Impact of Insertion Devices on Storage Ring Optics

Simon C. Leemann
MAX-MAC 10, April 27–28, 2015

MAX IV

Insertion Devices Affect Many Ring Aspects

- Focus here is impact on optics for fixed (min.) gap settings
  - using undulator and wiggler models in optics codes (DIMAD, OPA)
  - using kick maps in tracking codes (Tracy-3)

IPAC'**15**, TUPJE038

- A priori assumption: local ID correctors and FOFB will remove any residual kicks to the beam
- Neglecting ID impact on emittance, energy spread, etc.
  (mainly an issue in 3 GeV ring ➔ cf. PRST-AB **17**, 050705, 2014)

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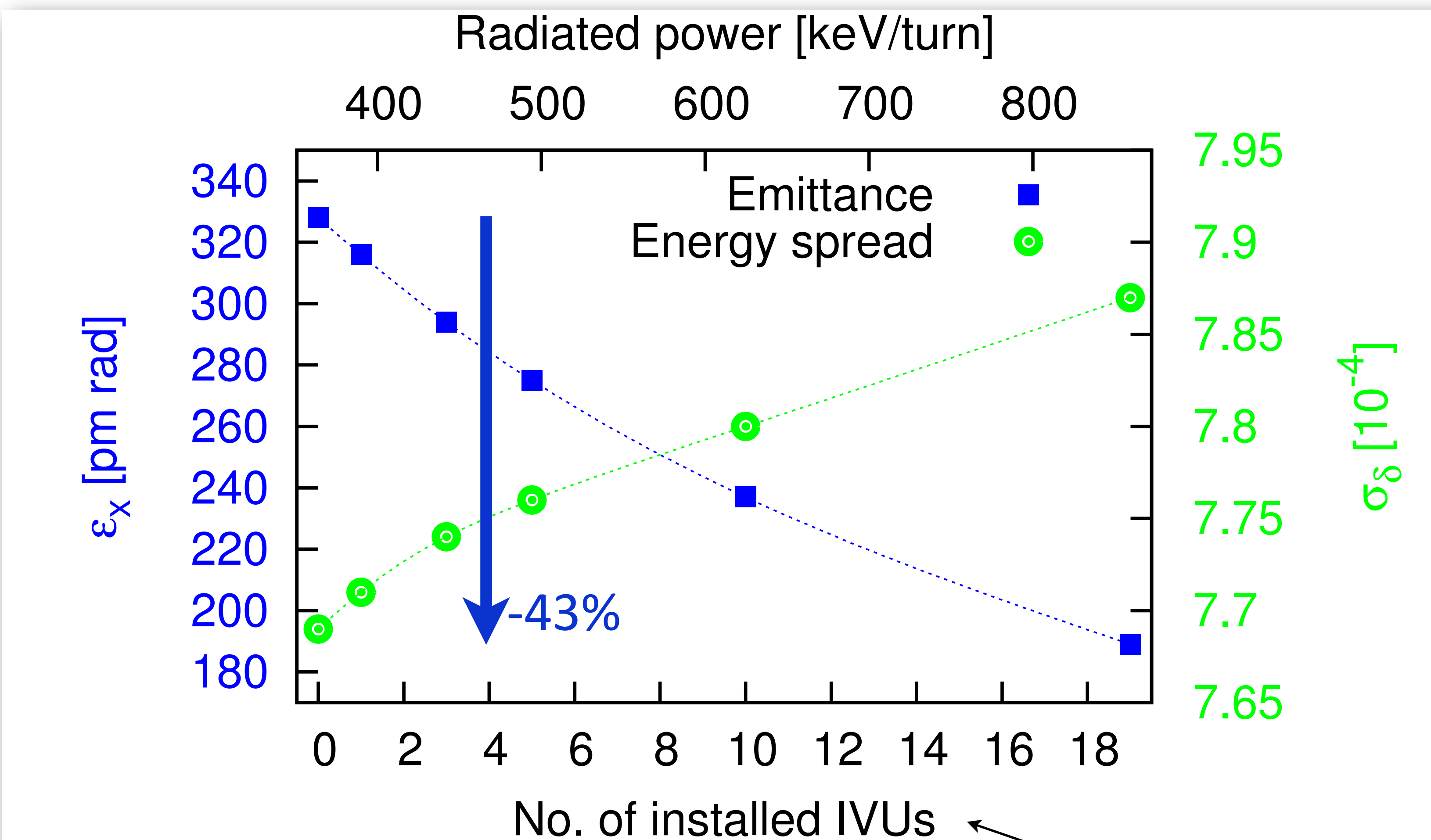

- d FOFB will
- spread, etc.

$$U_0 \propto \gamma^4 I_2 \qquad I_2 = \int \frac{ds}{\rho^2}$$

$$\varepsilon_0 \propto \gamma^2 \frac{I_5}{I_2 - I_4} \qquad I_5 = \int \frac{\mathcal{H}}{|\rho^3|} ds$$

$$I_4 = \int \frac{\eta}{\rho} \left(2k + \frac{1}{\rho^2} \right) ds$$

IVU: 3.7 m, λ_u = 18.5 mm, B_{eff} = 1.1 T

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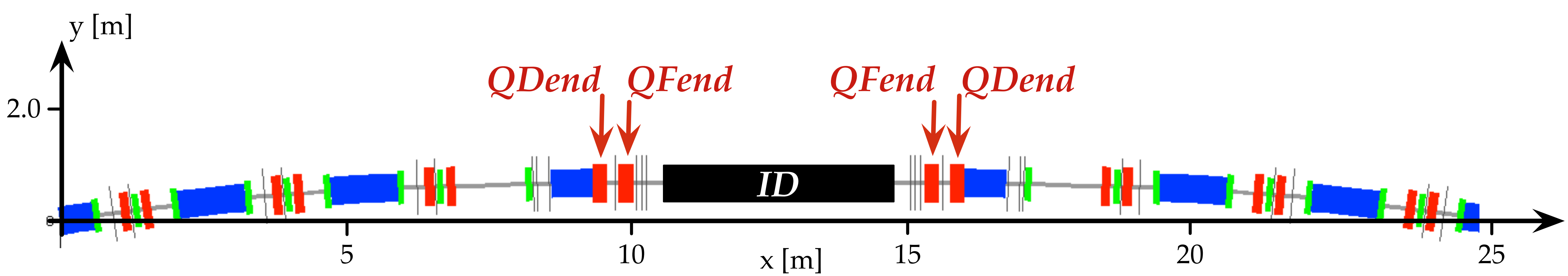
- Neglecting ID impact on emittance, energy spread, etc.
  (mainly an issue in 3 GeV ring ➔ cf. PRST-AB **17**, 050705, 2014)
- Neglecting ID impedance & collective effects issues
- Neglecting dynamic multipoles

PAC'**11**, TUP235, p.1262

  - In the optics design phase set up limits for multipole content of IDs (multipoles in principle only allowed to perturb nonlinear corrections by ~ 10%)

Optics Matching in the 3 GeV Ring

- Local: adjacent quadrupole doublets adjusted to compensate vertical/horizontal focusing of ID (via $\beta_{y/x}$ squeeze) **cf. MAC3**
  - prevents beta beating
  - can be done individually if ID is installed off-centered
  - via lookup tables and feedforward



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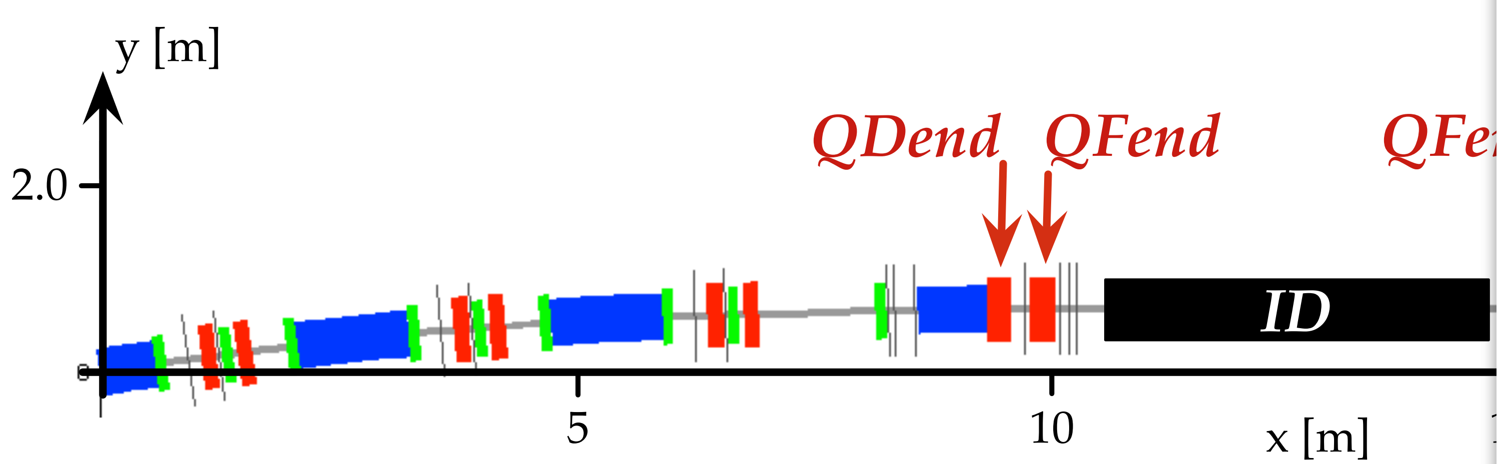
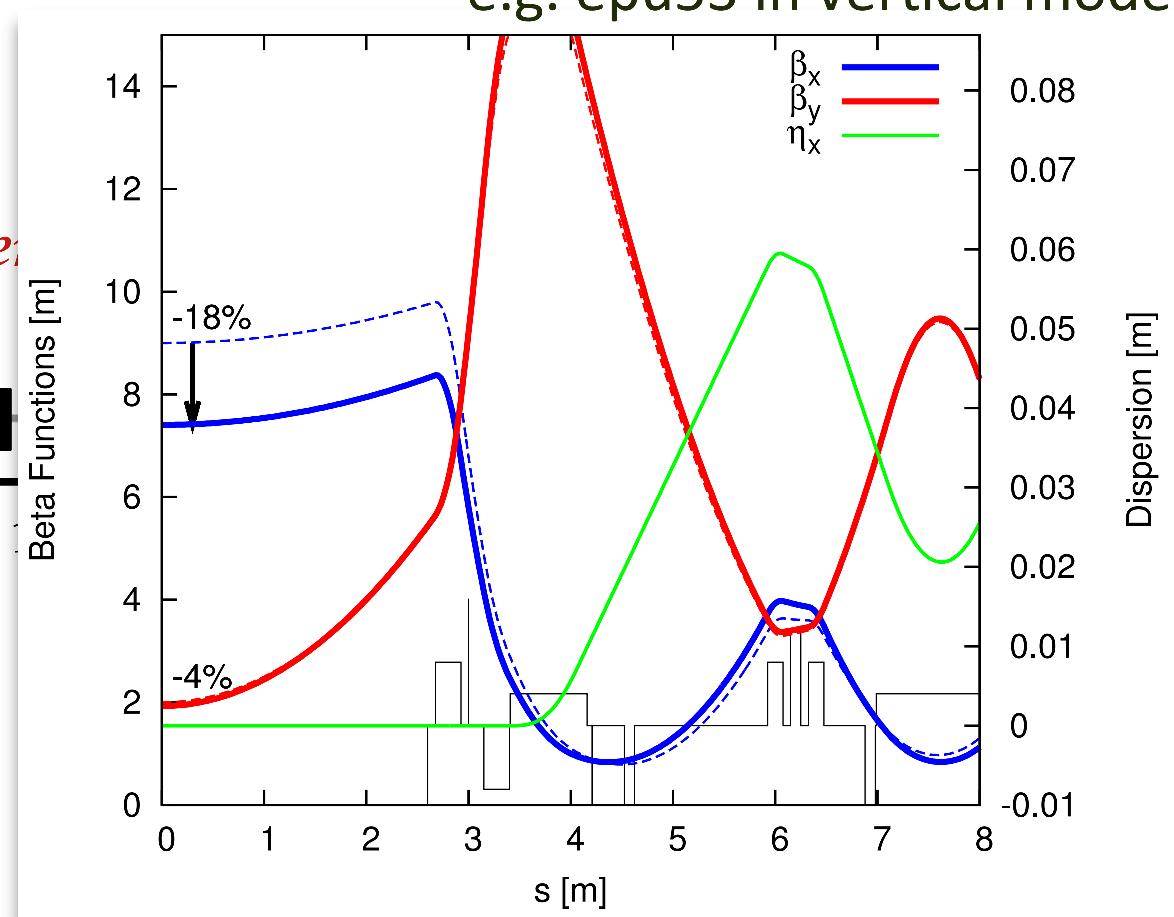


e.g. epu53 in vertical mode



MAX IV

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  - prevents beta beating
  - can be done individually if ID is installed off-centered
  - via lookup tables and feedforward
- Global: by nudging all quadrupole doublets can remove any residual phase advance to restore design working point
  - important to ensure nonlinear optics optimization not perturbed
  - should be implemented as feedback (via online tune measurement)
- The result should make ID transparent to nonlinear optics
  - in principle no need to re-adjust sextupoles and octupoles

Optics Matching in the 1.5 GeV Ring

- Local: ~~only for very strong IDs (i.e. SCW for Solaris)~~ **cf. MAC4**
  - via adjacent SQFo's and DIP PFSs (break series connections, "floating" PSs)
  - prevents beta beating
  - via lookup tables and feedforward

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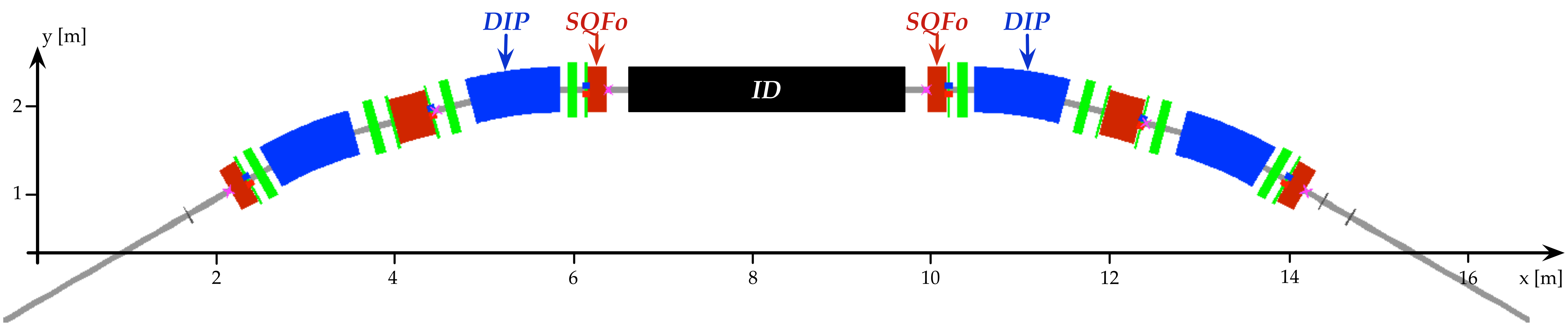

Optics Matching in the 1.5 GeV Ring (cont.)

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  - via lookup tables and feedforward

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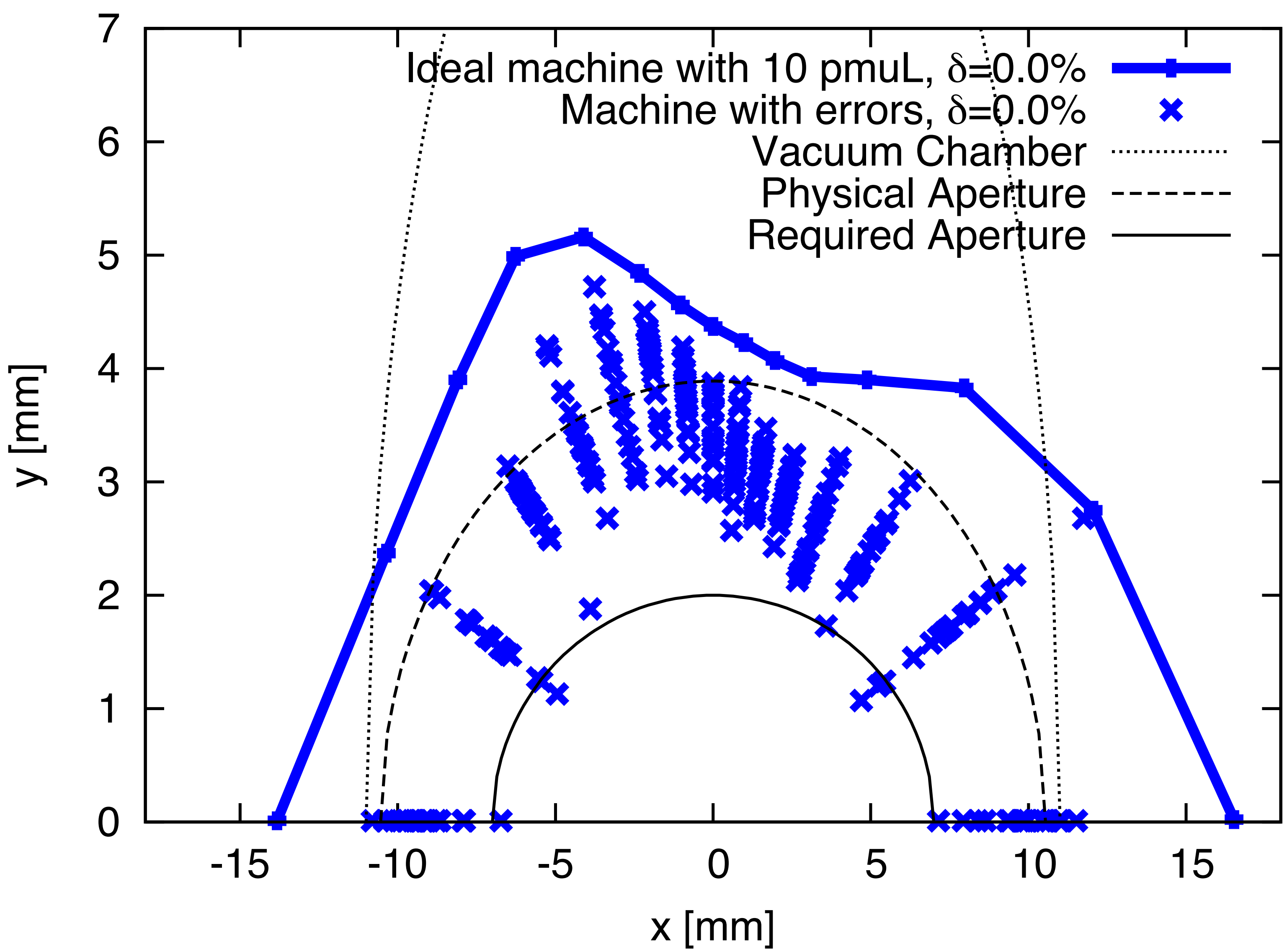
- Global: by nudging SQFo family and PFSs can remove any residual phase advance to restore design working point
  - should be implemented as feedback (via online tune measurement)
- Unlike 3 GeV ring, PFSs in 1.5 GeV ring do not excite significant dipole contribution...
- ...but this compensation does require PFSs ➔ focusing change in dispersive location ➔ dispersion leaks? $\xi_{x,y}$ change...

Recall MAC3: 10 IVUs in 3 GeV Ring

- Example: 10 planar in-vac. undulators, gaps fully closed, ring optics matched, magnet and alignment errors incl. (20 seeds)



- 10 IVUs of type "pmuL":
  3.7 m long, 1.1 T peak field,
  18.5 mm period, 4.2 mm gap
- Misalignments:
  50 μm rms H/V
  0.2 mrad rms roll } for each magnet block
  25 μm rms H/V
  0.2 mrad rms roll } for all magnets within
- Field Errors:
  0.05% rms within each family
- Multipole Errors:
  Upright and skew multipoles added

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Example: Hitachi IVU in 3 GeV Ring

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- BioMAX and NanoMAX beamlines
- 18 mm period, 1.26 T peak field (K=1.95), 2 m long, kick map at 4.2 mm magnetic gap used in Tracy-3
  - During design phase: 3.8 m pmuL, so no problems expected

Example: Hitachi IVU in 3 GeV Ring (cont.)

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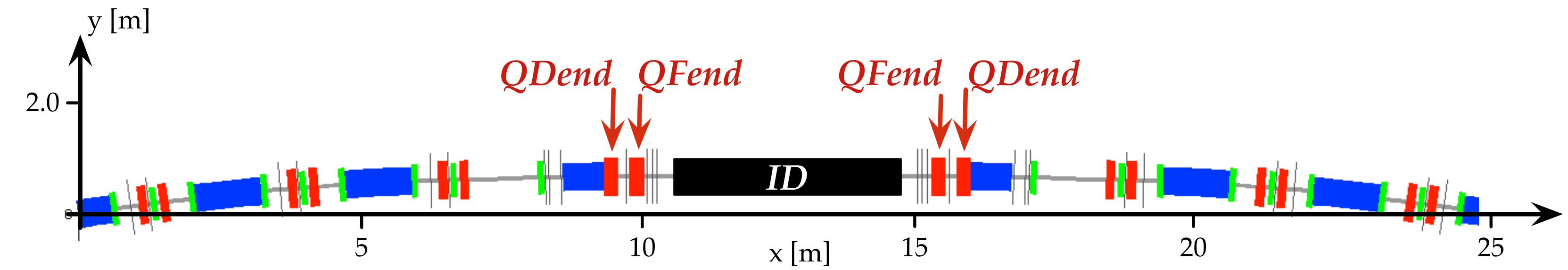
	Local		Global	
Gap	**QFend**	**QDend**	**QFend**	**QDend**
4.2 mm	+0.106%	+0.429%	−0.009%	−0.035%



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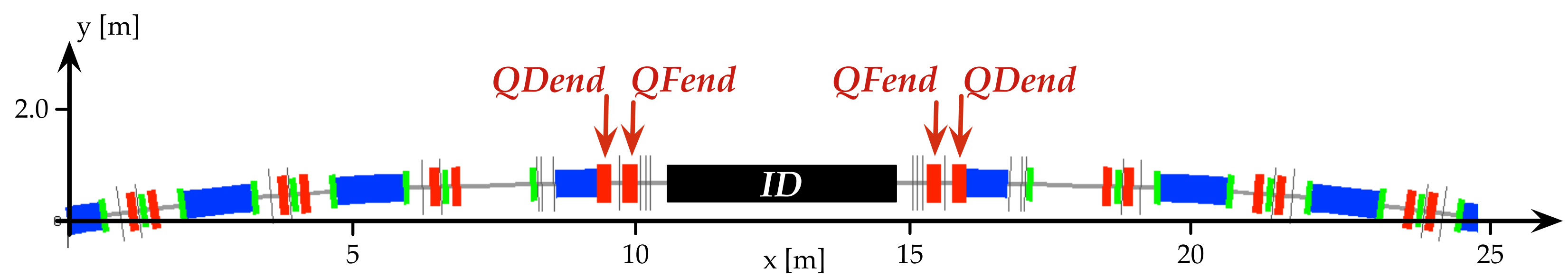
- no nonlinear dynamics issues
  (vertical limitation is IVU acceptance, not DA)



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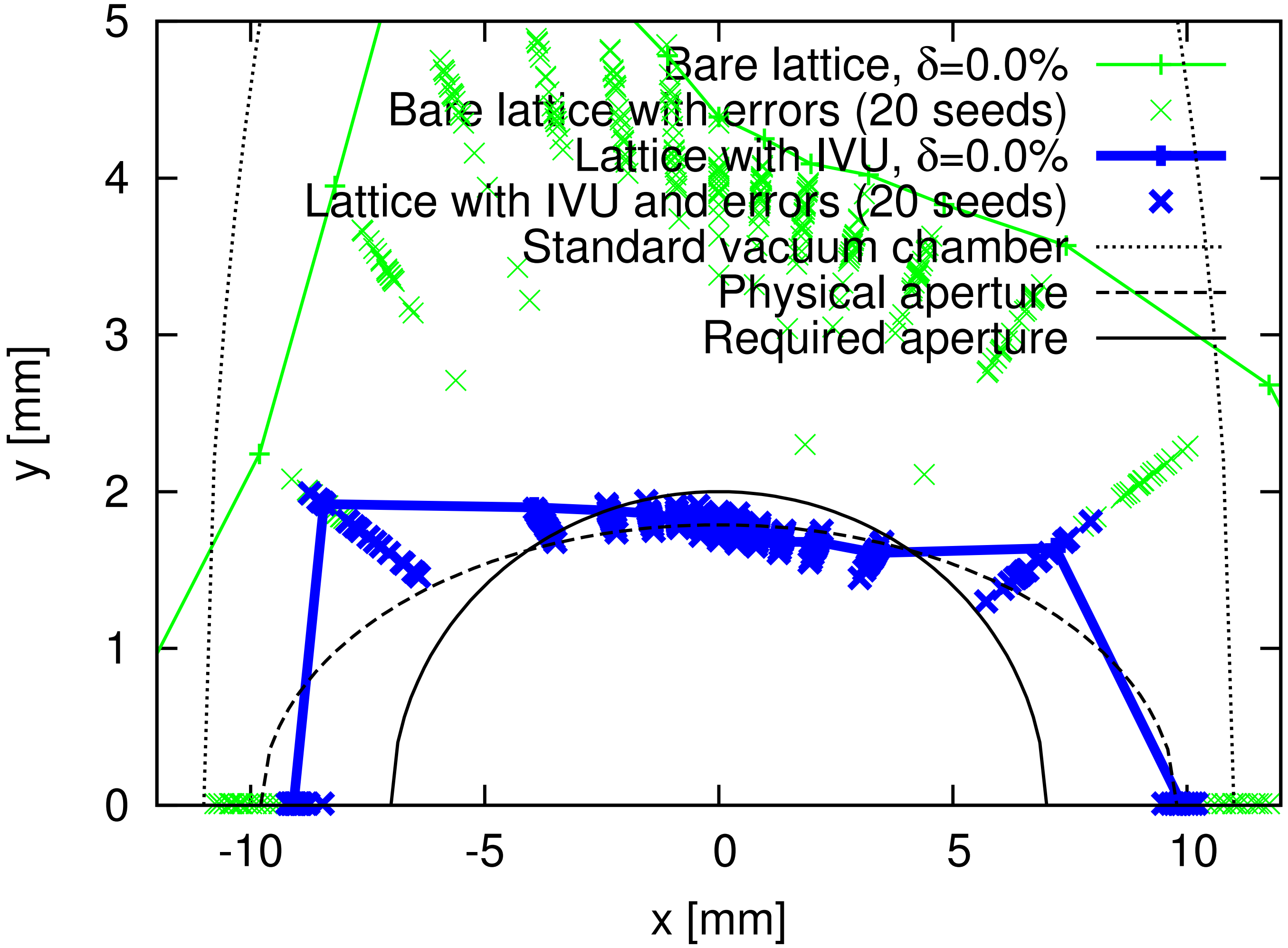

Example: epu53 in 3 GeV Ring

IPAC'**15**, TUPJE038

- HIPPIE beamline
- 53 mm period, 1.1 T max. field (K=5.2), 3.9 m long, kick maps for each EPU mode at 11 mm magnetic gap used in Tracy-3

Example: epu53 in 3 GeV Ring (cont.)

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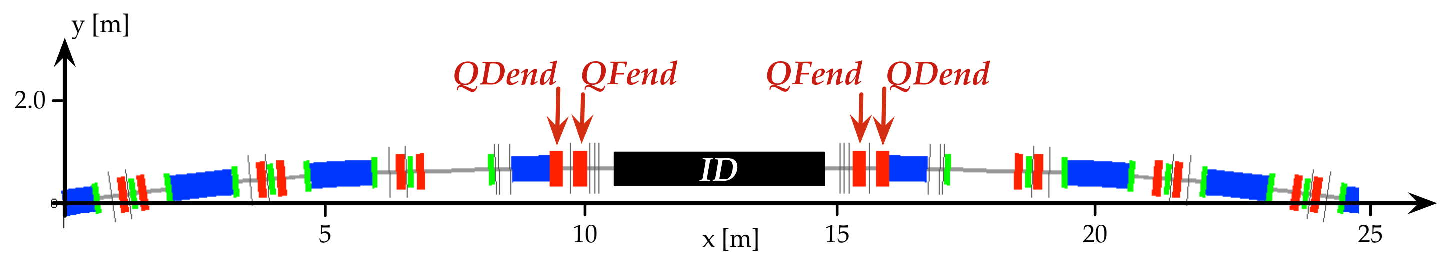
Mode	**QFend**	**QDend**	**QFend**	**QDend**
Planar	−0.496%	−0.004%	−0.005%	−0.033%
Vertical	+2.28%	+1.92%	−0.032%	−0.075%
Inclined	+0.054%	+0.508%	−0.014%	−0.057%
Circular	+1.22%	+1.18%	−0.022%	−0.058%



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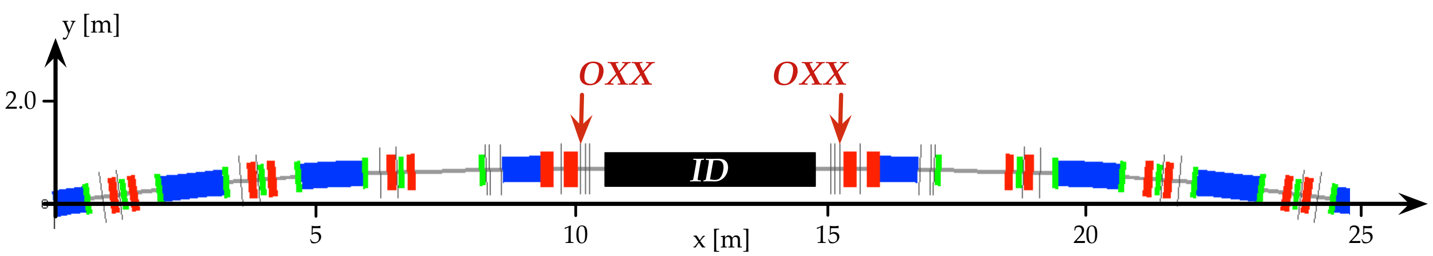

- INCL: coupling increase to 0.8%
  - ➡ -0.3 T/m skew on aux. coil on flanking OXXs

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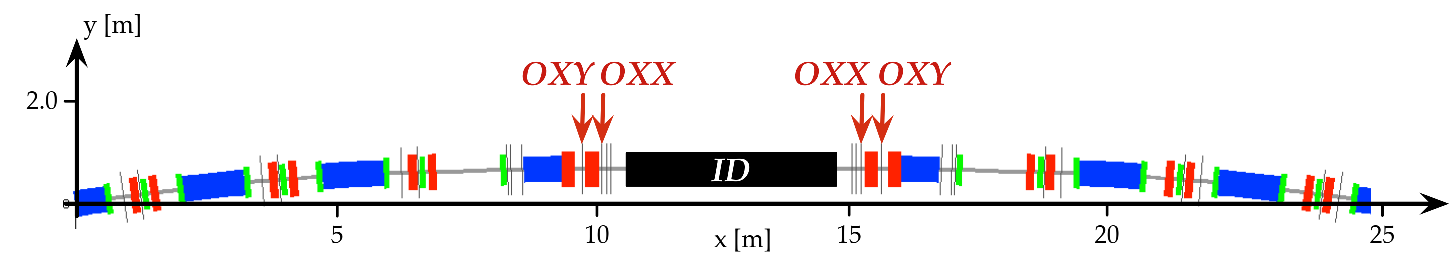
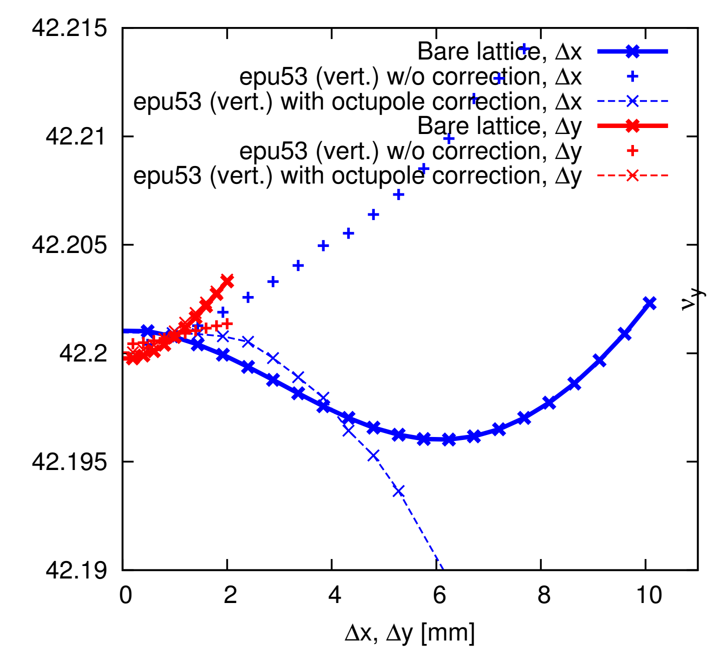
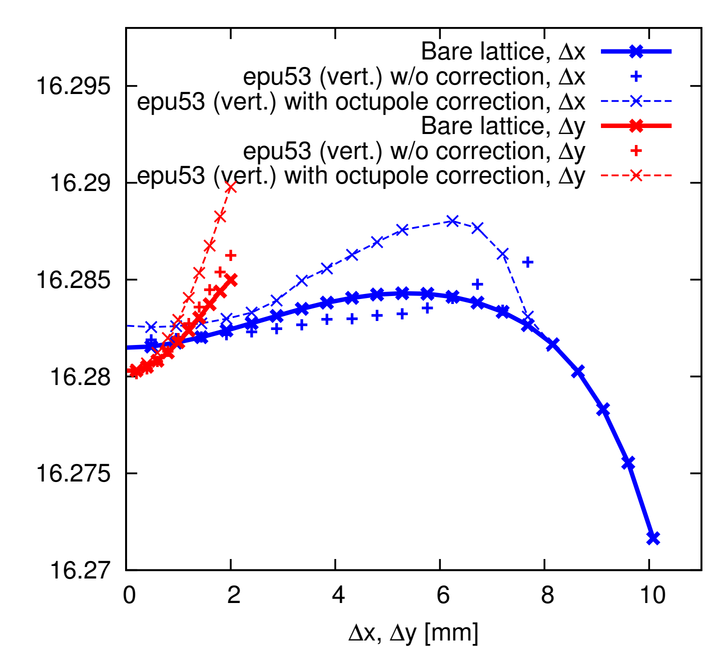


- INCL: coupling increase to 0.8%
  - ➡ -0.3 T/m skew on aux. coil on flanking OXXs
- VERT: decrease of DA caused by perturbation of $\partial\nu_x/\partial J_x$ pushing towards $2\nu_x+2\nu_y = 117$ for large horizontal amplitudes
  - ➡ +15% on OXX, +5% on OXY to re-adjust $\partial\nu_x/\partial J_x$ and $\partial\nu_x/\partial J_y = \partial\nu_y/\partial J_x$





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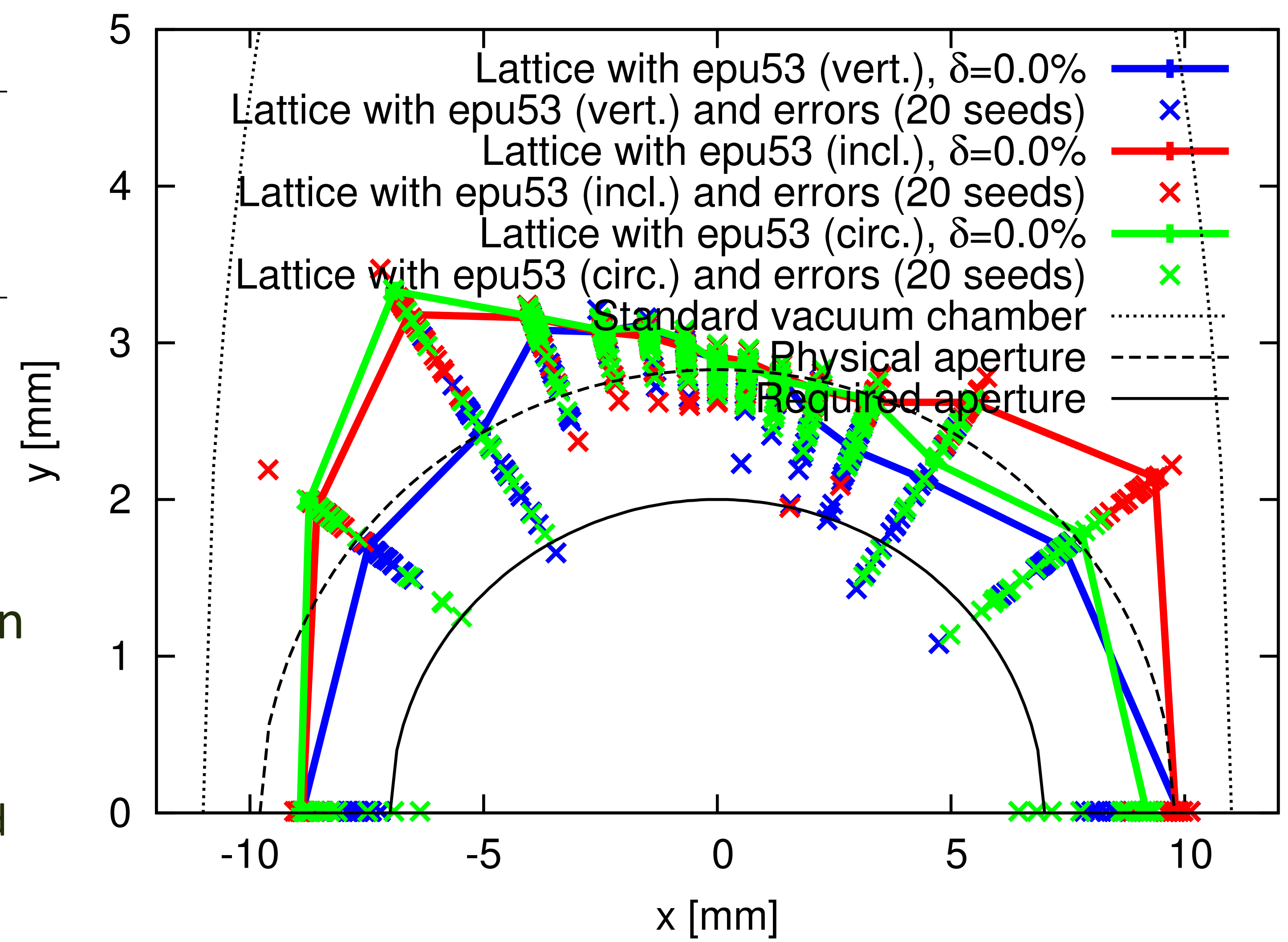

Example: epu95.2 in 1.5 GeV Ring

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- FinEstBeaMS beamline
- 95.2 mm period, 1.2 T max. field (K=10.5), 2.6 m long, kick maps for EPU modes at 14 mm magnetic gap used in Tracy-3

Example: epu95.2 in 1.5 GeV Ring (cont.)

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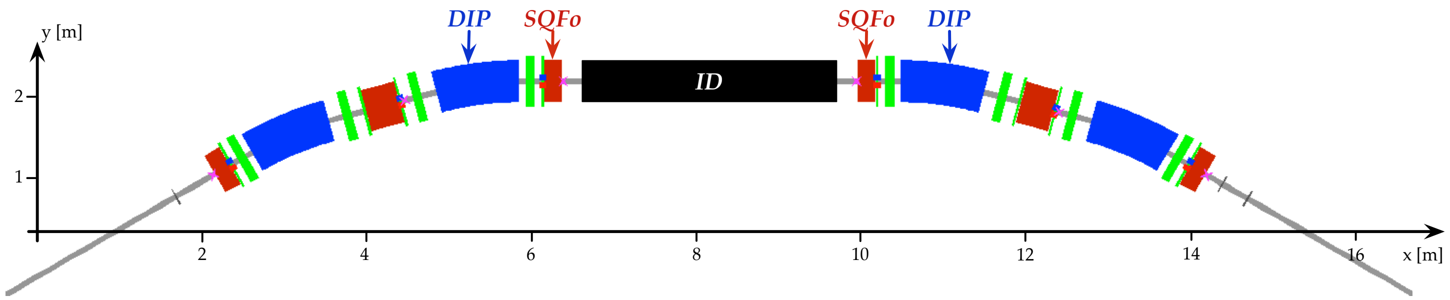
	Local		Global	
Mode	**SQFo**	**DIP**	**SQFo**	**DIP**
Vertical	+9.36%	−2.36%	−0.173%	+0.164%
Inclined	+0.328%	+3.41%	−0.035%	−0.373%
Circular	+5.23%	+4.18%	−0.104%	−0.365%

- PFS excitation within limits; no excessive dispersion leaking observed



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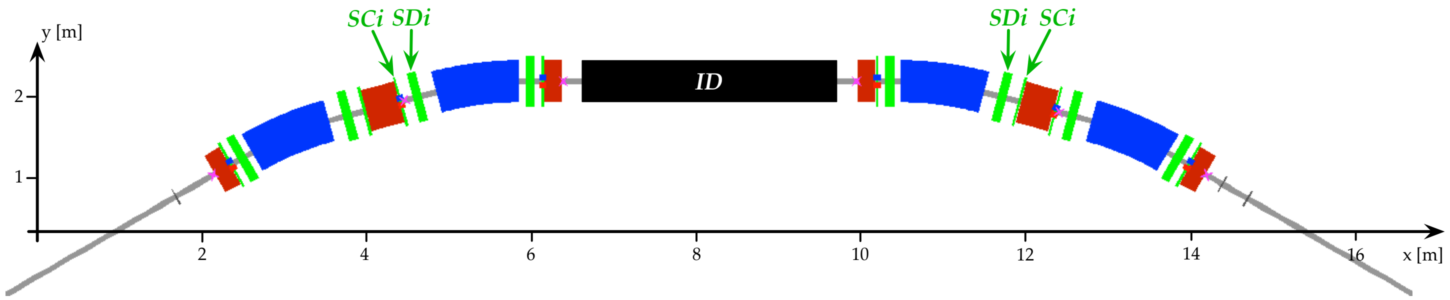

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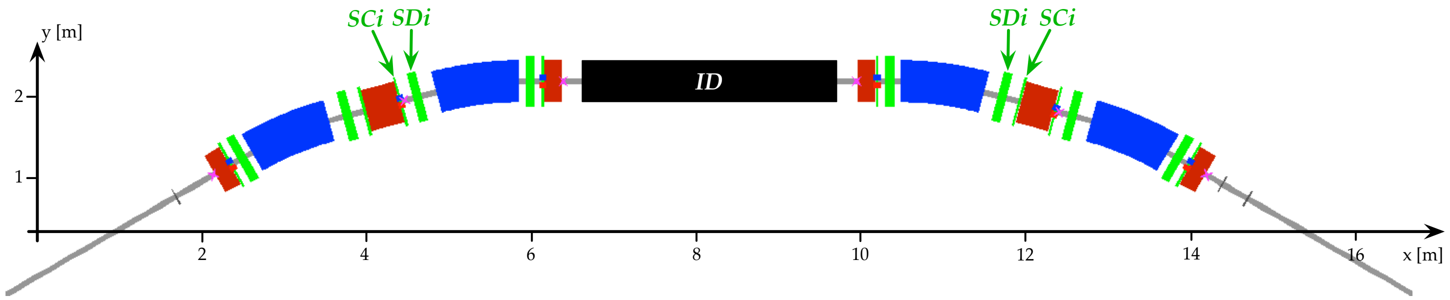

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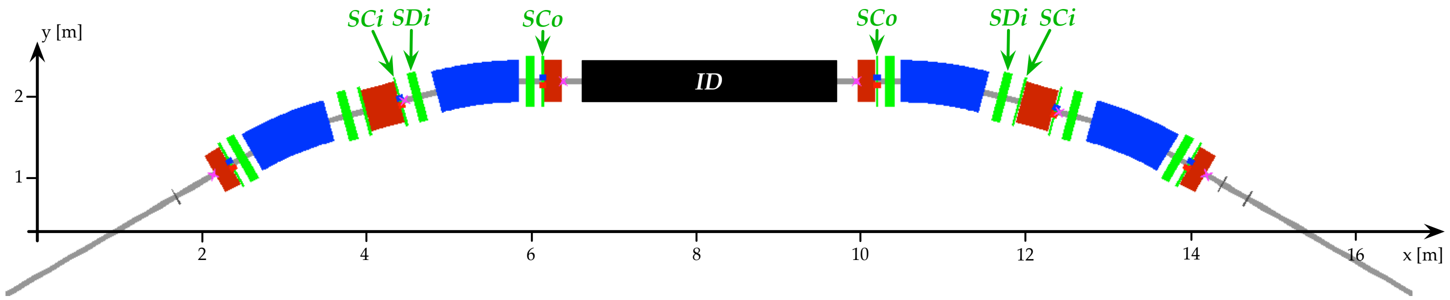

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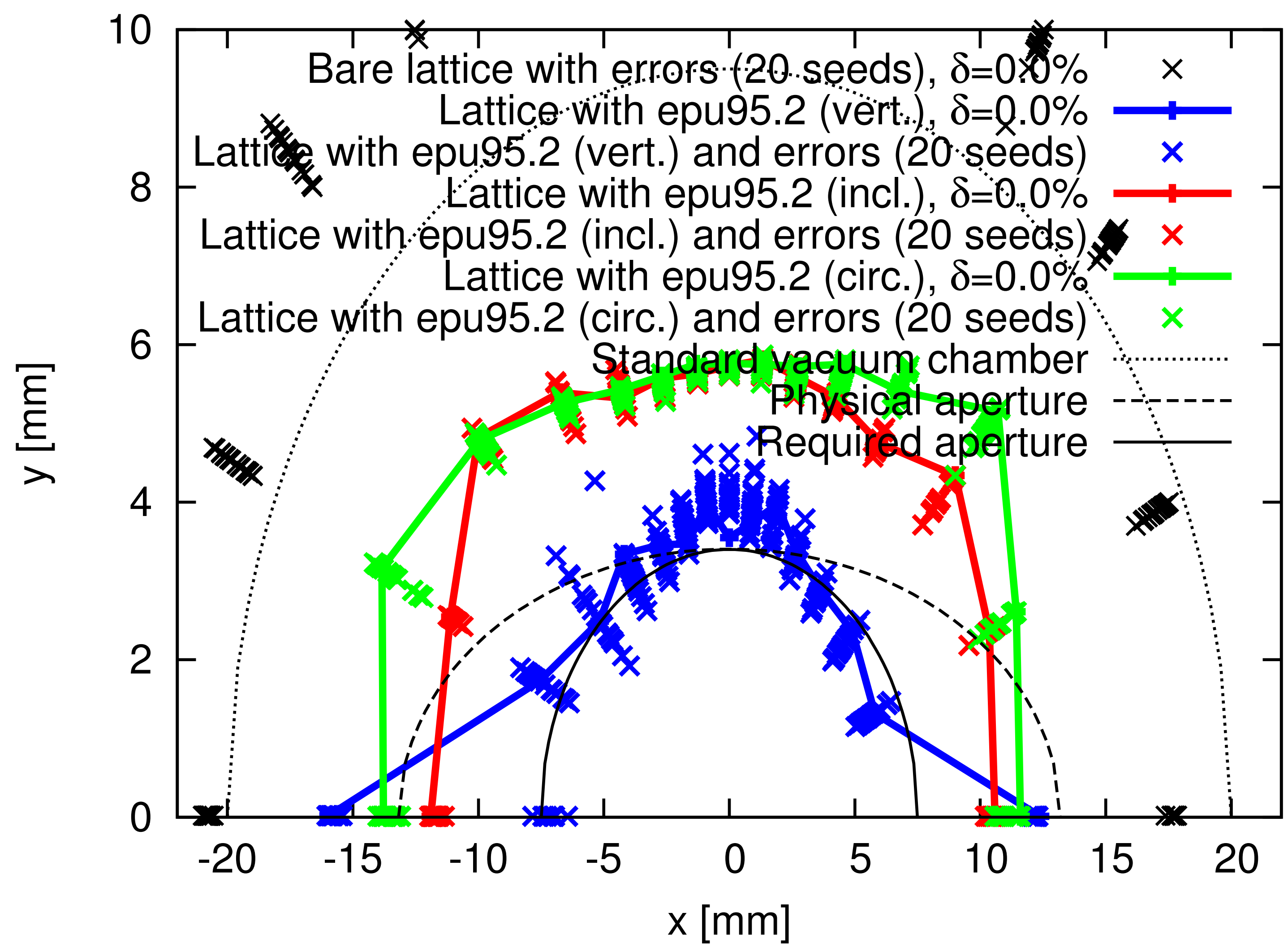

What remains to be done

- 3 GeV storage ring:
  - epu48 very similar to modeled epu53; will have weaker impact
  - SOLEIL IVW for BALDER will have weaker effect than 4 m PMDW used during design phase, so expect no problems; however, want to verify no unpleasant surprises from off-center installation
- 1.5 GeV storage ring:
  - epu95.2 planar mode (no trouble expected)
  - epu84 very similar to modeled epu95.2; will have weaker impact
- Phase IIa IDs:
  - 3 GeV: IVU for CoSAXS, EPU for SoftiMAX
  - 1.5 GeV: epu61 for SPECIES, U for FlexPES, EPU for MAXPeem