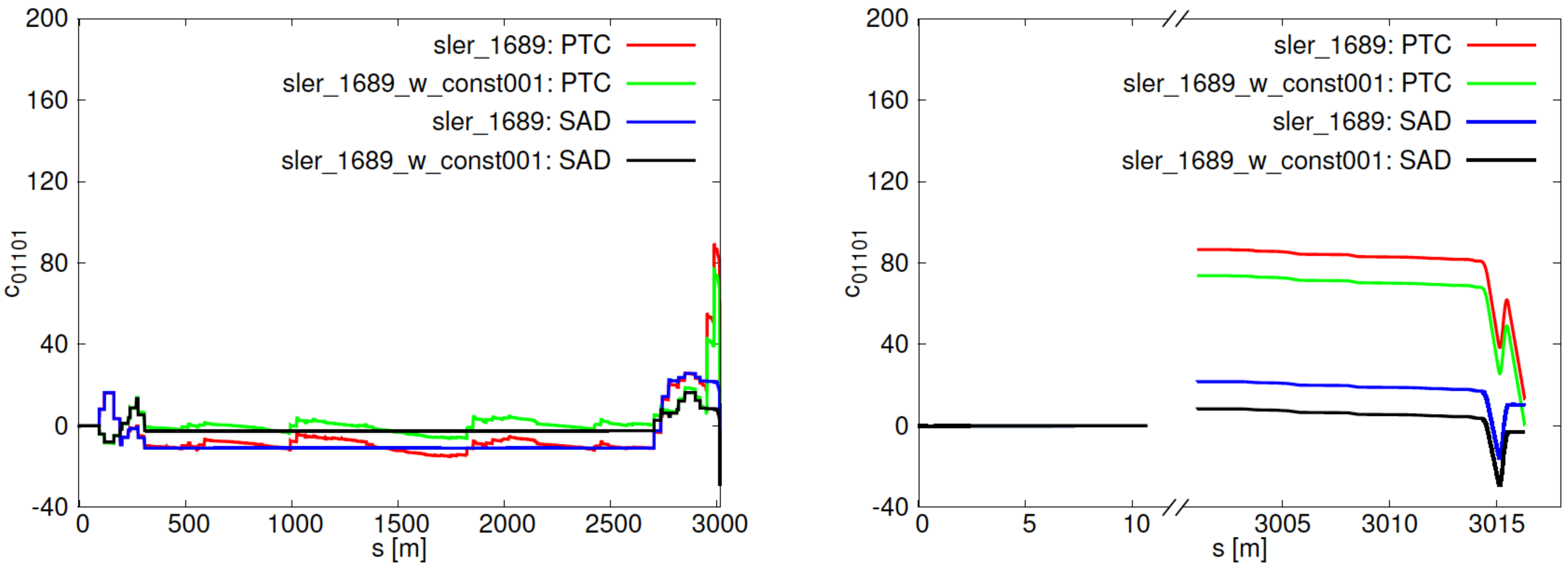




4. Compare with SAD

➤ Important nonlinear terms (sler_1689)

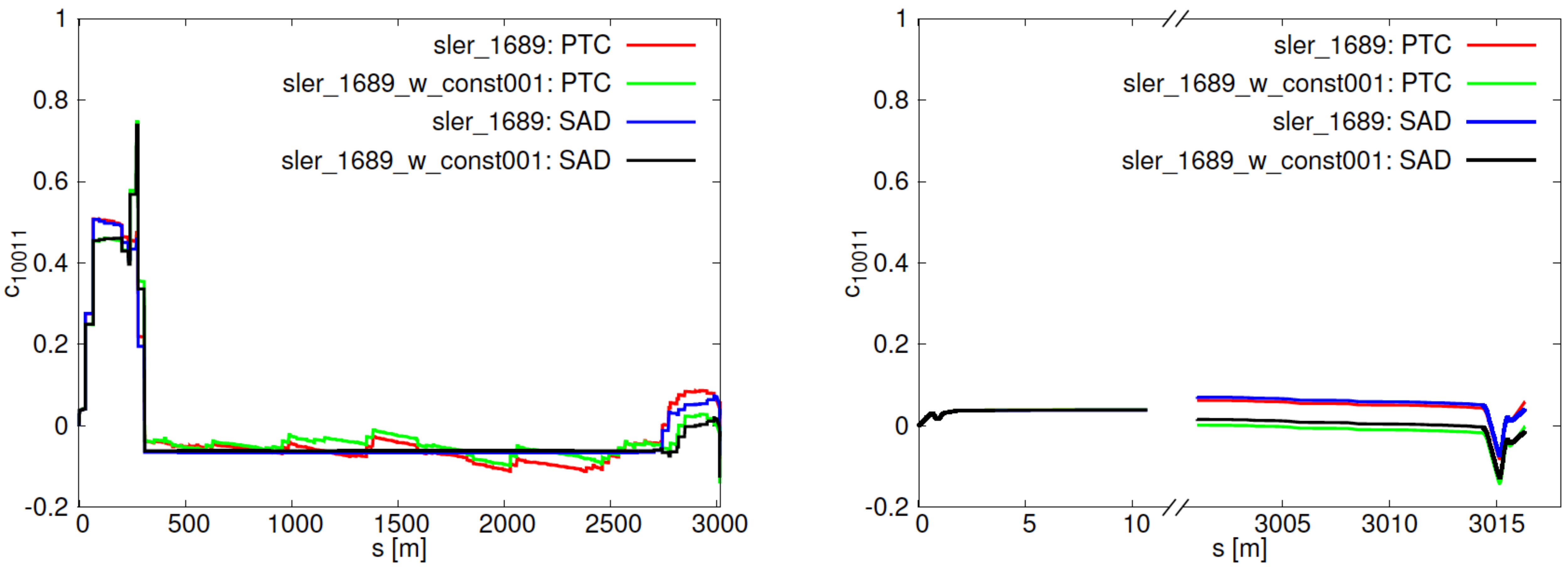
- $p_x y \delta$
- Discrepancy is due to different modelings of SAD and PTC (mainly related to time patching)



4. Compare with SAD

➤ **Important nonlinear terms (sler_1689)**

- **$xp_y\delta$**
- **Discrepancy is due to different modelings of SAD and PTC (mainly related to time patching)**



5. Summary

- **Previous findings**
  - BB + Lattice nonlinearity cause luminosity loss in SuperKEKB
  - Lum. drop happens at low beam current
  - Related to amplitude-dependent latt. nonlin.
- **DA optimization w/ new constraints [by H. Sugimoto]**
  - Small loss of DA and lifetime (reasonable)
  - Nonlinearity in chromatic beta, alpha, tune, and coupling functions [related to RDTs] suppressed successfully
  - Lum. gain achieved at low current
- **Calculation of RDTs using PTC**
  - Suppression of chromatic RDTs observed
- **Compare PTC and SAD in nonlinear terms (3rd order)**
  - Good agreement
  - Source (almost) well understood

5. Summary

- **Luminosity calculation**
  - **Sources of luminosity loss (almost) well understood**
  - **Calculations for latest lattices to be done**
- **Nonlinear optimization scheme**
  - **Use the knowledge of PTC and SAD calculation**
  - **Use available correctors for correction**
  - **Consider strategy of simultaneous optimization of DA and luminosity**