Ideas on beam dynamics issues in SuperKEKB and benchmark of SAD and PTC

D. Zhou

SuperKEKB mini optics meeting

Aug. 20, 2015

Personal scenario

- Target lum. of 8E35 => Beam-beam has to be accepted
  - Relaxing beam-beam means loss of luminosity
- Lattice nonlinearity is the key issue
  - Try every method to suppress it
- Crab waist is attractive
  - But fundamentally limited by LN
- Space charge is a concern
  - Should be solvable if LN is well suppressed
- Interplay of BB+LN+SC+… in SuperKEKB sets request to interactions of different teams and also advanced tools
  - Optics group vs. Collective effect group
  - SuperKEKB team vs. FCC teams (SLAC, IHEP, INFN, CERN)
  - SuperKEKB needs better SAD, or supplementaries for SAD: MADX, Bmad, FPP/PTC, SCTR, etc.

Personal scenario (cont'd)

➤ **Ideas for nonlinear lattice analysis and suppression of LN**

- **Analyse turn-by-turn tracking data (like Y. Zhang's idea)**
- **Lie Algebra analysis (like Y. Cai's method applied to PEPX and FCC)**
- **Try alternatives for downhill simplex DA optimisation (like Genetic Algorithms(GA), Multi-Objective Genetic Algorithm (MOGA), etc. popular for light sources)**

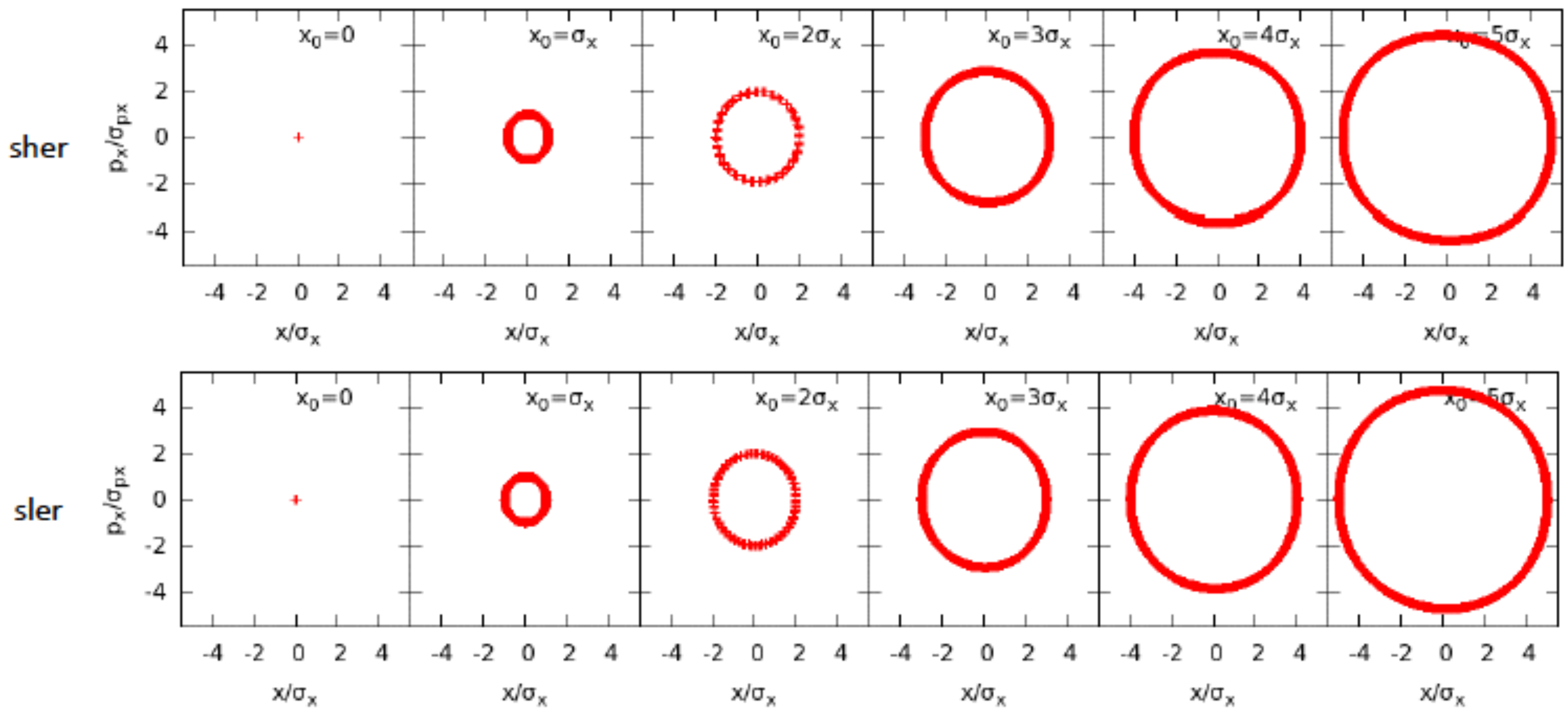
➤ **Extend international collaborations as well ensuring mutual benefits**

- **KEK-Cornell (SAD-Bmad, D. Sagan)**
- **KEK-SLAC (General acc. physics, Y. Cai, G. Stupakov et al.)**
- **KEK-CERN (SuperKEKB-FCC, K. Oide et al.)**
- **KEK-INFN (SuperKEKB-DAFNE, M. Biagini et al.)**
- **KEK-IHEP (SuperKEKB-CEPC, Y. Zhang, J. Gao et al.)**

1. Y. Zhang's idea

➤ **Realistic lattice**

sher-5767 vs ler-1689 in X direction

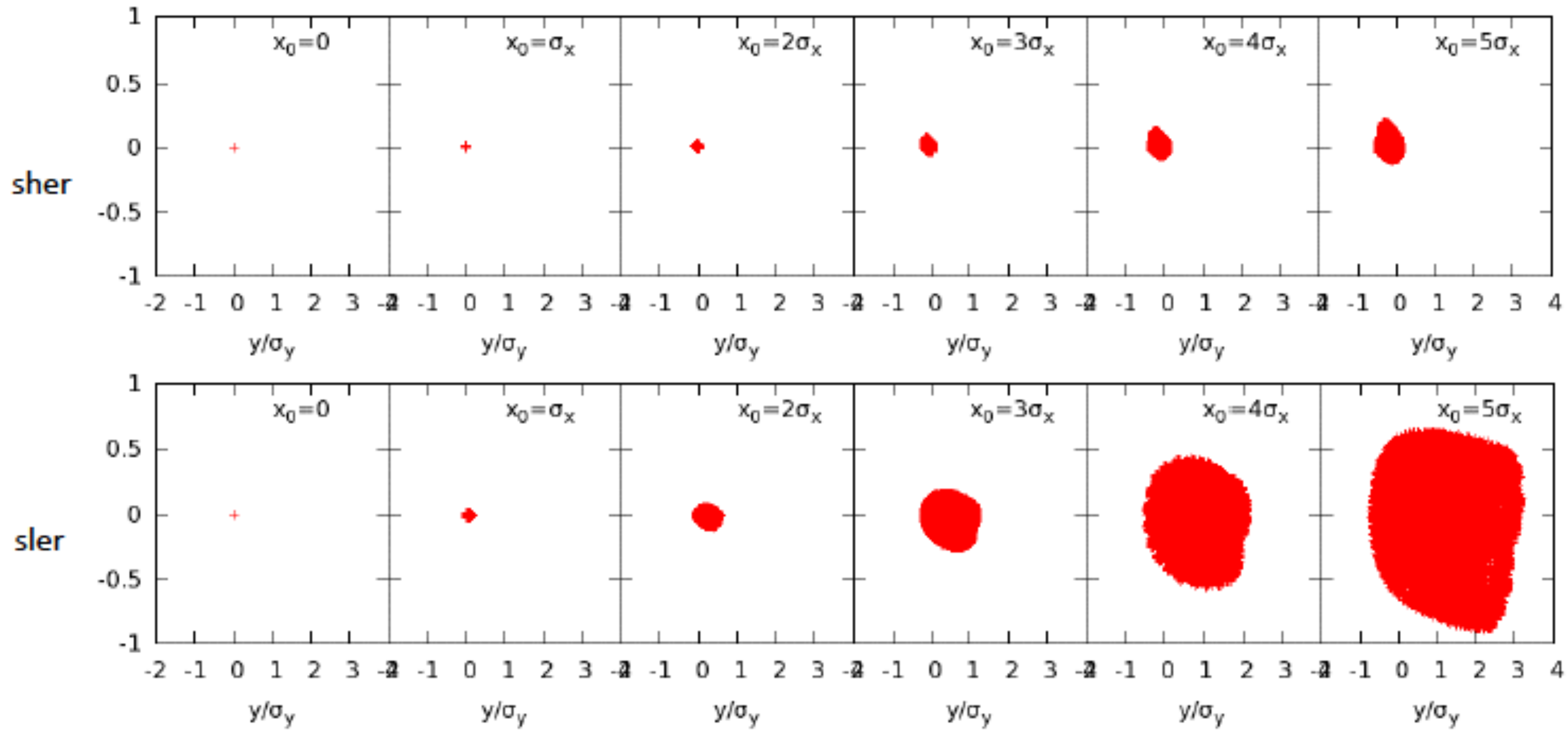


D. Zhou, SuperKEKB optics meeting, Apr.17, 2014

1. Y. Zhang's idea

- **Realistic lattice**
- **Evidence of nonlinear X-Y coupling?**
- **COD in y direction as function of X offset**

sher-5767 vs ler-1689 in Y direction



D. Zhou, SuperKEKB optics meeting, Apr.17, 2014

1. Y. Zhang's idea

Frequency Analysis

- Linear Normalized Coordinate

$$\hat{x} = \frac{x}{\sqrt{\beta_x}}, \hat{p}_x = p_x * \sqrt{\beta_x}$$

$$\hat{y} = \frac{y}{\sqrt{\beta_y}}, \hat{p}_y = p_y * \sqrt{\beta_y},$$

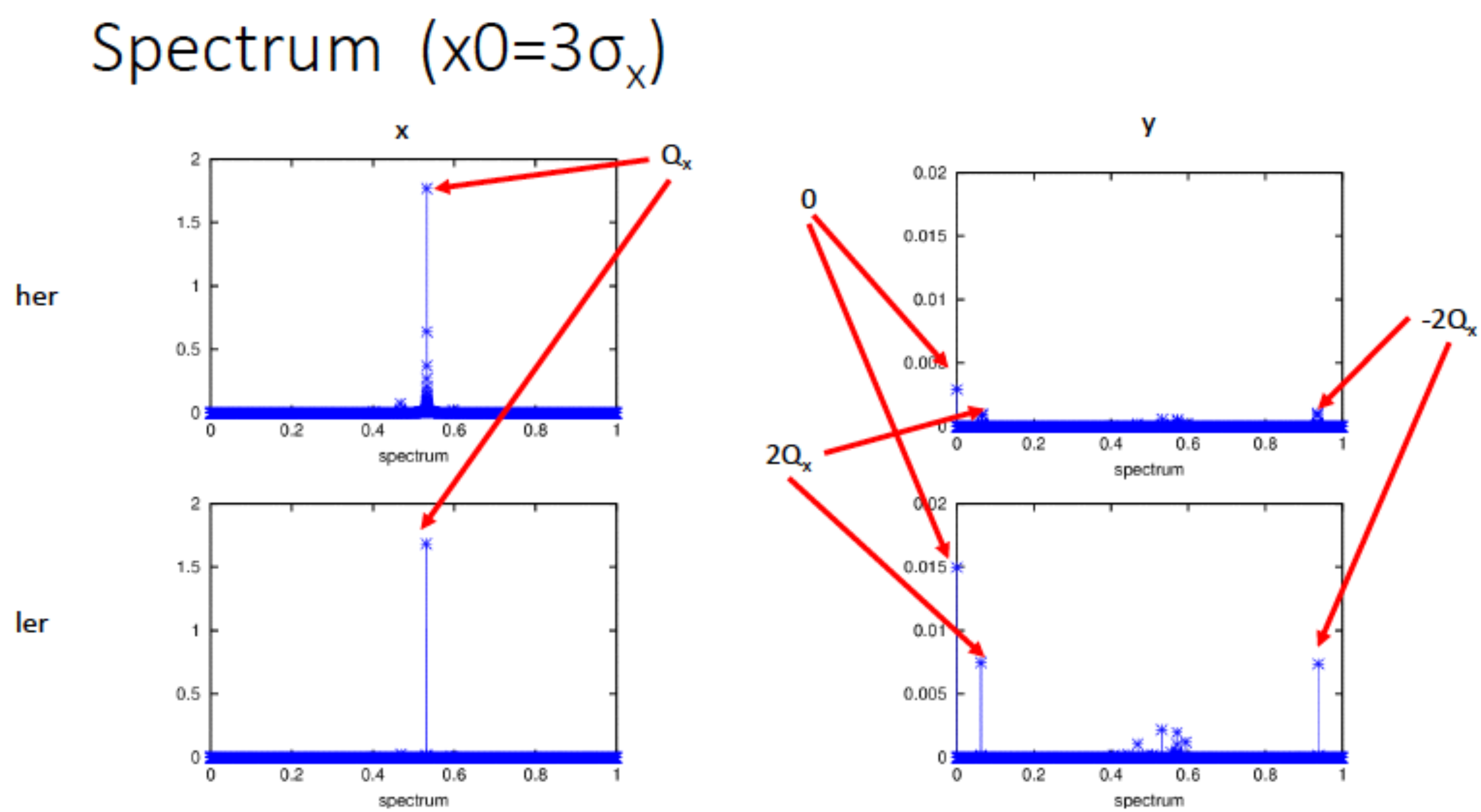
- Turn-by-Turn data could be represented by (with first order approximation)

$$\hat{x}(m) - i\hat{p}_x(m) = \sqrt{2A_x}e^{i(m\mu_x+\phi_{x,0})} - \sum_{abcd} 2iaf^{(3)}_{abcd}(2A_x)^{\frac{a+b-1}{2}}(2A_y)^{\frac{c+d}{2}}e^{i(b-a+1)(m\mu_x+\phi_{x,0})}e^{i(d-c)(m\mu_y+\phi_{y,0})}$$

$$\hat{y}(m) - i\hat{p}_y(m) = \sqrt{2A_y}e^{i(m\mu_y+\phi_{y,0})} - \sum_{abcd} 2icf^{(3)}_{abcd}(2A_x)^{\frac{a+b}{2}}(2A_y)^{\frac{c+d-1}{2}}e^{i(b-a)(m\mu_x+\phi_{x,0})}e^{i(d-c+1)(m\mu_y+\phi_{y,0})}$$

D. Zhou, SuperKEKB optics meeting, Apr.17, 2014

1. Y. Zhang's idea



D. Zhou, SuperKEKB optics meeting, Apr.17, 2014

1. Y. Zhang's idea

Sepctrum

- There exist very strong 'oscilation' at 0, 2Qx, -2Qx for LER
- It is suspected the cause is

  f1110 -> 0 in vertical direction, the amplitude is proportional to $(2A_x)$

  f0210 -> 2Qx in vertical direction, the amplitude is proportional to $(2A_x)$

  f2010 -> -2Qx in vertical direction, the amplitude is proportional to $(2A_x)$

All these terms may come from a skew sextupole like magnet.

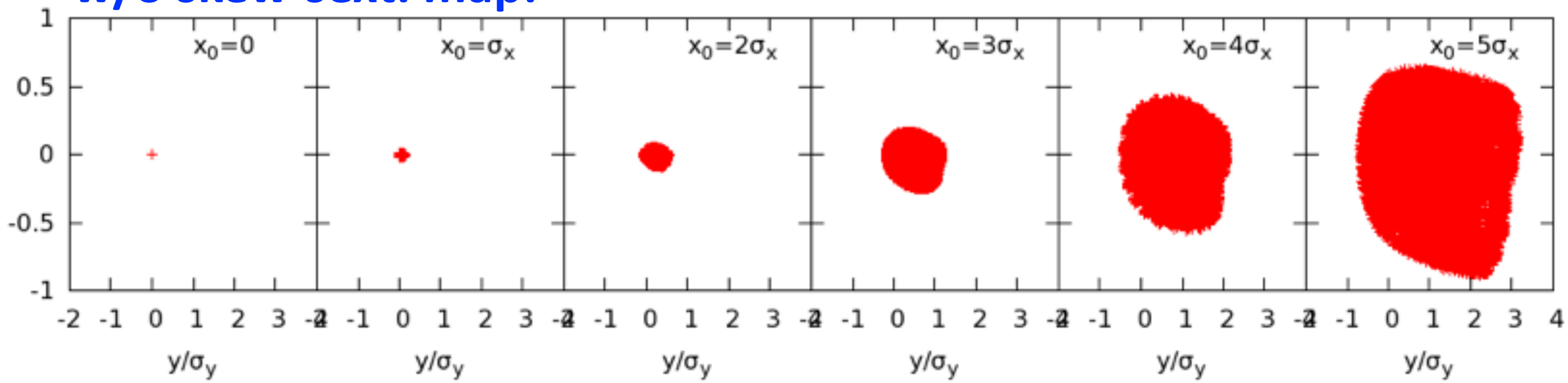
$H \sim 3x^2y-y^3$

D. Zhou, SuperKEKB optics meeting, Apr.17, 2014

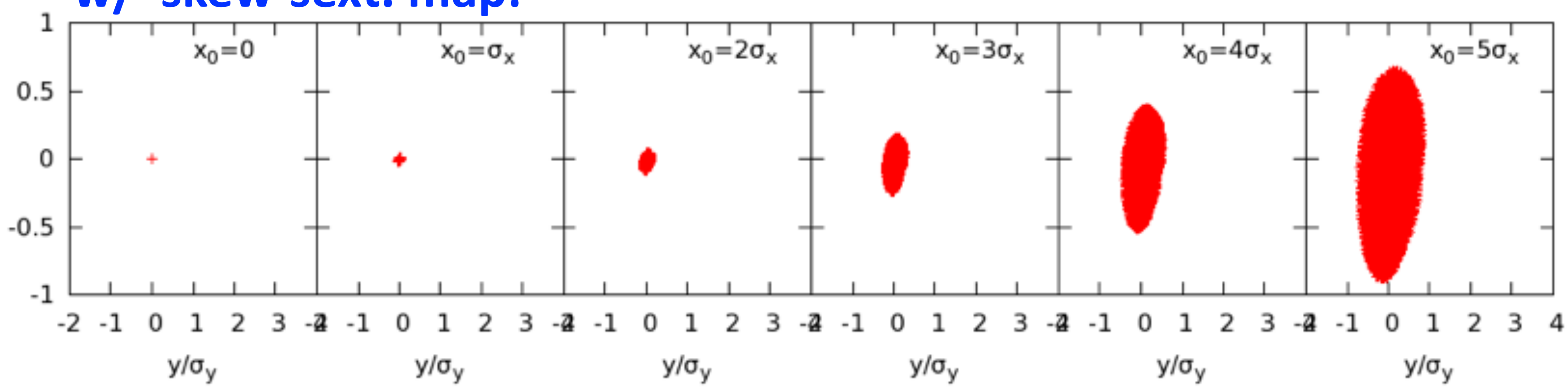
1. Y. Zhang's idea

- ➤ Test by inserting a map of $H=K*x^2y$ into the LER lattice
- ➤ COD and oscillation amplitude in y are well suppressed as expected

w/o skew-sext. map:



w/ skew-sext. map:

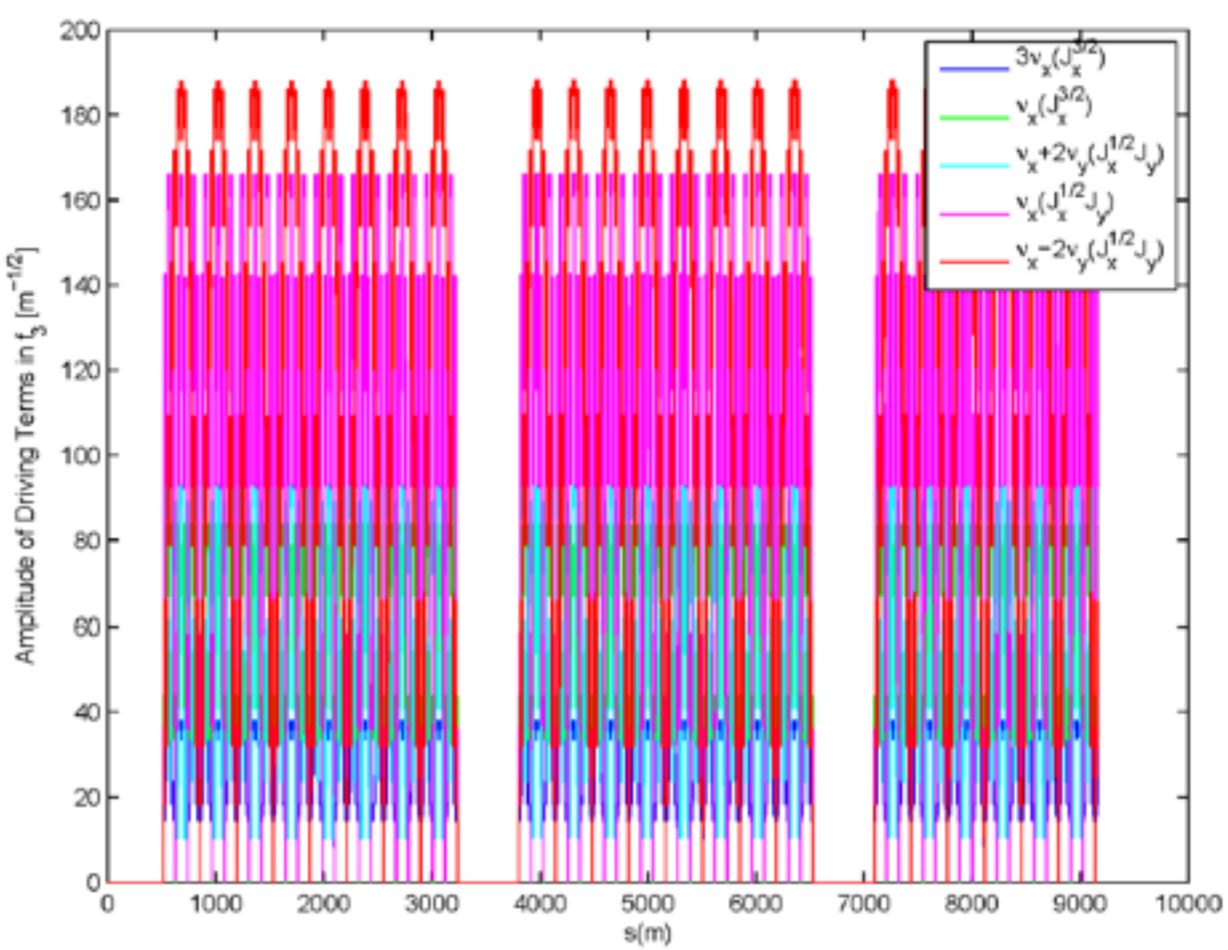


D. Zhou, SuperKEKB optics meeting, Apr.17, 2014

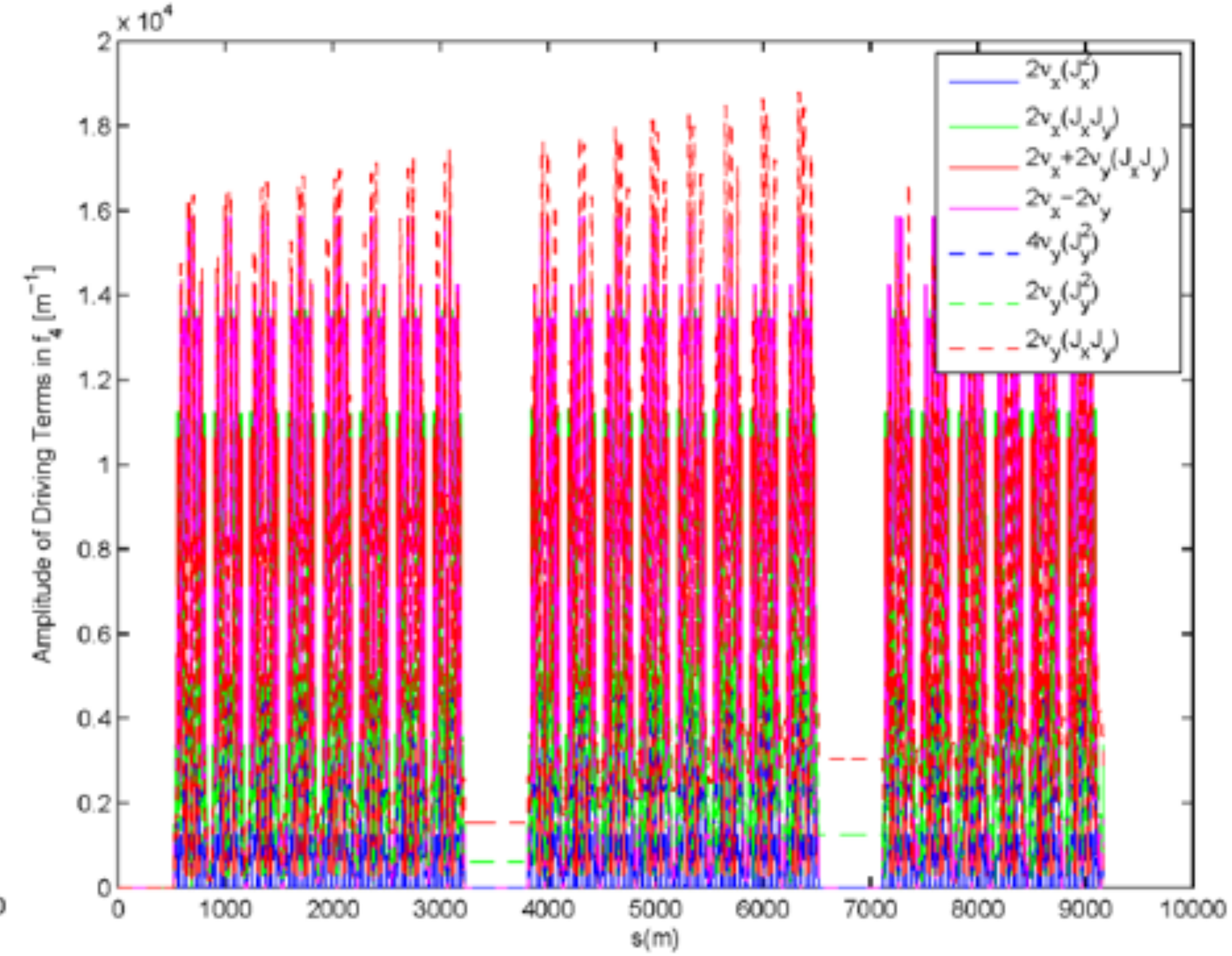
2. Lie algebra method

➤ **Look into high-order driving terms instead of linear optics**

3rd order driving terms



4th order driving terms



Y. Cai, FCC kick-off meeting, Feb. 12-16, 2014

2. Lie algebra method

➤ **Look into high-order driving terms instead of linear optics**

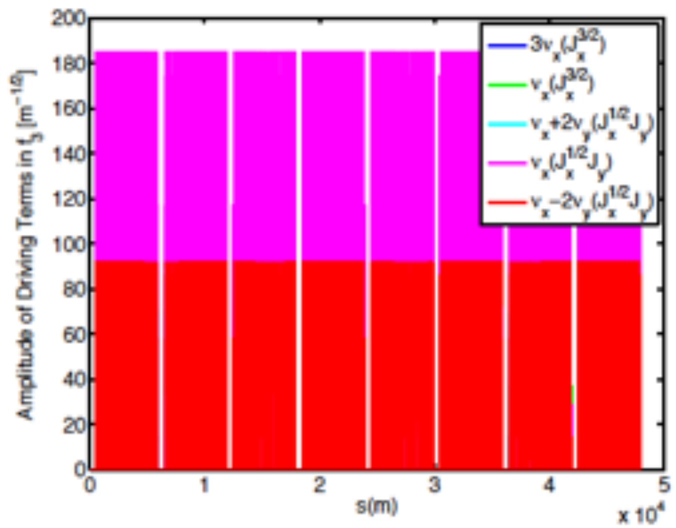


Figure 2: *All third-order resonances driven by sextupoles.*

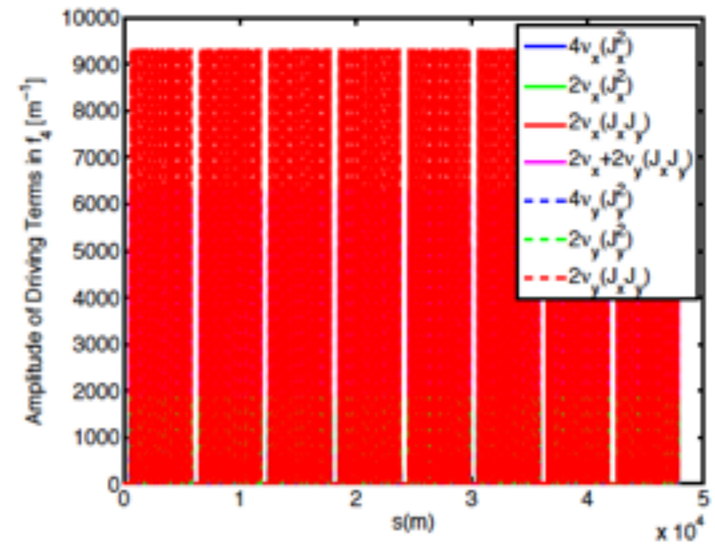


Figure 3: *Fourth-order resonances driven by sextupoles.*

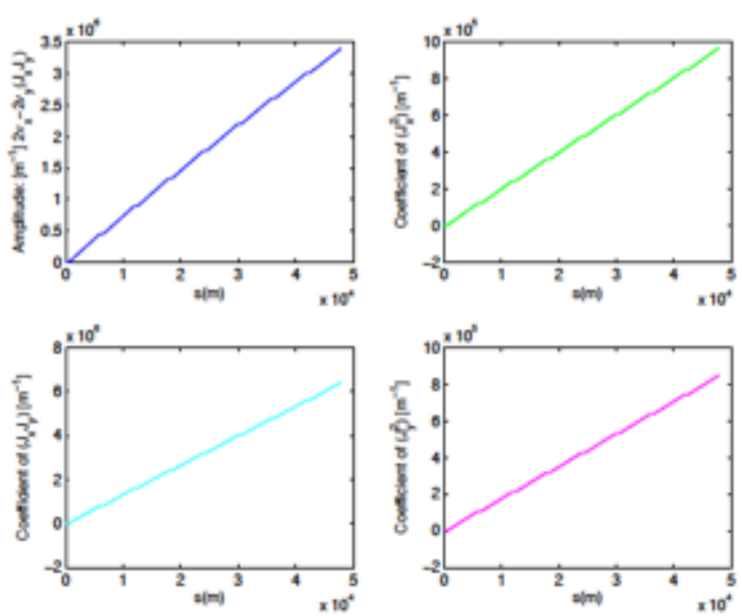


Figure 4: *The four residual 4th-order terms in the Lie operator: f_4.*

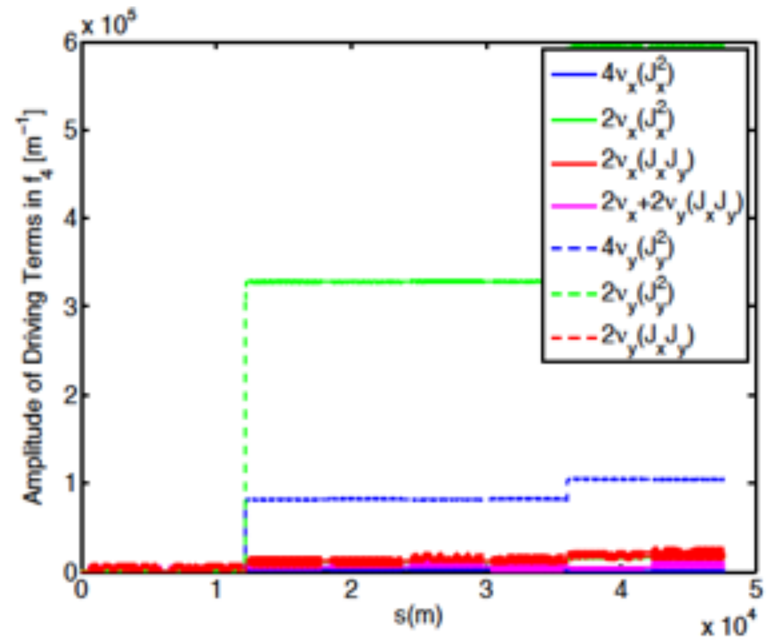


Figure 11: *Fourth-order resonances driving terms in the lattice with two interaction regions.*

Y. Cai, SLAC-PUB-16127, Oct. 2014

2. Lie algebra method

➤ **Y. Cai's method is a subset of PTC (by E. Forest)**

➤ **PTC can even do better**

- **Handle double rings simultaneously**
- **Beam-beam included**
- **Sophisticated lattice analysis**
- **PTC applied to SuperKEKB is under development**

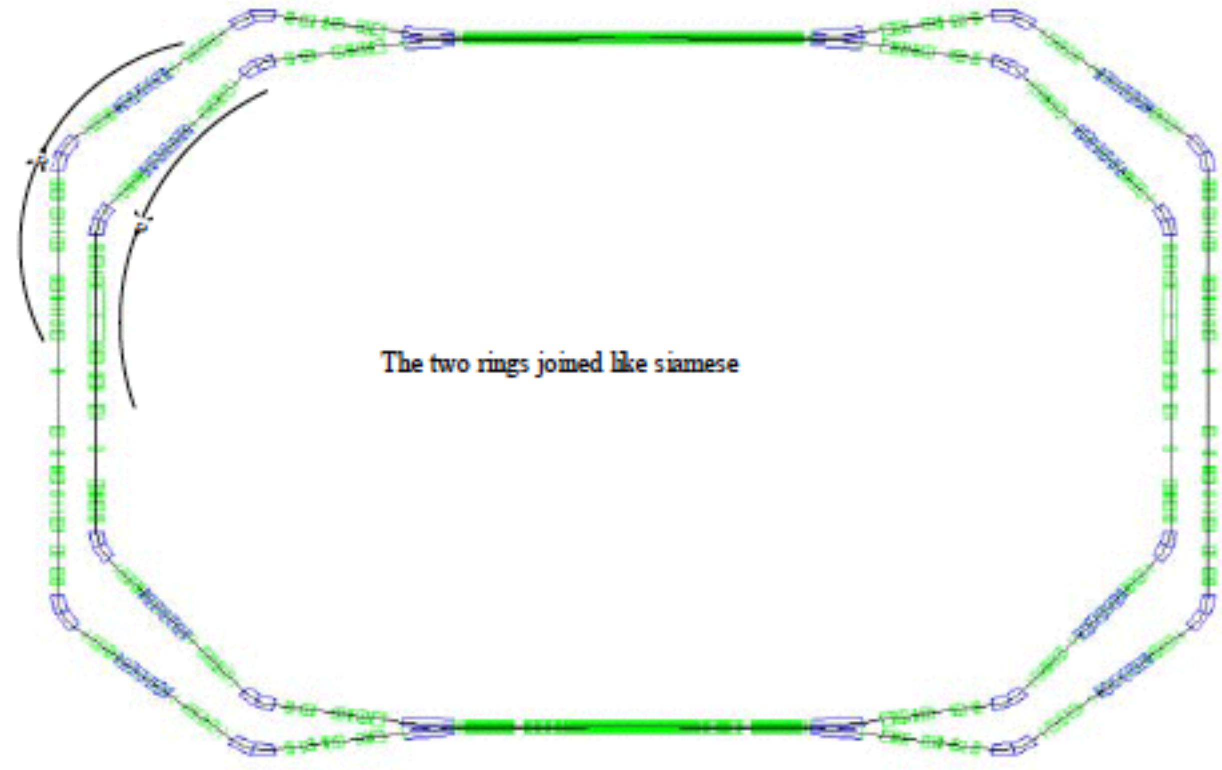


Figure 2: Both Rings of DAΦNE.

E. Forest et al., EPAC'06, Jun. 2006

3. Benchmark: Parameters at IP with δ=0.

sler-1689

Bmad:

βx=0.031935787m, αx=0.5912462E-3, νx=44.530088,
Dx=0.20343695E-6m, D'x=0.16998011E-4,
βy=2.6352853E-4m, αy=-0.3626459E-3, νy=46.56811,
Dy=-0.14648086E-7m, D'y=0.20250707E-4,

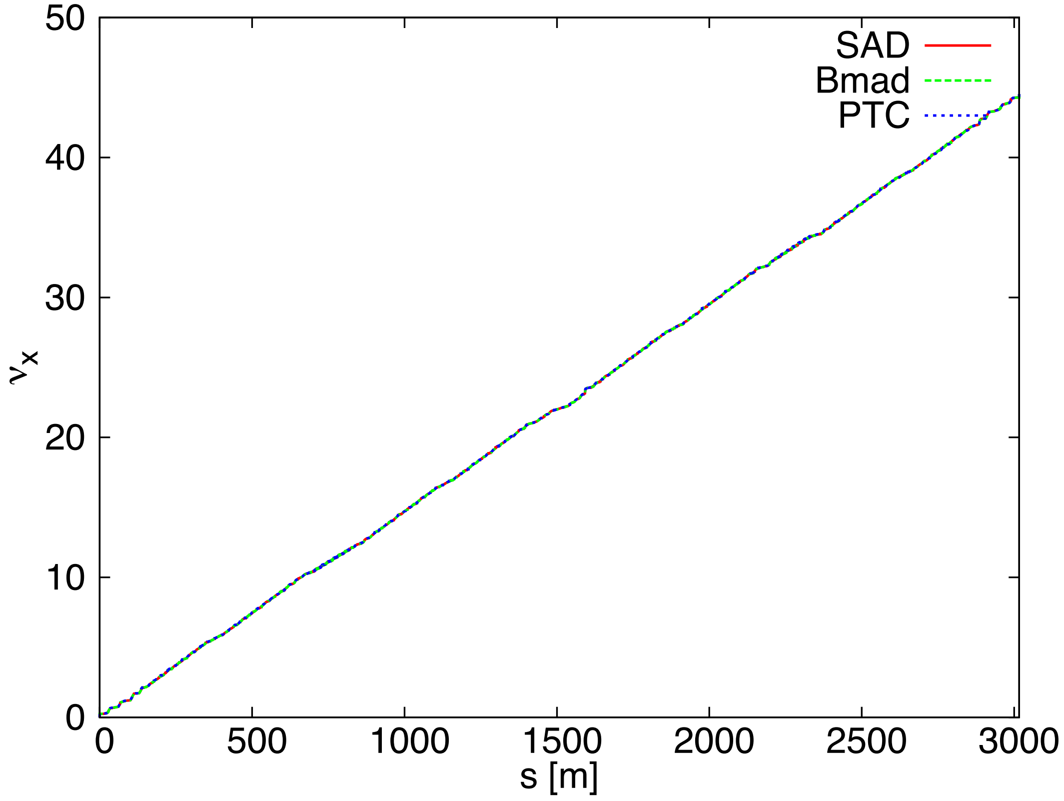
SAD:

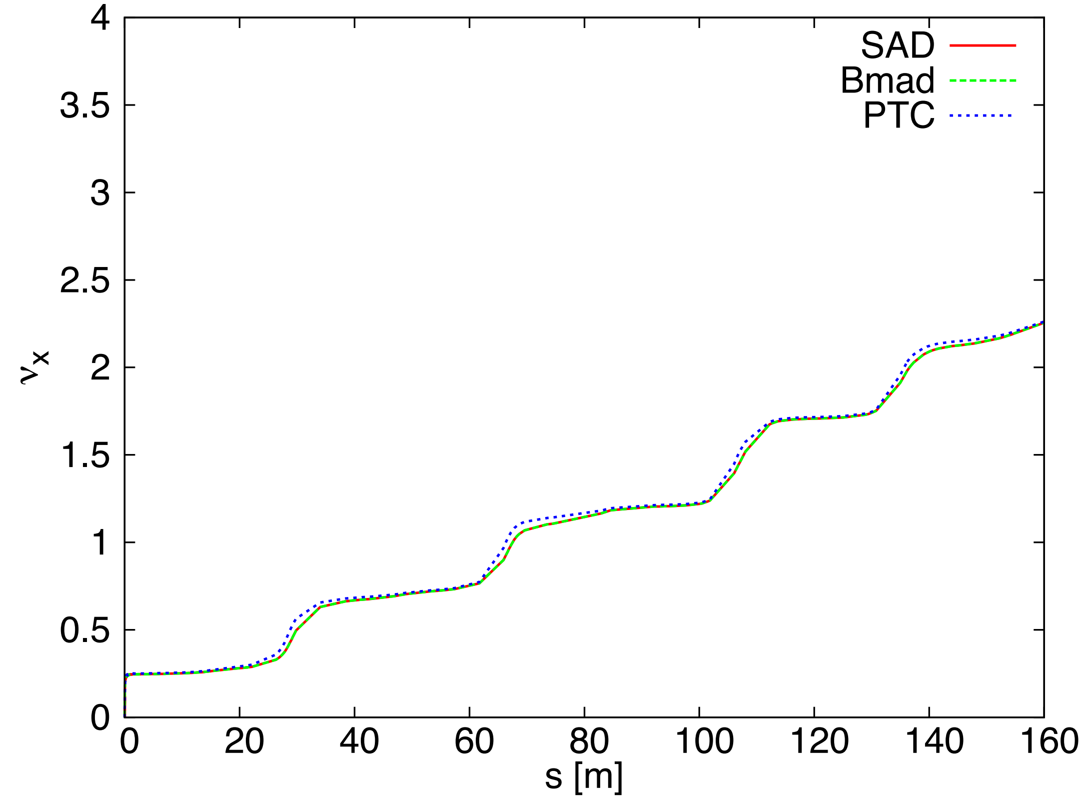
βx=0.032m, αx=-4.05E-11, νx=44.53,
Dx=-2.08E-13m, D'x=-1.84E-12,
βy=2.7E-4m, αy=-2.22E-11, νy=46.57,
Dy=1.856E-14m, D'y=-8.34E-12,

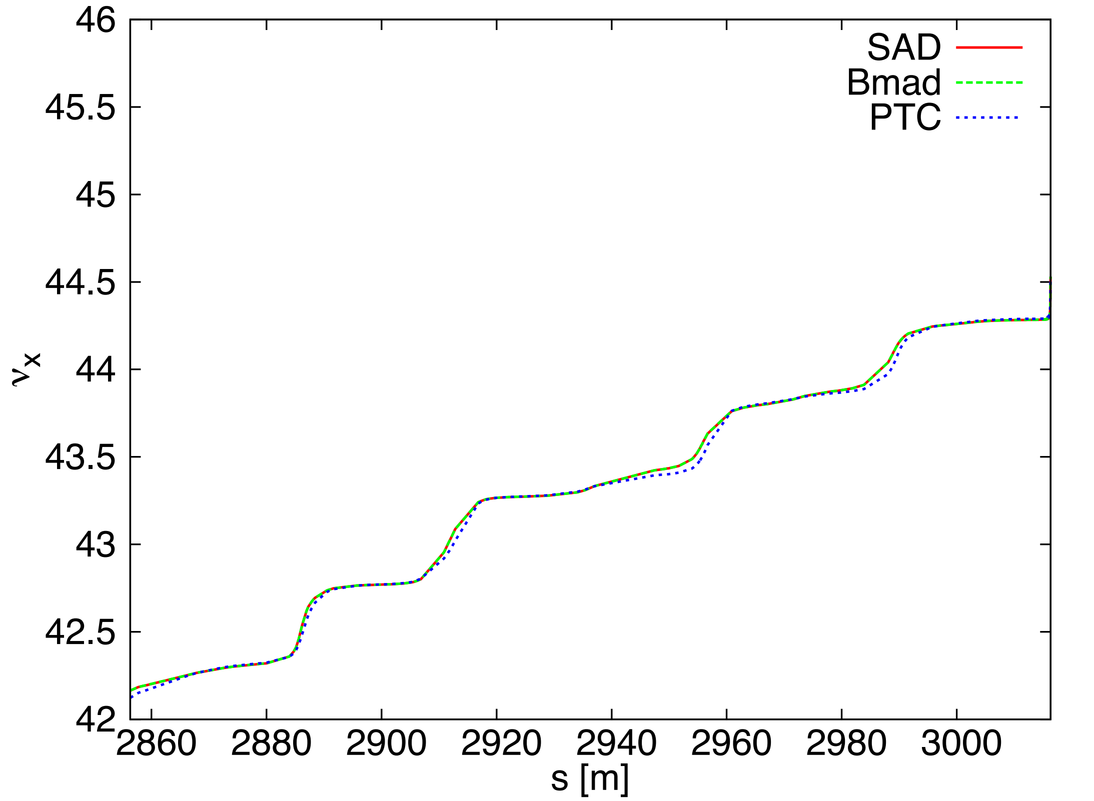
PTC:

βx=0.0338427m, αx=0.0279223, νx=44.53119,
Dx=0.0006m, D'x=-0.003632,
βy=2.682E-4m, αy=0.1103326, νy=46.57137,
Dy=9.98E-7m, D'y=-4.14E-4,

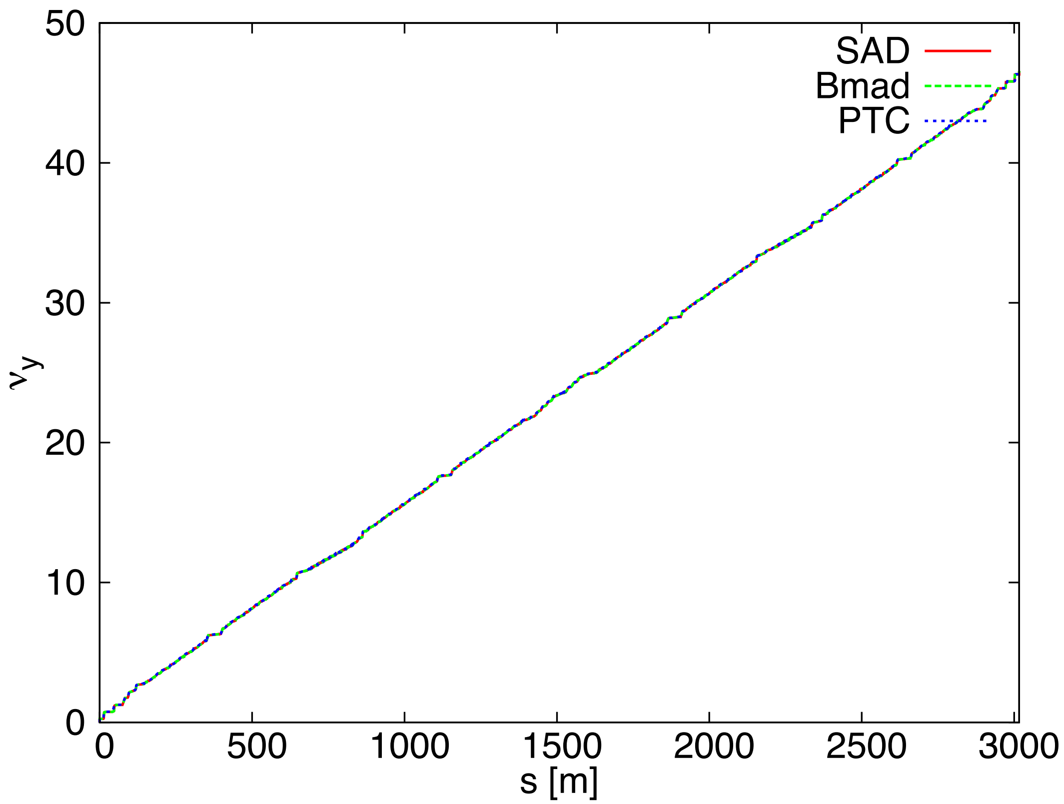
3. Benchmark: NuX

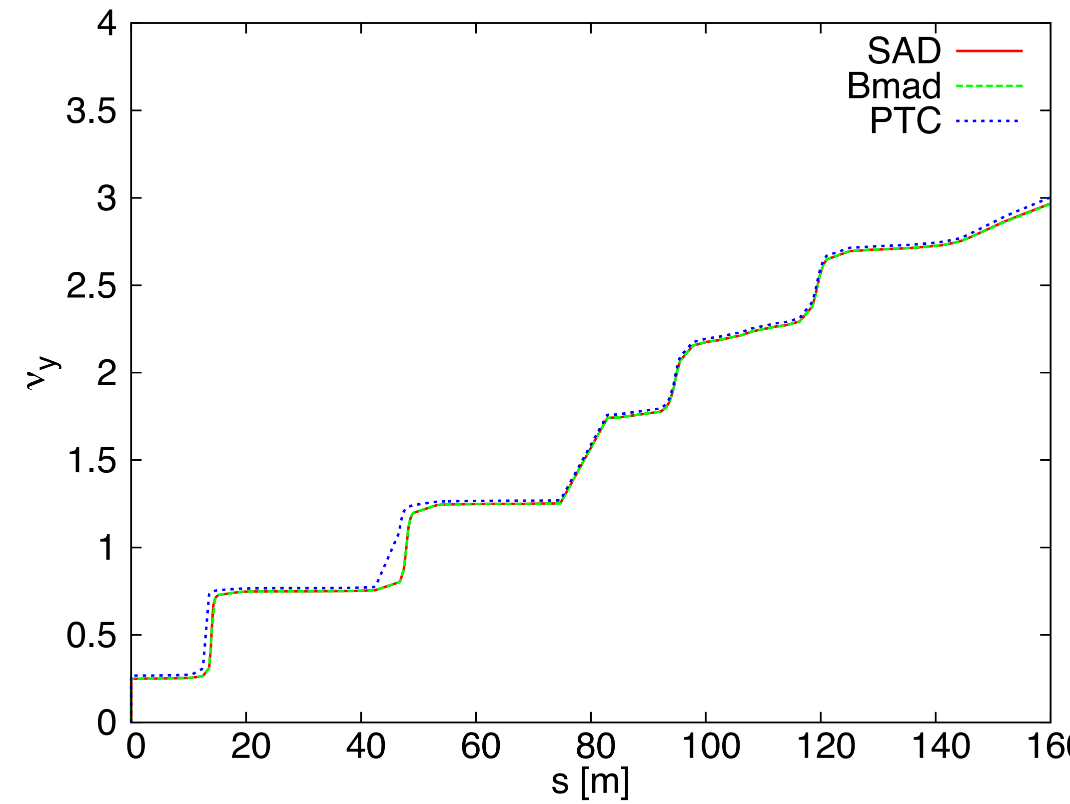


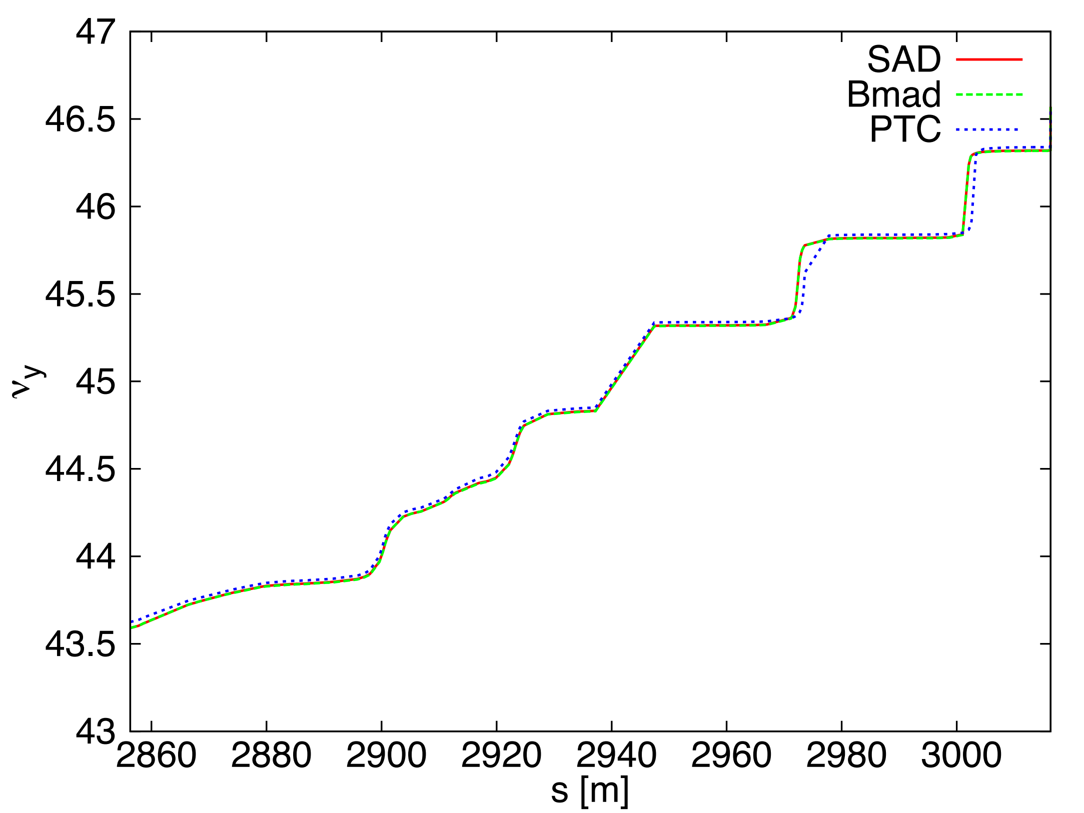




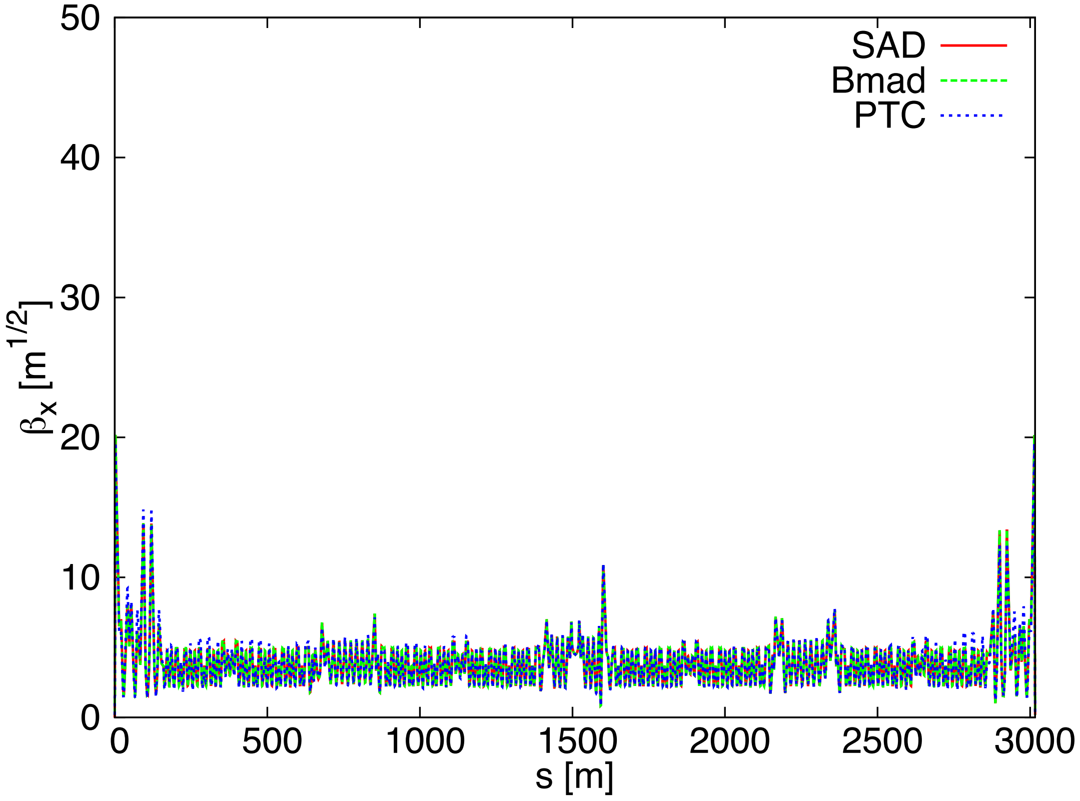
3. Benchmark: NuY

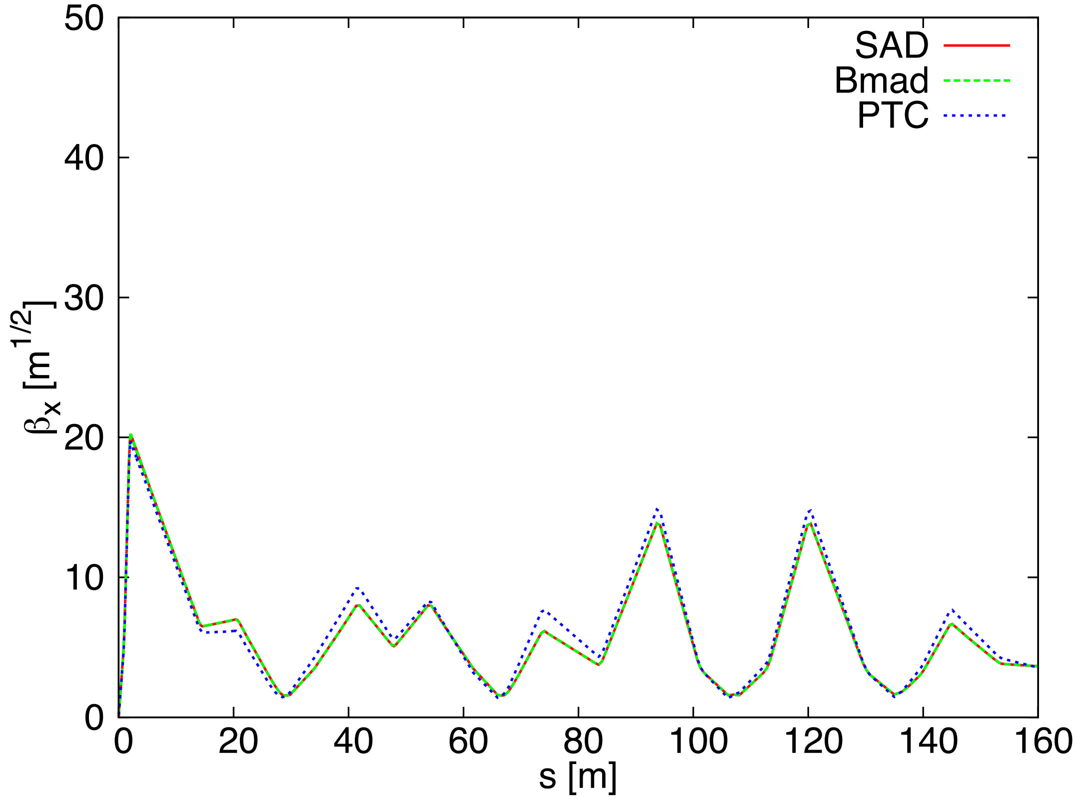


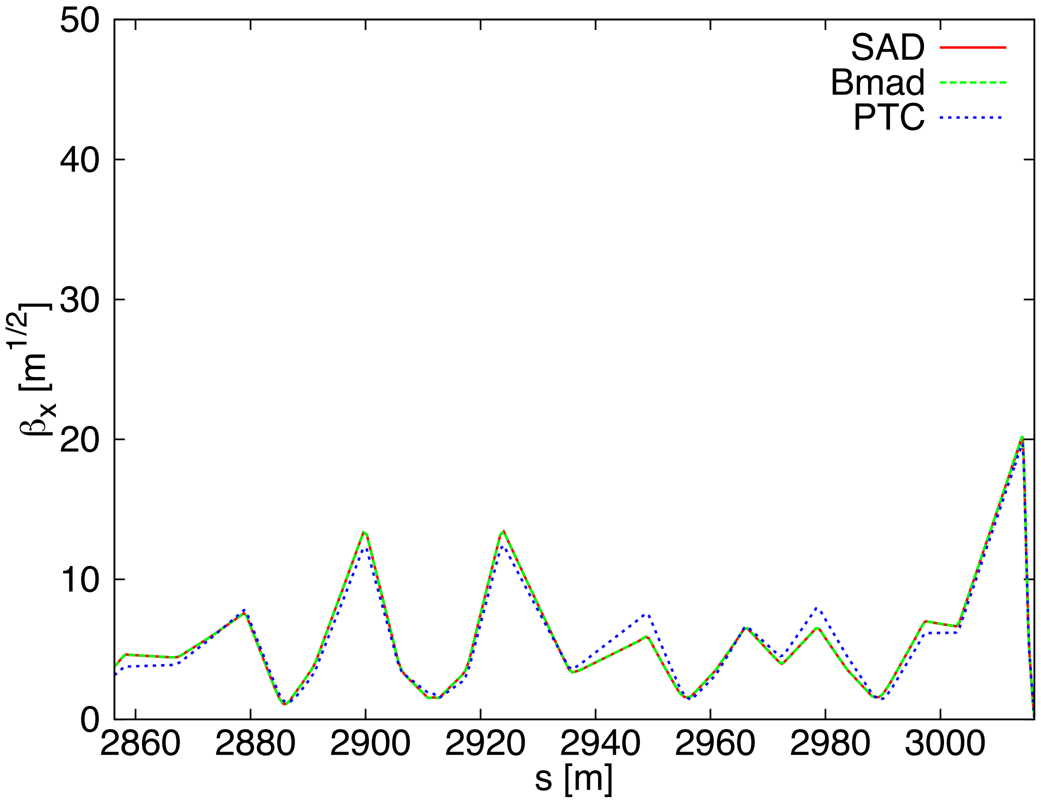




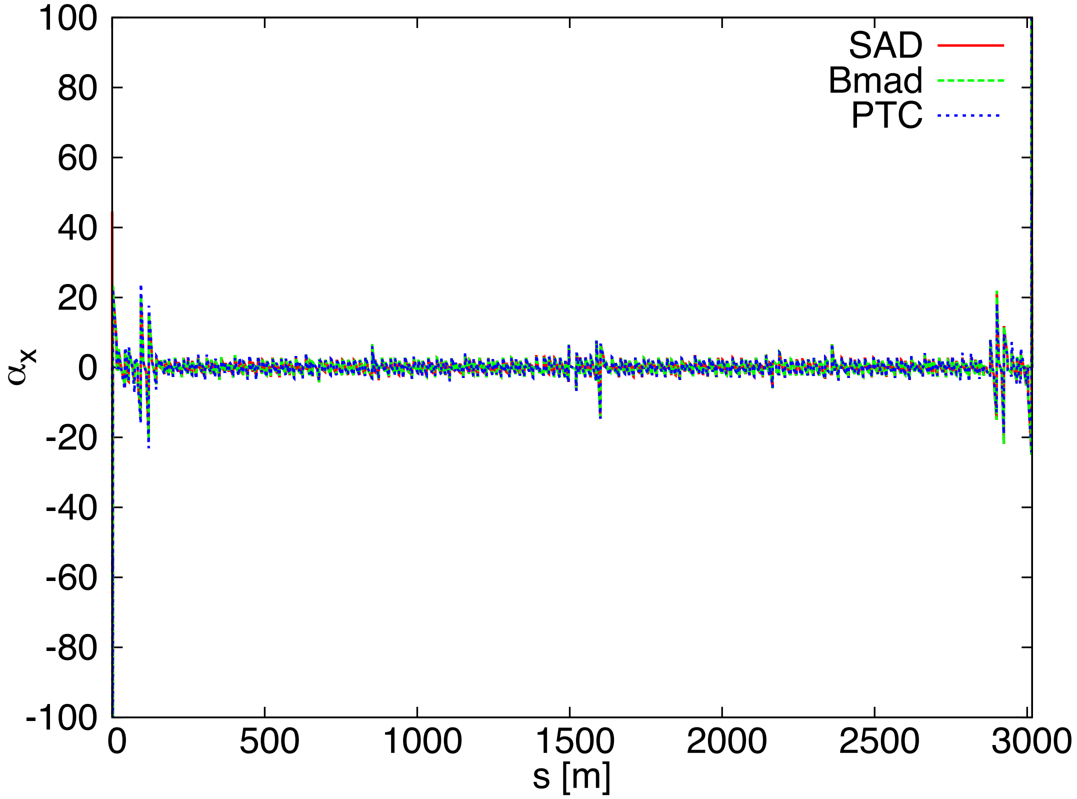
3. Benchmark: BetaX

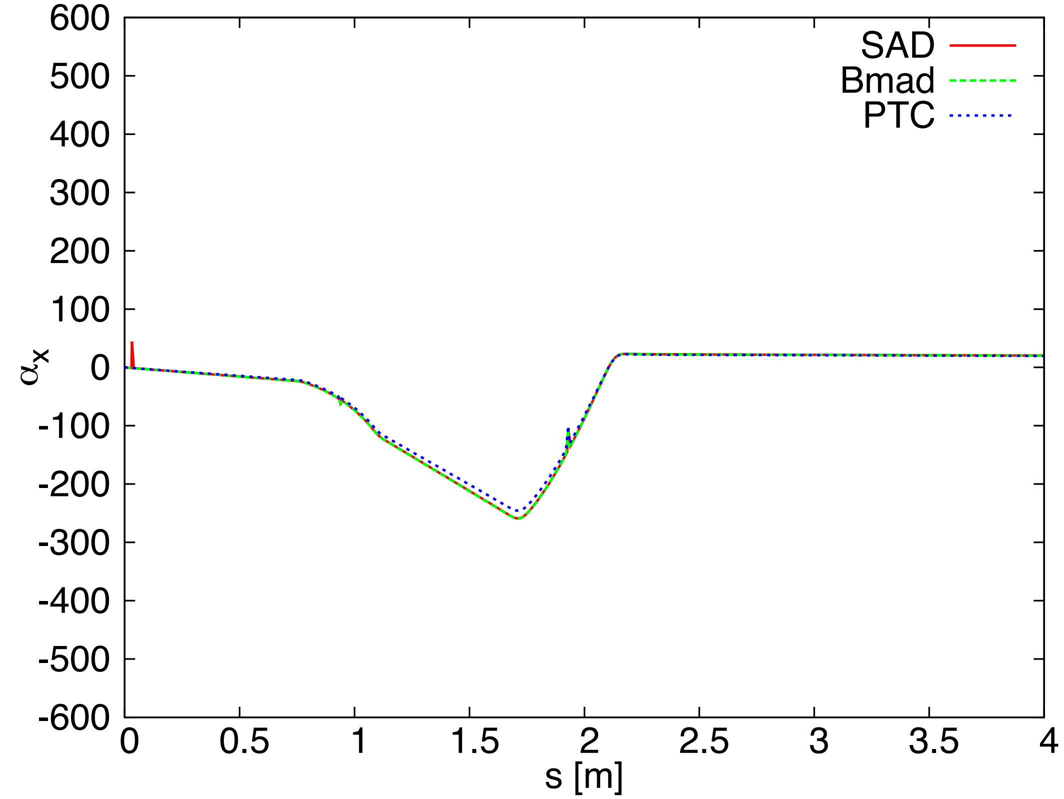


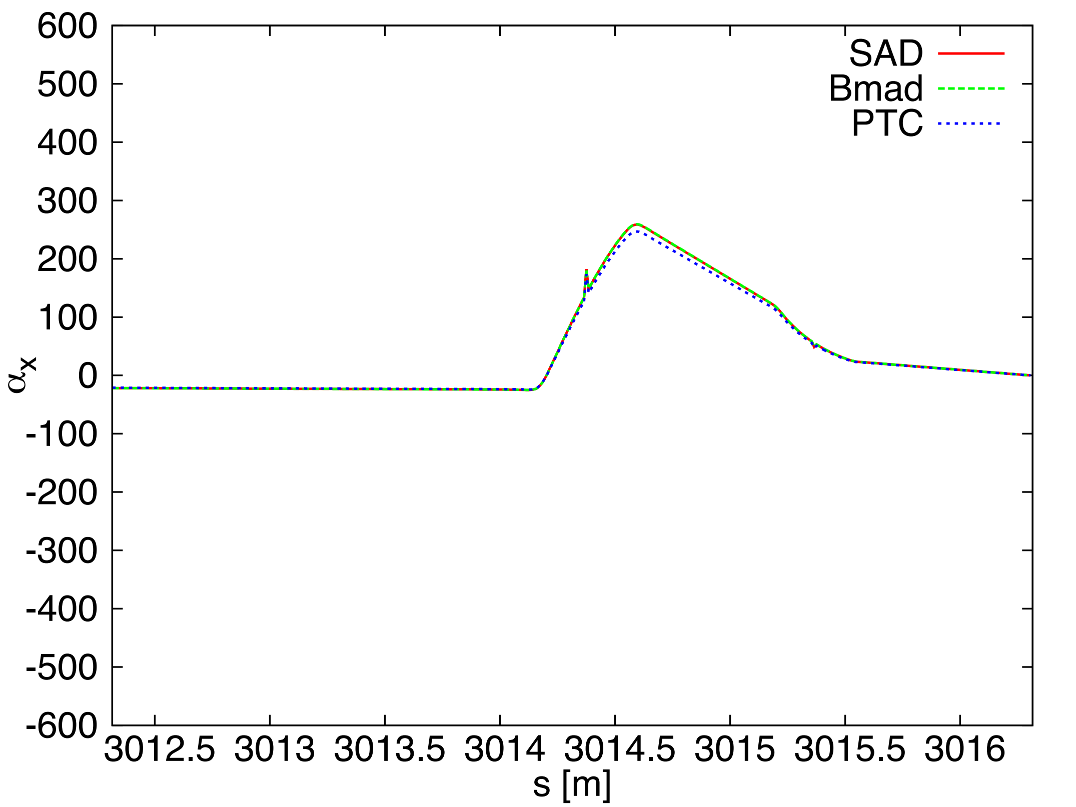




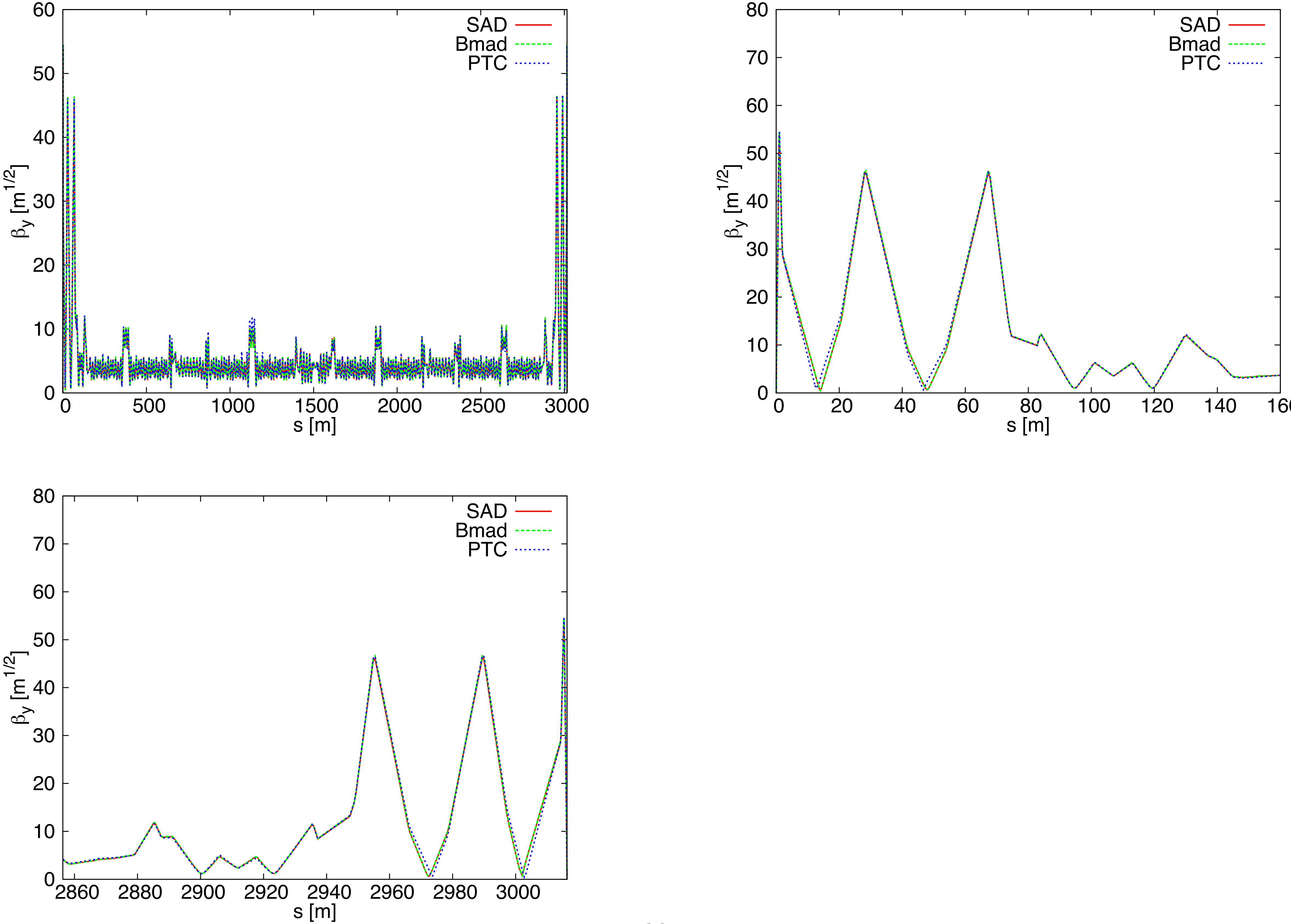
3. Benchmark: AlphaX



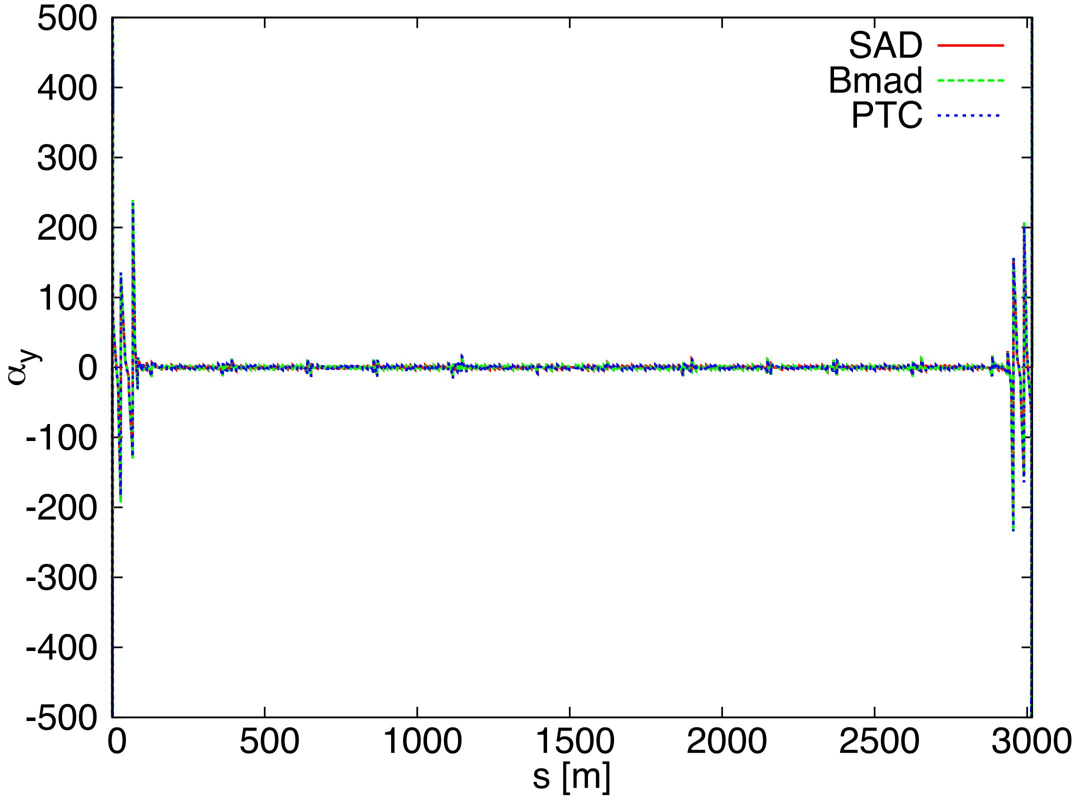


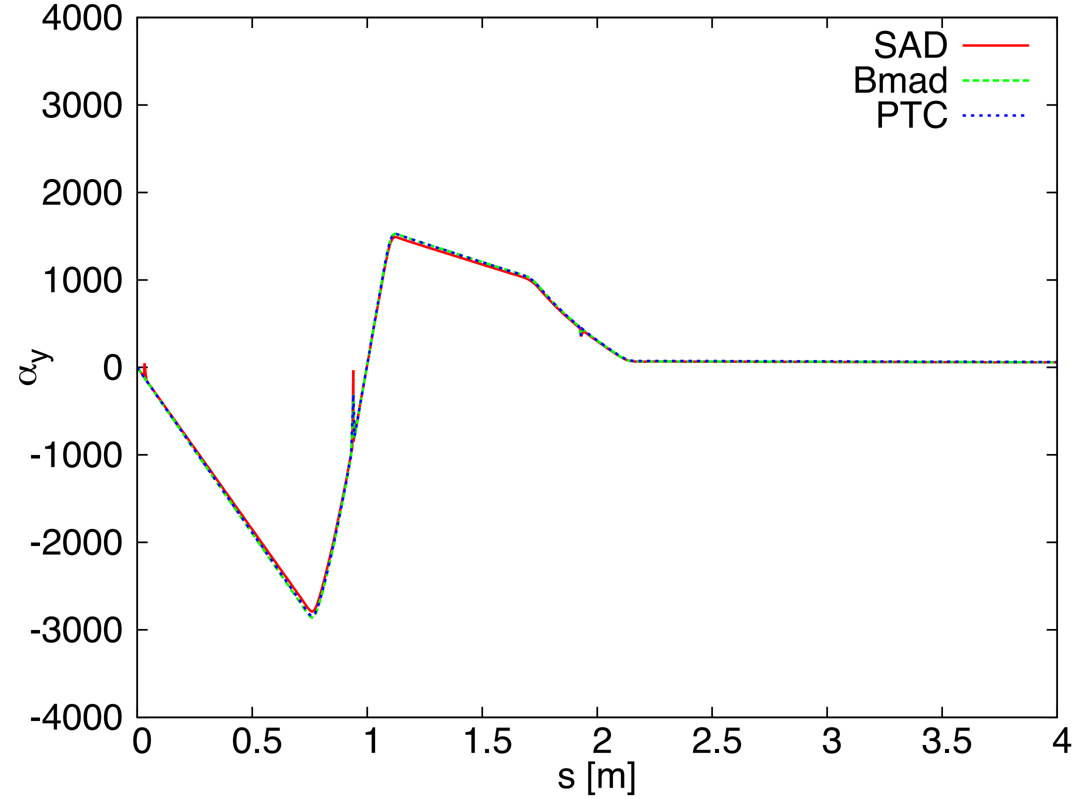


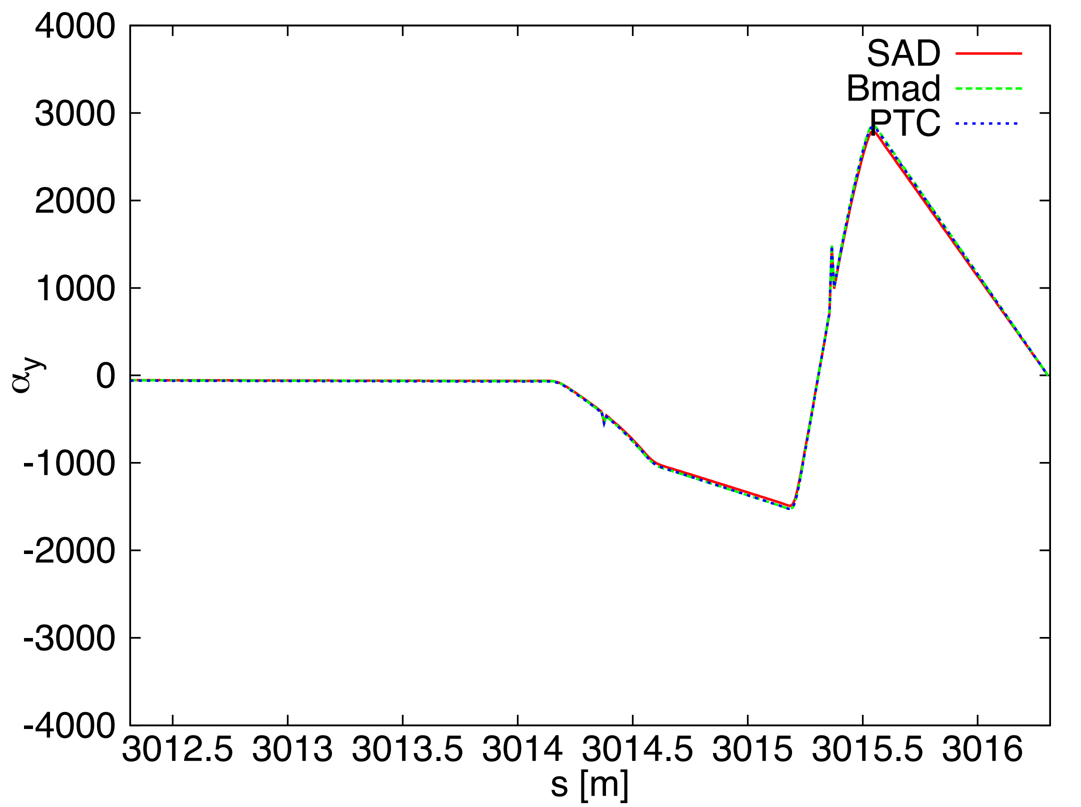
3. Benchmark: BetaY



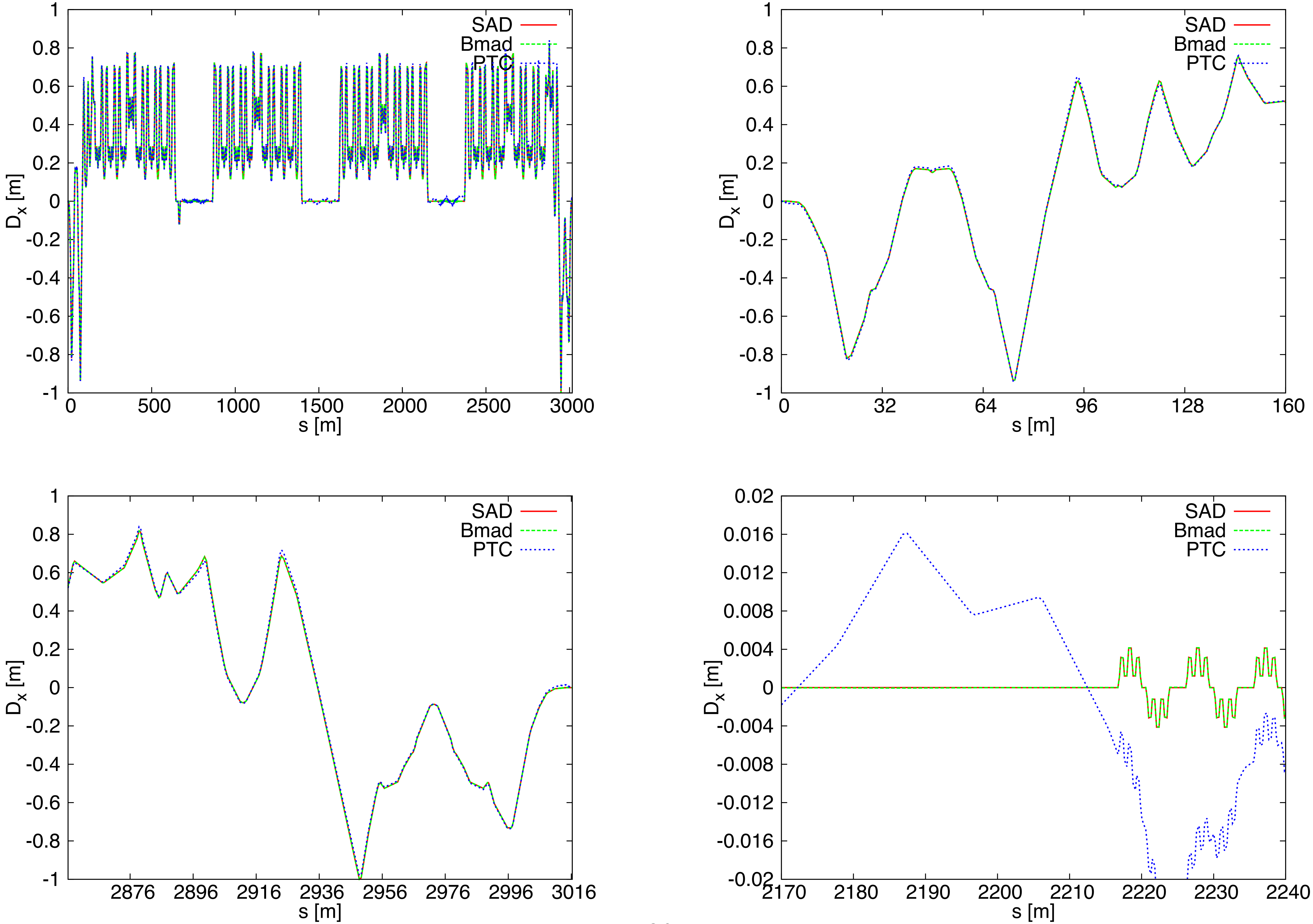
3. Benchmark: AlphaY



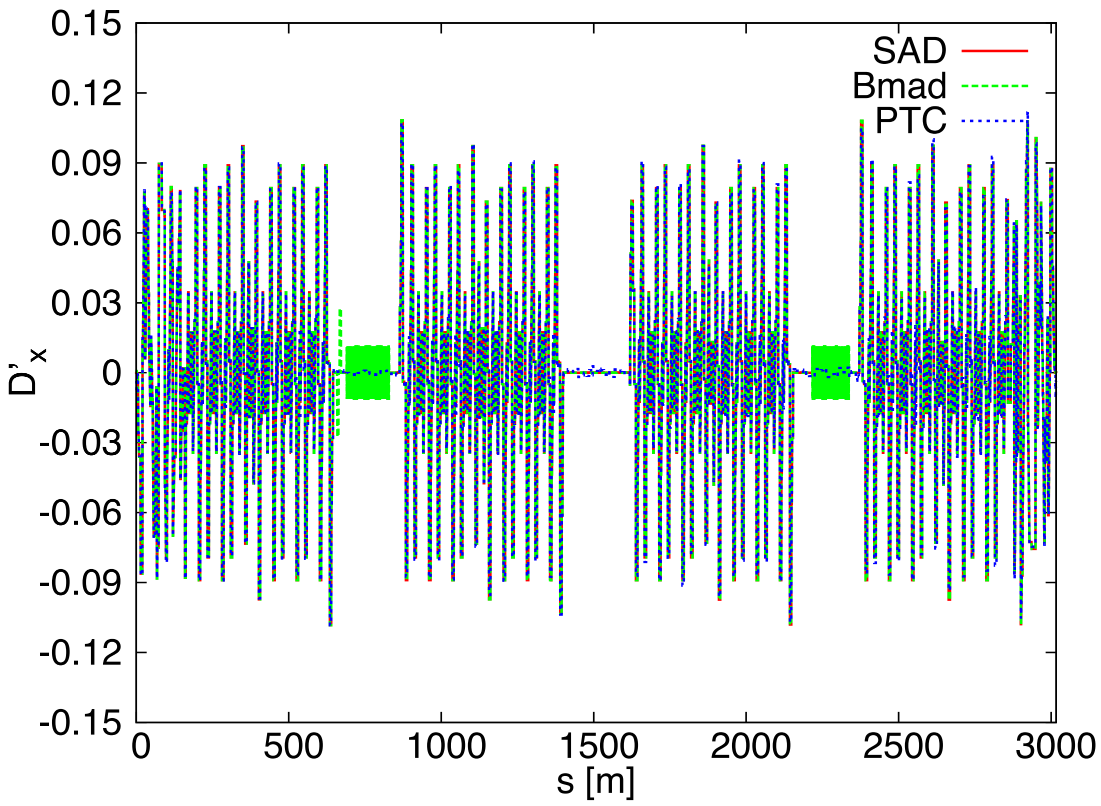


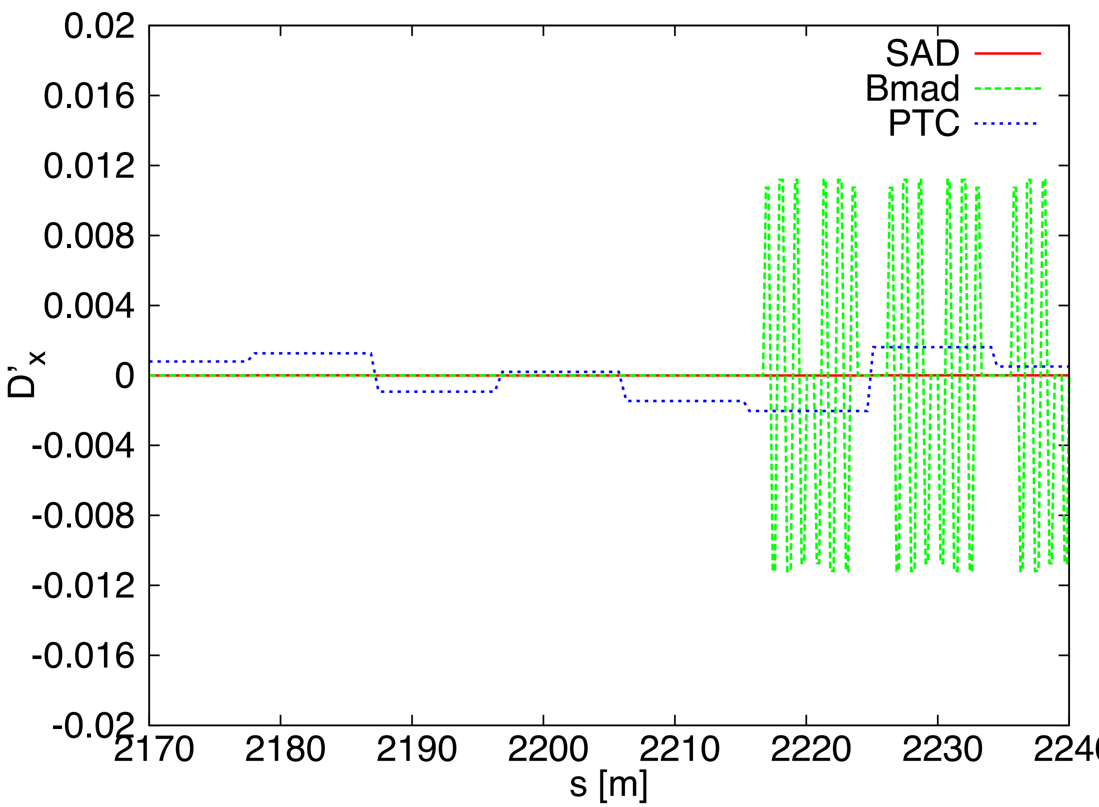


3. Benchmark: Dispersion-X

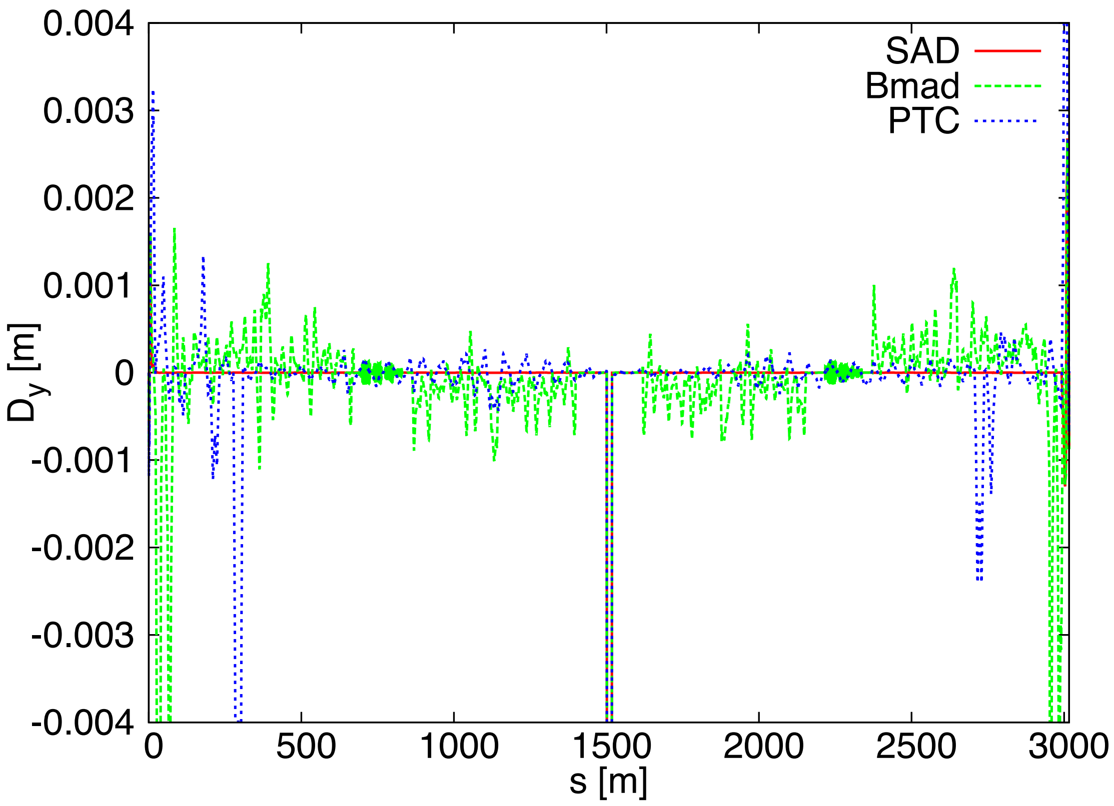


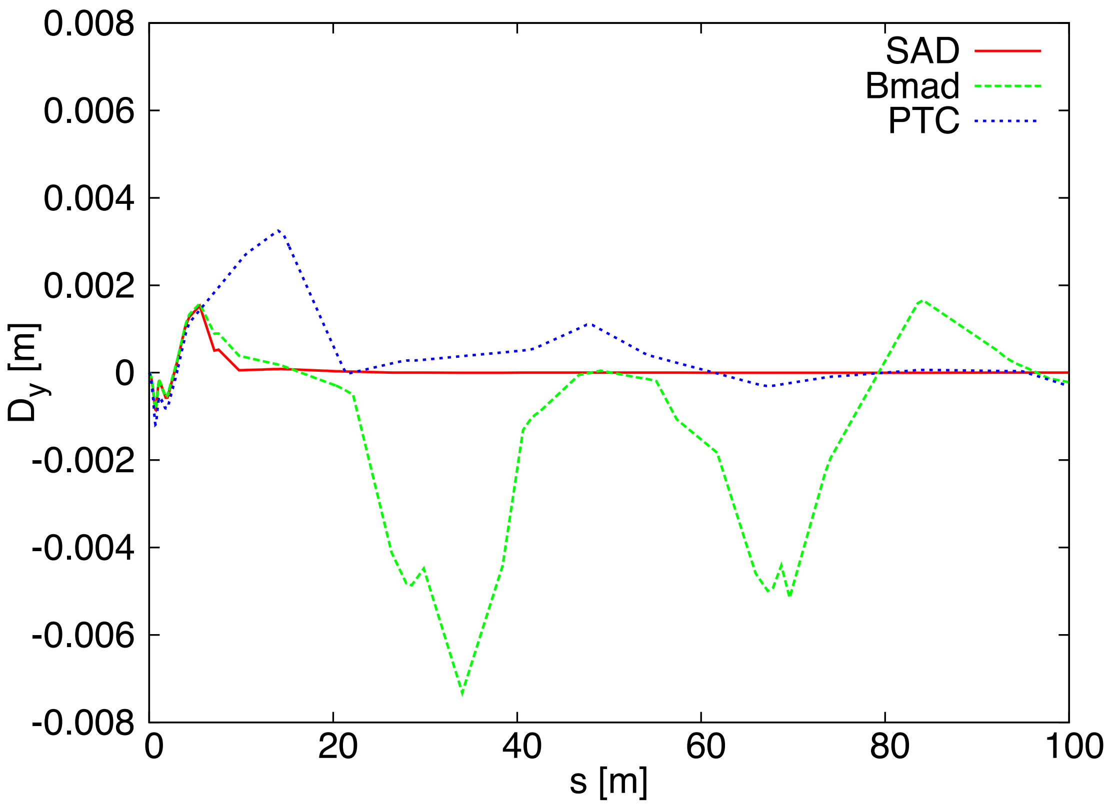
3. Benchmark: Dispersion-X-Prime

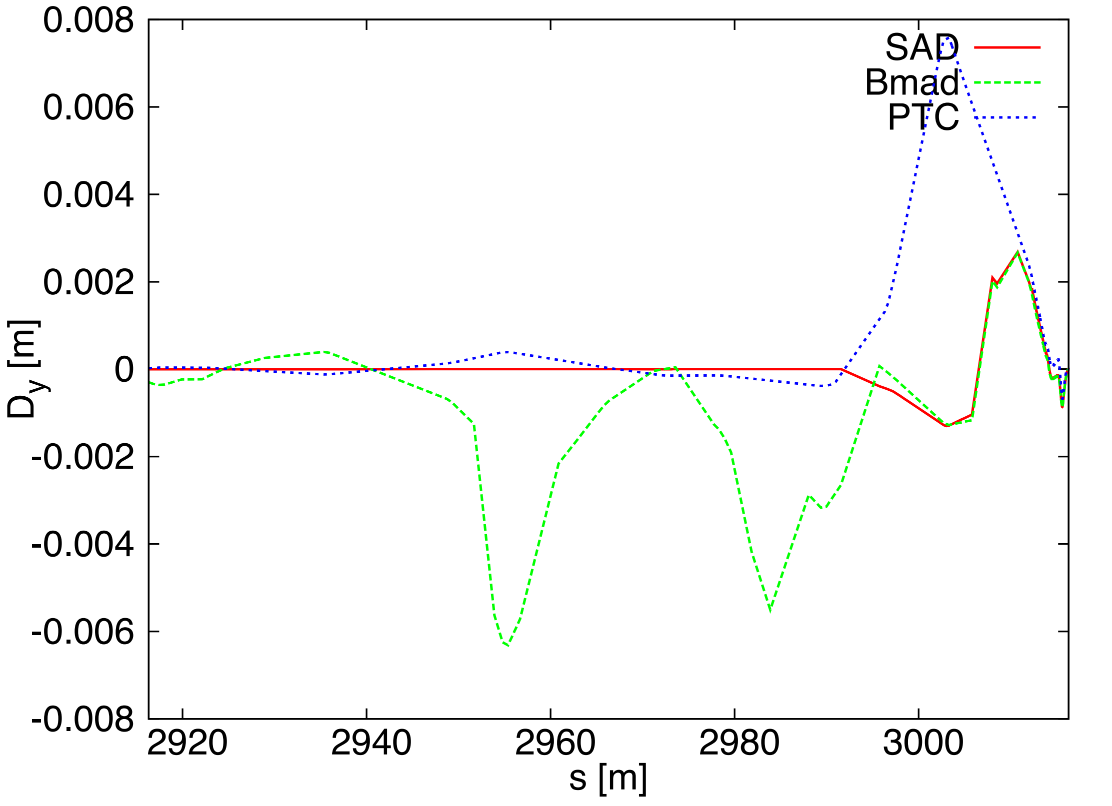




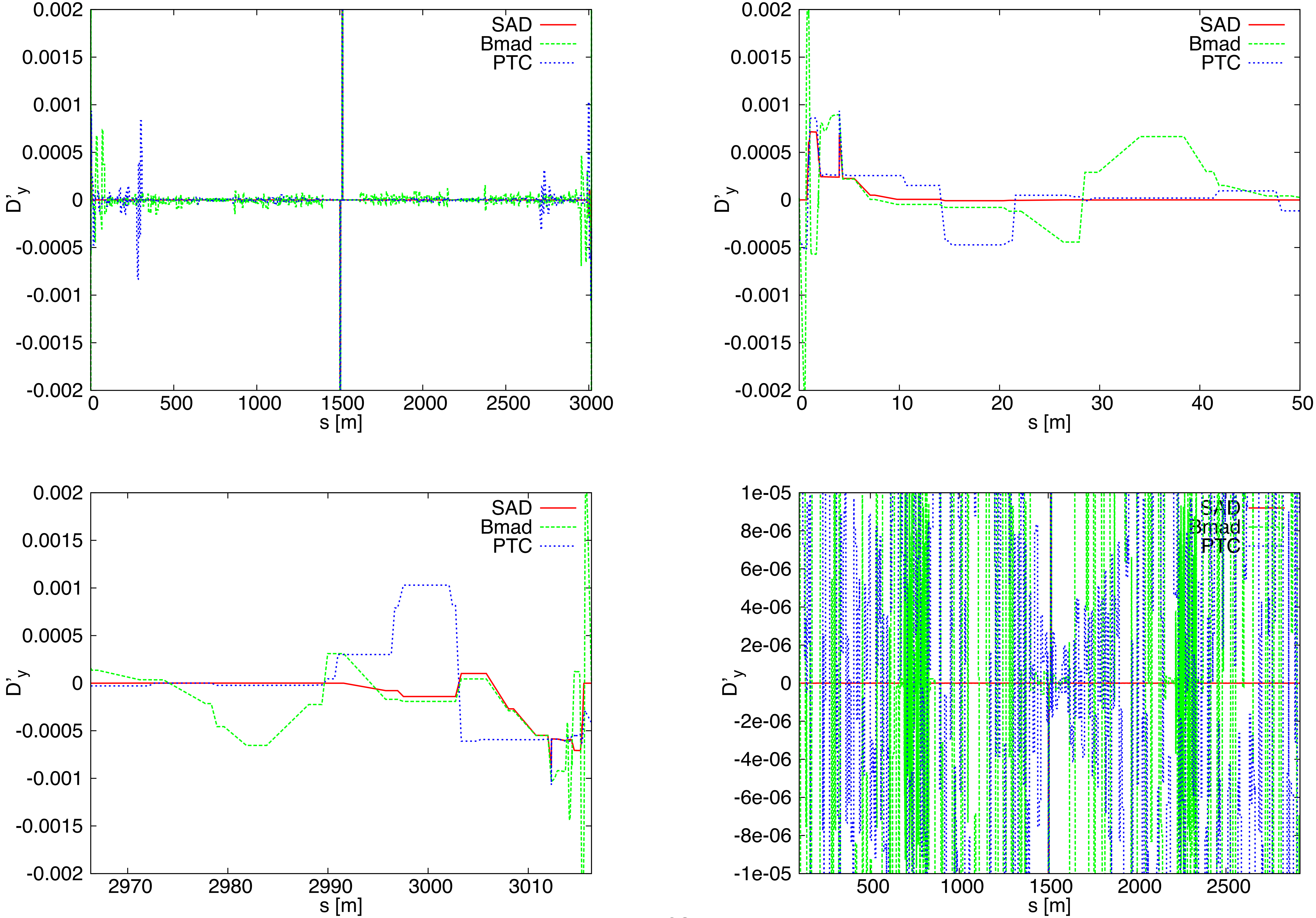
3. Benchmark: Dispersion-Y







3. Benchmark: Dispersion-Y-Prime



4. Future work for SuperKEKB

➤ **Self-consistency of present simulations**

- **Double-check & Benchmark did not reveal serious problems**

➤ **Nonlinear lattice analysis for SuperKEKB**

- **Y. Zhang's idea: no progress yet**
- **PTC: lattice translation and benchmark look good (discrepancies to be understood), we can move to next step of calculating nonlinear terms.**

➤ **Other ideas**

- **E. Forest wants to: 1) look into the details of solenoid effects; 2) construct double rings with common IR.**
- **Y. Wang from J. Gao's group of IHEP will visit KEK (Oct. 2015), he may continue Y. Zhang's idea, even consider reconfiguration of IR (refer to Oide's idea for FCC-ee?)**