Preliminary simulation of Magnet misalignment and external field sensitivities and Low emittance tuning in ILC-DRs.

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Misalignment sensitivities

- Equilibrium vertical emittance was simulated with random misalignment of magnets:

  (A) Offset of sextupoles, rms 10 micron,

  (B) Rotation of quadrupoles, rms 30 micro-radian,

  (C) Offset of all magnets, rms 0.4 micron,
- 7 designs of ILC-DR were simulated
- Computer code “SAD”.
- No corrections were applied.

External field sensitivities

- Equilibrium vertical emittance was simulated with random external field using SAD.
- Horizontal magnetic field (vertical kick) was set at every 100 m; the strength was random with rms 1E-6 [Tm]. (1E-6 [Tm] kicks 5GeV beam by 6E-8 radian.)
- No corrections.
- The results give sensitivities to some kind of stray field. (Slower than damping but faster than corrections.)

Misalignment sensitivities.

	PPA 2.8 km, 5.0 GeV, pi	OTW 3.2 km, 5.0 GeV, TME	OCS 6.1 km, 5.1 GeV, TME	BRU 6.3 km, 3.7 GeV, FODO	MCH 15.9 km, 5.0 GeV, FODO	DAS 17.0 km, 5.0 GeV, pi	TESLA 17.0 km, 5.0 GeV, TME
Sext offset 10 μm	0.99	52.11	1.06	0.09	0.30	3.10	19.03
Quad rotation 30 μ-rad	0.23	35.46	5.08	0.41	1.23	0.53	12.68
All element offset 0.4 μm	0.16	21.62	0.03	0.22	0.79	1.78	15.01

External field sensitivities.

	PPA	OTW	OCS	BRU	MCH	DAS	TESLA
External field sensitivities.	0.014	0.16	0.006	0.28	3.70	4.85	9.85

Equilibrium normalized vertical emittance, unit: nm.
Average of 100 random seeds.

Simulation of low emittance tuning of DRs

- Equilibrium vertical emittance was simulated with random misalignment of magnets and random error of BPMs assuming consecutive corrections of; orbit correction, dispersion correction and coupling corrections.
- Simulations were performed using SAD [1], for seven Damping Ring designs on the web [2].

Assumed errors in simulations.

Magnet offset misalignment	Magnet rotation misalignment	BPM offset error (w.r.t. nearest magnet)	BPM rotation error
30 micron	0.3 mrad	100 micron	20 mrad

BPM and Correctors

Decks of TESLA and OTW include BPMs and correctors but others do not.

BPMs:TESLA and OTW: All BPMs in the decks were used

Others: Put BPMs at Quadrupoles, making total number is about 1000,

Dipole correctors: TESLA and OTW: Select about 135 correctors from correctors.

Others: Put correctors at Quads, making total number is about 135

Skew correctors: TESLA and OTW: Select about 100 correctors from skew correctors.

Others: Put correctors at Sextupoles, total number is about 100.

Number of correctors and BPMs

	PPA 2.8 km, 5.0 GeV, pi	OTW 3.2 km, 5.0 GeV, TME	OCS 6.1 km, 5.1 GeV, TME	BRU 6.3 km, 3.7 GeV, FODO	MCH 15.9 km, 5.0 GeV, FODO	DAS 17.0 km, 5.0 GeV, pi	TESLA 17.0 km, 5.0 GeV, TME
Number of dipole correctors, x/y	128/128	120/120	127/127	131/131	99/99	135/135	135/135
Number of skew quad correctors	56	92	96	101	101	56	101
Number of BPMs	768	240	760	850	1038	808	946

Three consecutive corrections [3].

- COD correction: using steering magnets, minimize

  $$\sum_{\mathrm{BPM}} x^2 \text{ and } \sum_{\mathrm{BPM}} y^2 \quad ,$$

  where is horizontal (vertical) BPM reading.

- Vertical COD-dispersion correction: using steering magnets, minimize

  $$\sum_{\mathrm{BPM}} y^2 + r^2 \sum_{\mathrm{BPM}} \eta_y^2 \ ,$$

  where η_y is the measured vertical dispersion. r is the weight constant which was set to be 0.05.

- Coupling correction: using skew quads, minimize

  $$C_{xy} \equiv \sqrt{\sum_{\mathrm{H-steers}} \left(\sum_{\mathrm{BPM}} \Delta y^2 \Big/ \sum_{\mathrm{BPM}} \Delta x^2 \right) \Big/ N_{\mathrm{steer}}}$$

  where Δx(Δy) is the horizontal (vertical) position change at a BPM due to excitation of a horizontal steering magnet. Two horizontal steering magnets were used in the simulations, (N_{steer}=2).

References

[1] SAD, Strategic Accelerator Design. http://acc-physics.kek.jp/SAD/sad.html

[2] http://www.desy.de/~awolski/ILCDR/Lattices.htm

Note: MAD to SAD translation was done by H.Koiso and correction of the optics in SAD was by Y.Ohnishi.

[3] K.Kubo, Phys.Rev.ST Accel.Beams 6:092801,2003

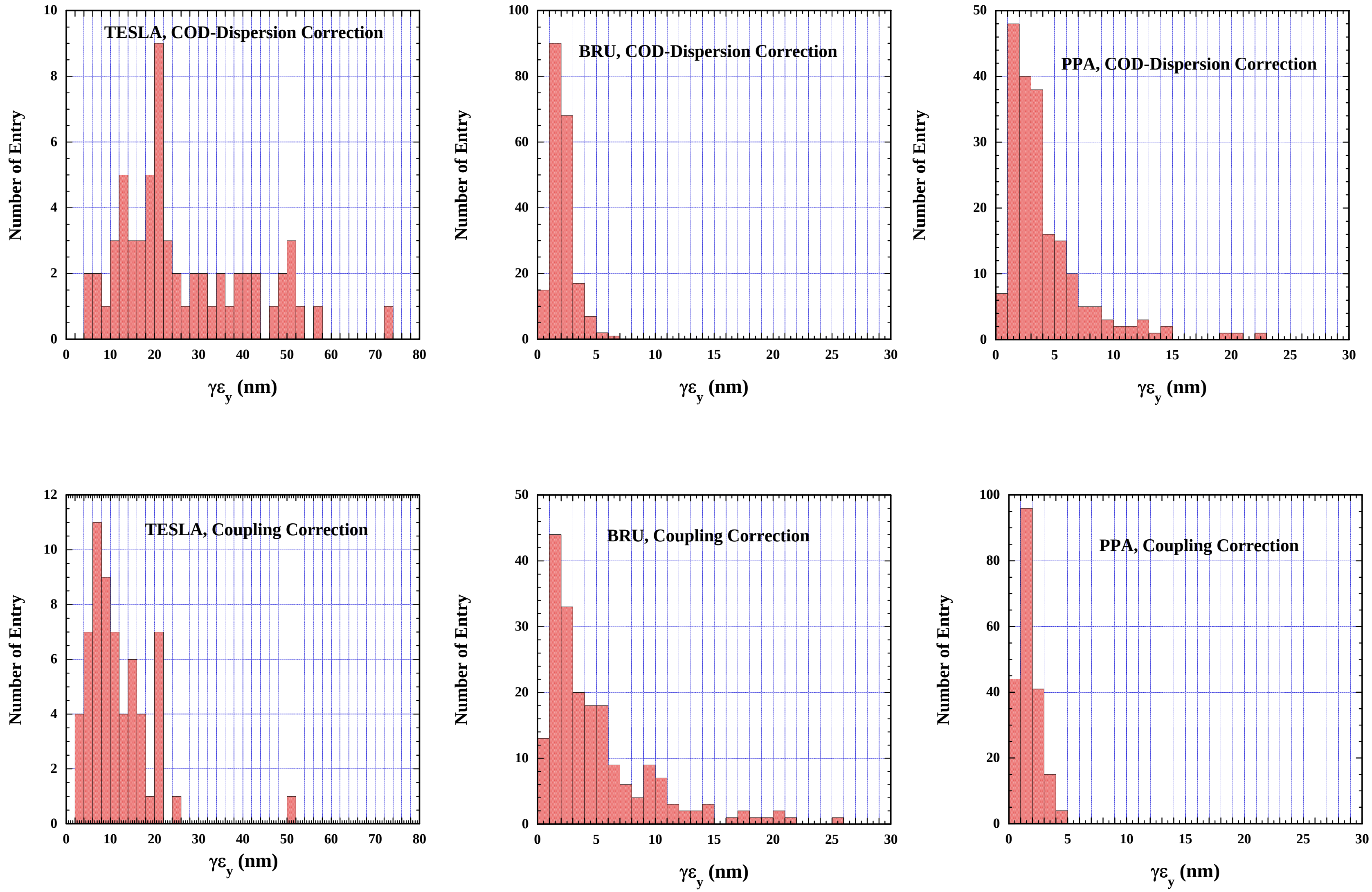
Equilibrium normalized vertical emittance after corrections, unit: nm.

Average of 200 random seeds.

	PPA 2.8 km, 5.0 GeV, pi	OTW 3.2 km, 5.0 GeV, TME	OCS 6.1 km, 5.1 GeV, TME	BRU 6.3 km, 3.7 GeV, FODO	MCH 15.9 km, 5.0 GeV, FODO	DAS 17.0 km, 5.0 GeV, pi	TESLA 17.0 km, 5.0 GeV, TME
No correction	879	1.01E5	667	1.63E3	4.70E3	1.00E4	8.81E4
COD correction	67.4	6.04E4	526	80.4	189	266	1.67E3
COD -Dispersion correction	4.12	2.68E3	106	2.09	6.88	22.5	29.6
Coupling correction	1.74	1.82E3	22.66	5.05	9.27	6.12	12.6

Distribution of emittance for TESLA, BRU and PPA.

COD-Dispersion correction(top) and COD-Dispersion-Coupling correction(bottom)



SUMMARY

Sensitivities study

- TESLA and OTW have large misalignment sensitivities.
- OSC has large quad rotation sensitivity. (because of small x-y tune fraction difference.: Yunhai Cai)
- Long rings (TESLA, DAS, MCH) have large external field sensitivities, probably because of the weak focusing long straight sections.
- ***Assumed errors are reasonable?***
- ***Realistic stray field model is needed. Who can give it?***

Tuning study

- Result of OTW is disastrous
- Result of OSC is not satisfactory, where extracted vertical emittance should be less than 20 nm including blowup due to intra-beam scattering etc..

  But positions of BPMs and correctors were not optimized. Putting them at different places may help, especially for OSC. Probably not for OTW.

  Also, changing operation tunes may help.
- ***Need more sutudy, but, from these kind of simulations, only OTW may be eliminated from the list of candidates.***