Status of Higher Luminosity at 250GeV

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2017.6.16 Parameter Group

Possibility of Higher Lumi at 250GeV

- Luminosity at 250GeV with 1312 bunches (no 10Hz collision) is 0.82×10^{34} /cm^{2}s in TDR
- Luminosity formula

$$\mathcal{L} \approx C \frac{P_B}{E} \sqrt{\frac{\delta_{BS}}{\epsilon_{y,n}}} \min\left(1, \sqrt{\sigma_z/\beta_y}\right) \quad (1)$$

  - C : universal constant
  - PB = beam power
  - The last factor express the hour-glass effect approximately
  - δ_{BS} = beamstrahlung energy loss

$$\delta_{BS} = \left\langle -\frac{\Delta E}{E} \right\rangle \approx 0.836 \frac{N^2 r_e^3 \gamma}{\sigma_z \sigma_x^2}, \qquad (\Upsilon \ll 1,\ \sigma_x \gg \sigma_y) \quad (2)$$

  - Beam size at IP

$$\sigma_x = \sqrt{\frac{\epsilon_{x,n}\beta_x^*}{\gamma}} \quad (3)$$

- δ_{BS} ~1% @250GeV in TDR suggests the possibility of higher luminosity with higher δ_{BS}
- To reduce σ_x seems to be the only way

How to reduce σ_x ?

- The simplest way is to reduce β_x
- But this will make the beam angle spread at IP larger

$$\theta_x^* = \sqrt{\frac{\epsilon_{x,n}}{\gamma \beta_x^*}} \qquad (4)$$

- → larger beam size at the final quad QD0
- Synchrotron radiation from tail particles hit the quad, causing back ground
- These particles must be collimated out upstream
- The horizontal collimation depth is already ~ 6 σ_x

Horizontal Emittance

- σ_x can be reduced by reducing the horizontal emittance from DR
    - Present lattice is presumably conservative
    - Circular colliders assumes much more aggressive horizontal emittance
- If $\varepsilon_{x,n} \rightarrow \varepsilon_{x,n}/a$,
- Then, $\sigma_x \rightarrow \sigma_x$ /sqrt(a), $\delta_{BS} \rightarrow a\delta_{BS}$, L → sqrt(a)L.
- This will make horizontal beam angle 1/sqrt(a) smaller.
- If we further make $\beta_x \rightarrow \beta_x /a$, then $\delta_{BS} \rightarrow a^2\delta_{BS}$, L → aL
- Smaller $\varepsilon_{x,n}$ would also help at other energies
    - Luminosity increase may be small but at least FFS tuning would become easier (allow larger β_x for same σ_x)

Problems

- Obvious problems are
  - Is it possible to reduce $\varepsilon_{x,n}$ of DR?
    - Technically possible?
    - Manpower problem
    - Now, Kiyoshi is trying …
    - Must include studies of e-cloud, FII, etc.
  - Disruption parameter too large

$$D_{x(y)} = \frac{2Nr_e}{\gamma} \frac{\sigma_z}{\sigma_{x(y)}(\sigma_x + \sigma_y)} \qquad (5)$$

  - Disruption parameter too large
    - $D_y \rightarrow aD_y$
    - Present D_y is already ~25
    - Feedback tolerance tighter

An Example Parameter Set

- Next page, right-most column
  - $\varepsilon_{x,n} \rightarrow \varepsilon_{x,n}$ /2, no change of β_x
- However, note that $D_x \sim 0.5$ is not negligible
  - This will cause effective σ_x smaller than σ_x /sqrt(2)
  - Hence, δ_{BS} larger than $2\delta_{BS}$, L larger than sqrt(2)L
- Beam-beam simulation being done by Daniel Jeans
  → talk by Daniel
  - First result shows L=1.65 x L_{TDR} = 1.35×10^{34} /cm^2s
- If everything is OK, may try smaller β_x
- Other parameter sets may also be possible
  - e.g., to increase β_y to relax the disruption

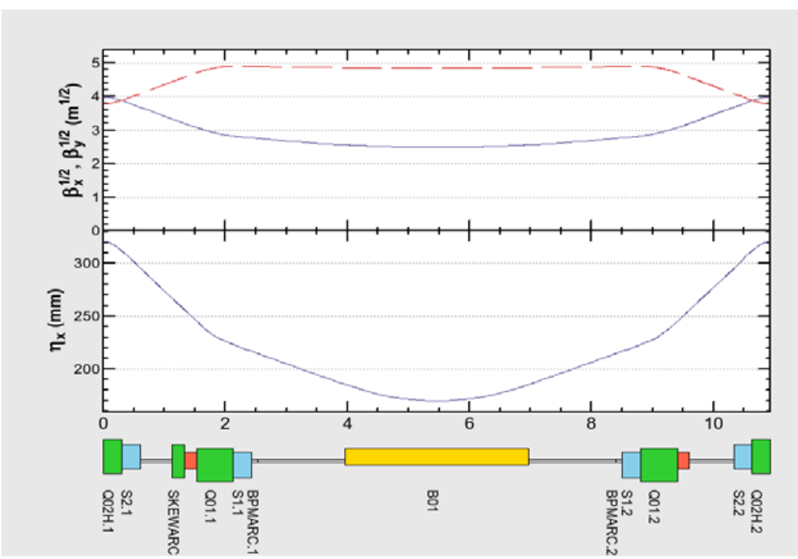
TDR (Combined TDR_machine_parameters_stamp.pdf and L study parameters 16-02-2012.xlsx

		Baseline						1TeV		New
							Full Power	A1	B1b	Param
Ecm	GeV	200	230	250	350	500	500	1000	1000	250
N	e10	2.0	2.0	2.0	2.0	2.0	2.0	1.737	1.737	2.0
Collision frequency	Hz	5.0	5.0	5.0	5.0	5.0	5.0	4.0	4.0	5.0
Electron linac rep rate	Hz	10.0	10.0	10.0	5.0	5.0	5.0	4.0	4.0	5.0
Nb		1312	1312	1312	1312	1312	2625	2450	2450	1312
Bunch separation	ns	554	554	554	554	554	366	366	366	554
Beam current	mA	5.78	5.78	5.78	5.78	5.78	8.75	7.60	7.60	5.78
PB	MW	4.2	4.8	5.3	7.4	10.5	21.0	27.3	27.3	5.3
sigz	mm	0.3	0.3	0.3	0.3	0.3	0.3	0.25	0.225	0.3
sige(e-)	%	0.206	0.193	0.188	0.156	0.124	0.124	0.083	0.085	0.188
sige(e+)	%	0.187	0.163	0.15	0.1	0.07	0.07	0.043	0.047	0.15
enx	μm	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	5.00
eny	nm	35.0	35.0	35.0	35.0	35.0	35.0	30.0	30.0	35.0
electron polarization	%	80	80	80	80	80	80	80	80	80
positron polarization	%	31	31	31	29	22	22	30	30	31
betax	mm	16.0	14.0	13.0	16.0	11.0	11.0	22.6	11.0	13.0
betay	mm	0.34	0.38	0.41	0.34	0.48	0.48	0.25	0.23	0.41
sigx	nm	904.2	788.7	729.0	683.5	474.2	474.2	480.6	335.3	515.5
sigy	nm	7.80	7.69	7.66	5.89	5.86	5.86	2.77	2.63	7.66
theta_x	μr	56.5	56.3	56.1	42.7	43.1	43.1	21.3	30.5	39.7
theta_y	μr	22.9	20.2	18.7	17.3	12.2	12.2	11.1	11.7	18.7
Dx		0.21	0.24	0.26	0.21	0.30	0.30	0.11	0.20	0.51
Dy		24.3	24.5	24.5	24.3	24.6	24.6	18.7	25.4	34.5
Upsilon (average)		0.013	0.017	0.020	0.030	0.062	0.062	0.128	0.203	0.028
Ngamma (formula)		0.95	1.08	1.16	1.23	1.72	1.72	1.43	1.97	1.62
deltaB (formula)	%	0.510	0.749	0.935	1.416	3.651	3.651	5.330	10.19	1.772
HDx		1.05	1.15	1.18	1.10	1.31	1.29	1.01	1.04	1.77
HDy		4.52	5.03	5.36	4.52	6.07	6.07	3.55	4.03	6.10
HD		1.69	1.84	1.90	1.73	2.09	2.07	1.53	1.62	2.43
Lgeo	1.0E+34	0.296	0.344	0.374	0.518	0.751	1.504	1.768	2.672	0.529
L (formula, no waist shift)	1.0E+34	0.501	0.632	0.712	0.896	1.567	3.117	2.706	4.337	1.285
L (simulation, waist shift)	1.0E+34	0.59	0.73	0.82	1.03	1.79	3.6	3.02	5.11	1.35

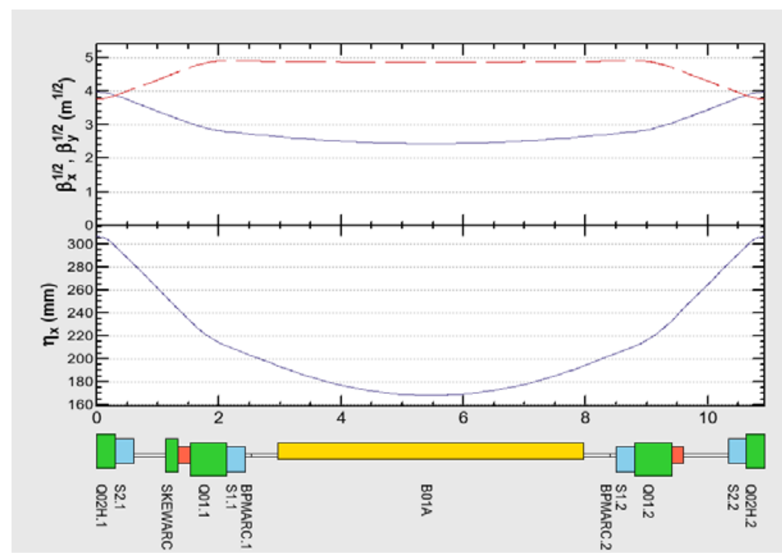
Re-visit Damping Ring Design

- Smaller horizontal emittance seems to be possible
  - Recent light sources adopt much more aggressive designs
- Kiyoshi Kubo is trying a new design
  - There is a space to lengthen the dipoles in the arcs
    - 3m → ~5m
  - Still conservative compared with light sources

Original



New (long bend)



Emittance Results

Kubo April 2017

previous report

new result

	Original	New (stronger focus)	New (long bend)
Horizontal normalized Emittance (um) wo, w IBS	5.74, 6.27	3.22, 4.00	3.14, 3.97
Tune x/y	48.26/26.76	57.79/26.46	49.33/26.86
phase adv./cell /2pi x/y	0.21891 /0.08098	0.2788 /0.08	0.2250 /0.0808
Damping time x/y/z (ms)	23.9/23.9/11.9	23.9/23.9/11.9	25.5/25.5/12.8

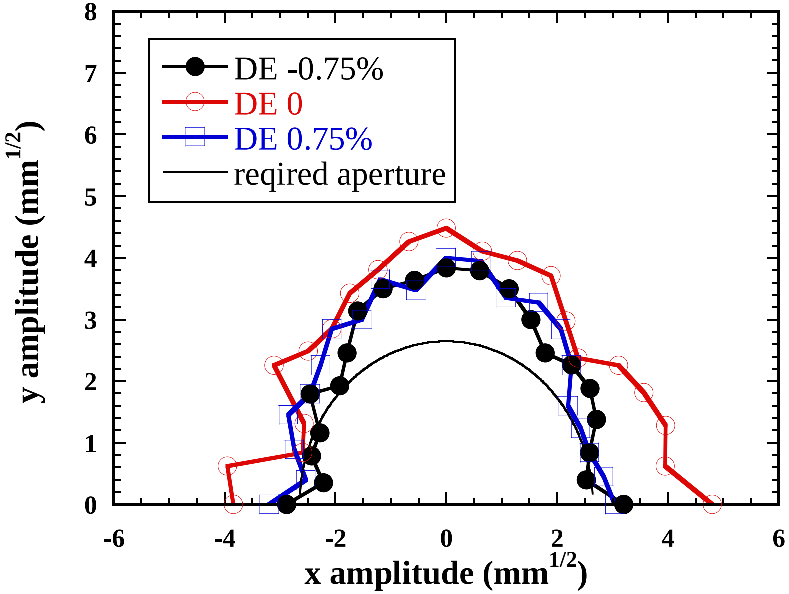
Some surveys of phase advances/cell and total tunes were performed, for good dynamic aperture. (Surveys were not complete.)

Almost the same emittance as in the previous report but ....

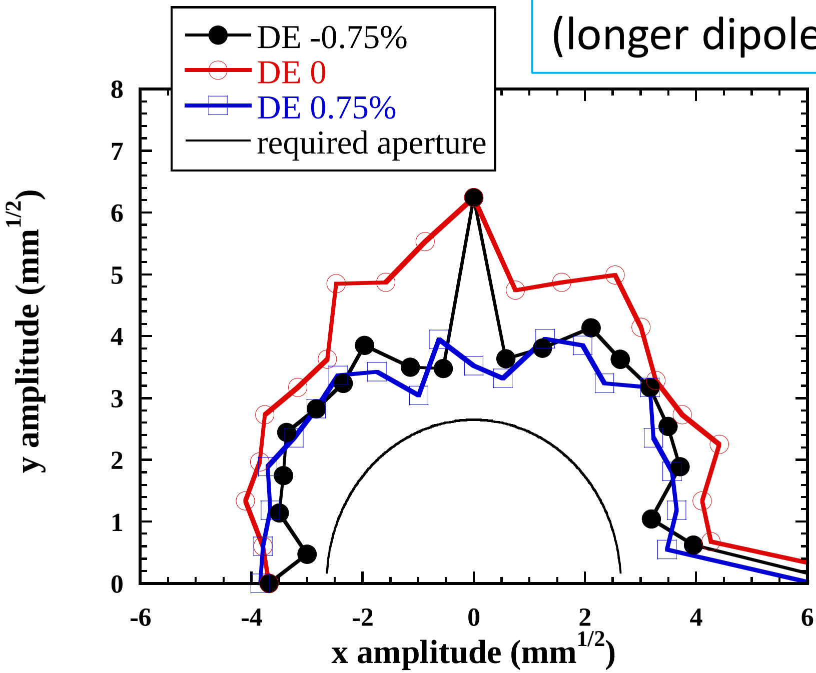
Dynamic Aperture

- Dynamic aperture greatly improved!

Previous report
(stronger focus)



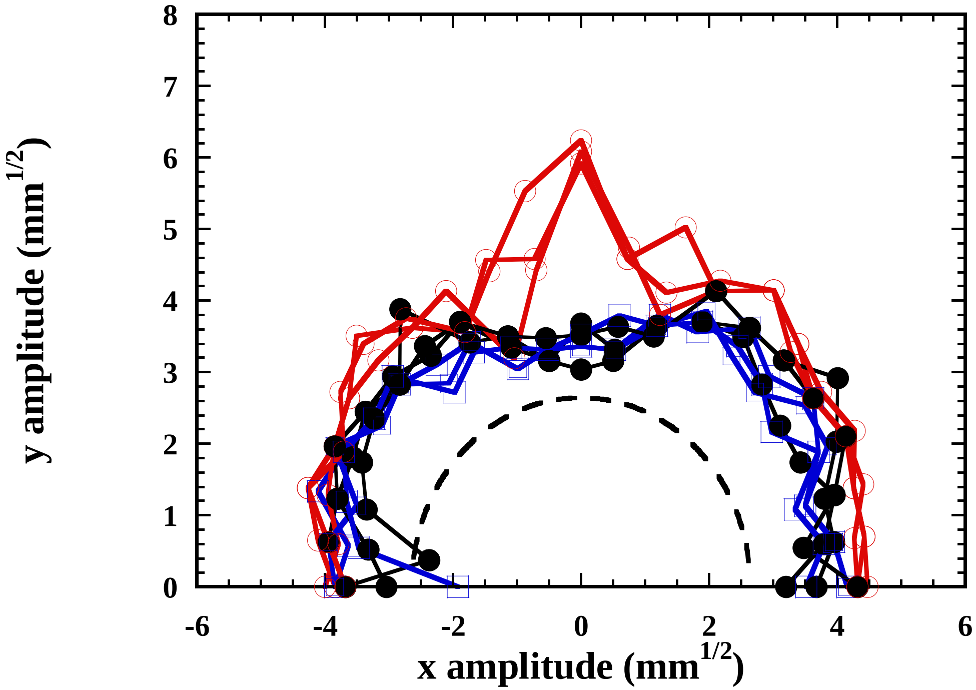
New result
(longer dipole)



Dynamic aperture: long bend Misalignment + correction

New arc cell: long (5 m) bend
tune/cell: x.225 y.0808
Tune: x49.33 y26.86

Quadrupole & sextupole offset: 50 um
Quadrupole roll: 100 urad
BPM offset: 100 um
BPM roll: 10 mrad
COD & Dispersion correction

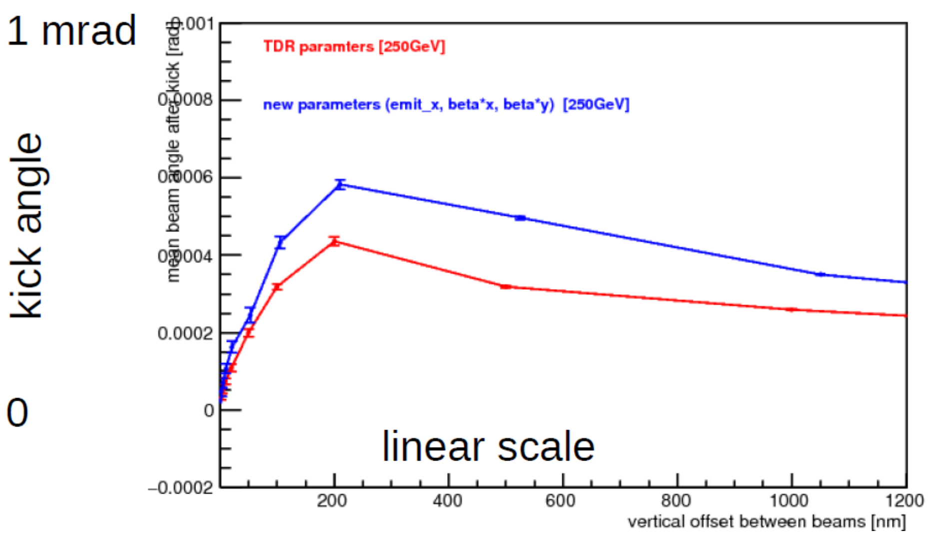


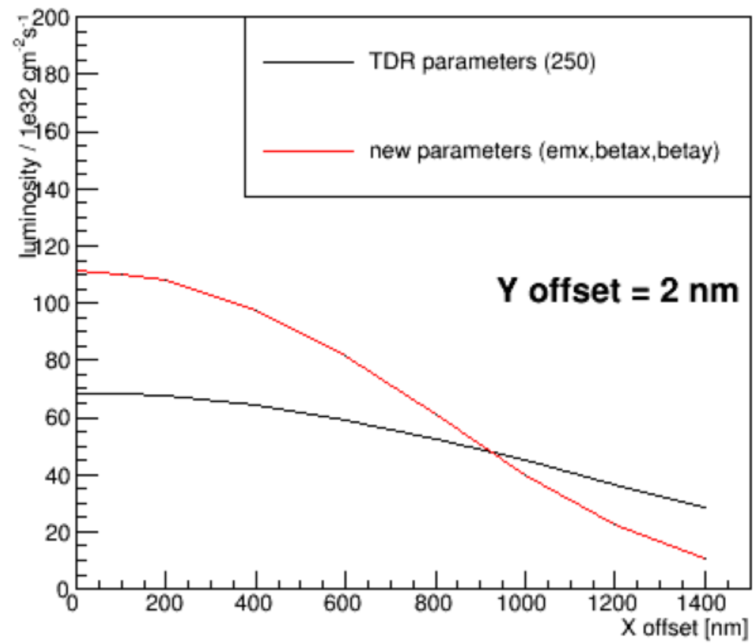
Beam-Beam Simulation

- Being done by Daniel Jeans
  - Sensitivity against vertical offset
  - Incoherent pairs
  - MC simulation
- To be reported in detail in AWLC

Sensitivity against vertical offset

- Deflection angle vs. offset does not change much from TDR
  - Turning point >> 50nm (dynamic range of feedback)
- Luminosity larger than TDR for $\Delta x < \sim 1\mu m$





Incoherent Pairs

- Number of pairs increases by 2~3x

Landau-Lifshits	$e^+ e^- \rightarrow e^+ e^- e^+ e^-$	L
Bethe-Heitler	e^{+-} ‘γ’ $\rightarrow e^{+-}\ e^+ e^-$	$L\, n_\gamma$
Breit-Wheeler	‘γ’ ‘γ’ $\rightarrow e^+ e^-$	$L\, n_\gamma^2$

‘γ’ = beamstrahlung photon