Possibilities of crab waist

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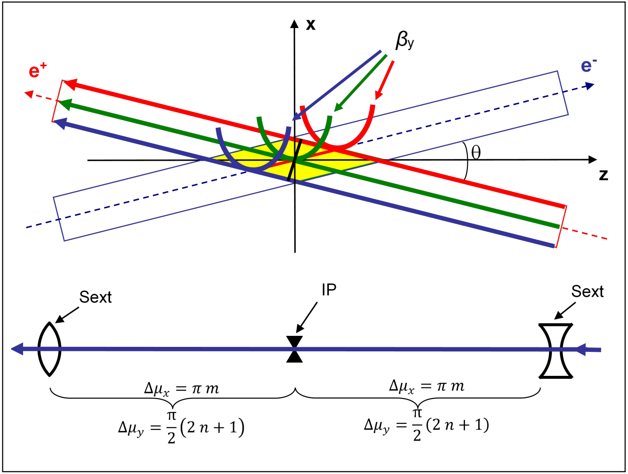
September 19-23, 2016

Crab waist [P. Raimondi 2006, tested at DAΦNE]



$$\varphi = \frac{\sigma_z}{\sigma_x^*} \tan\left(\frac{\theta}{2}\right)$$

$$\beta_y^* \sim \frac{\sigma_x^*}{\theta}$$

$$\xi_y \propto \frac{N\beta_y^*}{\sigma_x^*\sigma_y^*\sqrt{1+\varphi^2}}$$

$$\xi_x \propto \frac{N}{\epsilon_x(1+\varphi^2)}$$

$$L \propto \frac{N\xi_y}{\beta_y^*}$$

$$K2L[m^{-2}] = \pm\frac{1}{\theta\beta_y^*\beta_y}\sqrt{\frac{\beta_x^*}{\beta_x}}.$$

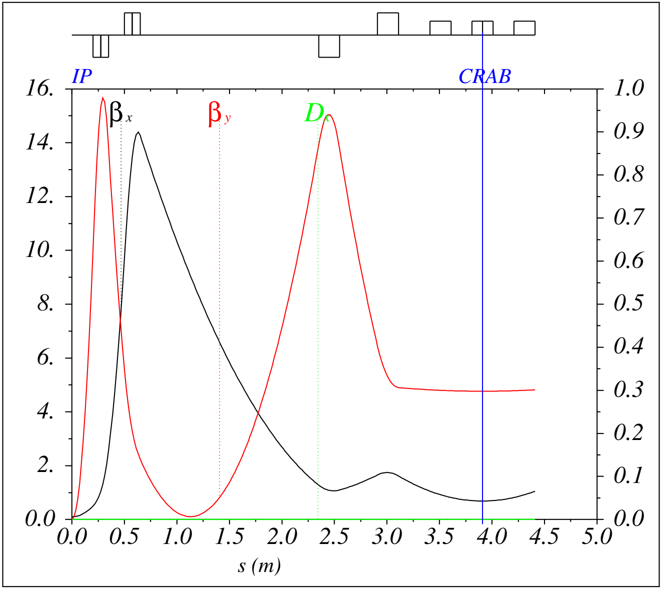
Upgrade of present colliders DAΦNE and SuperKEKB

	DAΦNE	SuperKEKB	
Run or ring	SIDDHARTA	LER	HER
Energy, GeV	0.51	4	7.007
Circumference, m	97.69	3016.315	
$\varepsilon_x/\varepsilon_y$, nm/pm	250/750	3.2/8.64	4.6/12.9
β_x^*/β_y^*, mm	250/9.3	32/0.27	25/0.3
Crossing angle, mrad	50	83	
σ_z, mm	17	6	5
Piwinski angle φ	1.7	25	19
Beam current e^-/e^+, A	2.45/1.4	3.6	2.6
Beam beam tune shift ξ_y	0.03	0.088	0.08
Luminosity, $\text{cm}^{-2}\text{s}^{-1}$	Achieved 4.5×10^{32}	Design 8×10^{35}	
Luminosity gain	$\times3$	$\times40$	

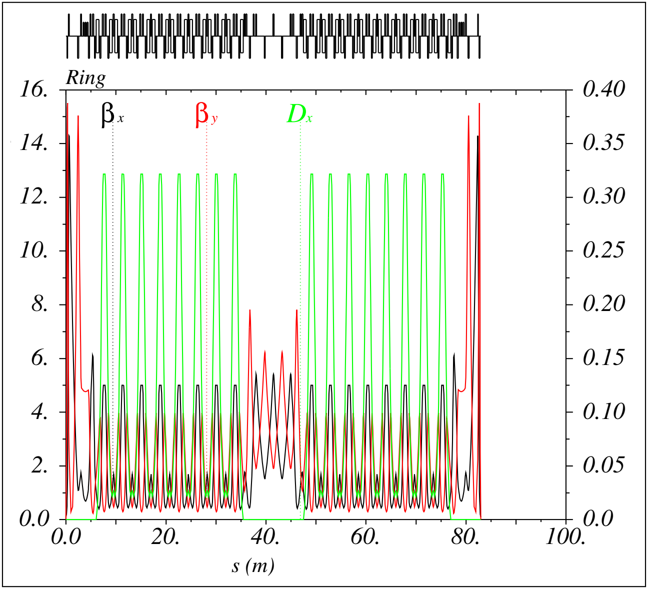
Small size: SuperPhi

Energy, GeV	1
Circumference, m	83
$\varepsilon_x/\varepsilon_y$, nm/pm	9(IBS)/90
β_x^*/β_y^*, mm	100/4
Crossing angle, mrad	100
σ_z [mm]	10.2(IBS)/3.1
Piwinski angle φ	17
Beam current, A	2.3
Number of bunches	80
Particles per bunch, 10^{10}	4.97
Beam beam tune shift ξ_y	0.12
Luminosity [$10^{34} cm^{-2} s^{-1}$]	1.5

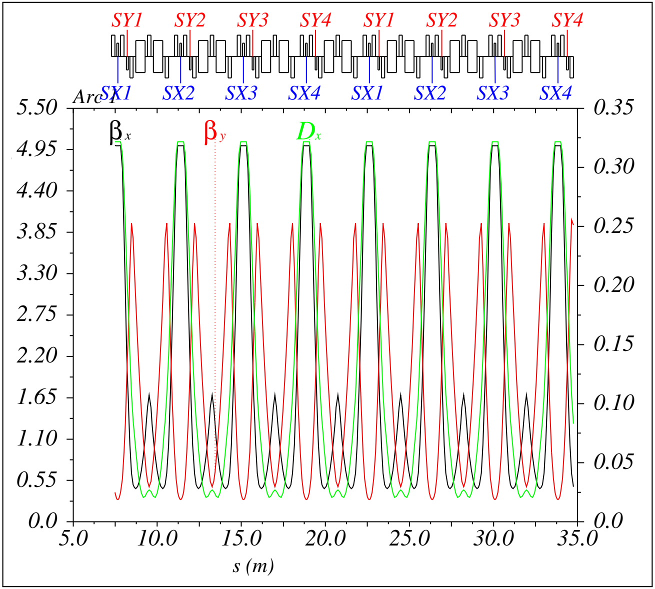
Interaction Region optical functions



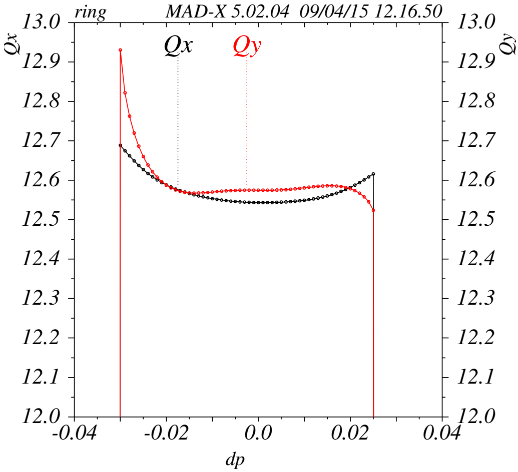
Ring optical functions



Four -I families of sextupoles (cell $\mu_{x,y} = 5\pi/4$)

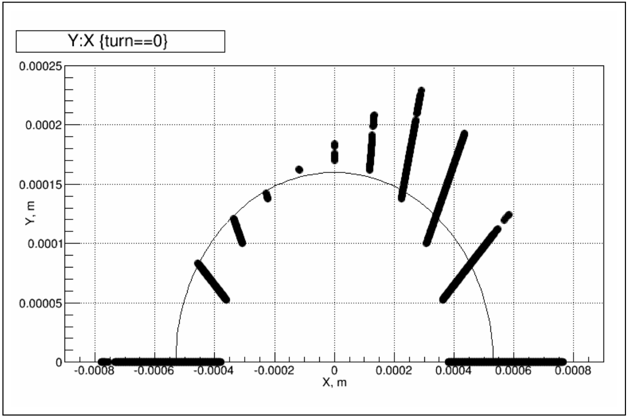


Energy acceptance III: four families [-3%;+2.5%]



	Value	$\Delta Q(2\%)$
Q_x	12.543	
Q'_x	0	0
Q''_x	90	0.018
Q'''_x	$-4.9 \cdot 10^3$	-0.006
Q''''_x	$2.8 \cdot 10^5$	0.002
Q_y	12.575	
Q'_y	0	0
Q''_y	0	0
Q'''_y	$6 \cdot 10^4$	0.08
Q''''_y	$6.6 \cdot 10^4$	0.0004

Dynamic aperture: on momentum, PTC



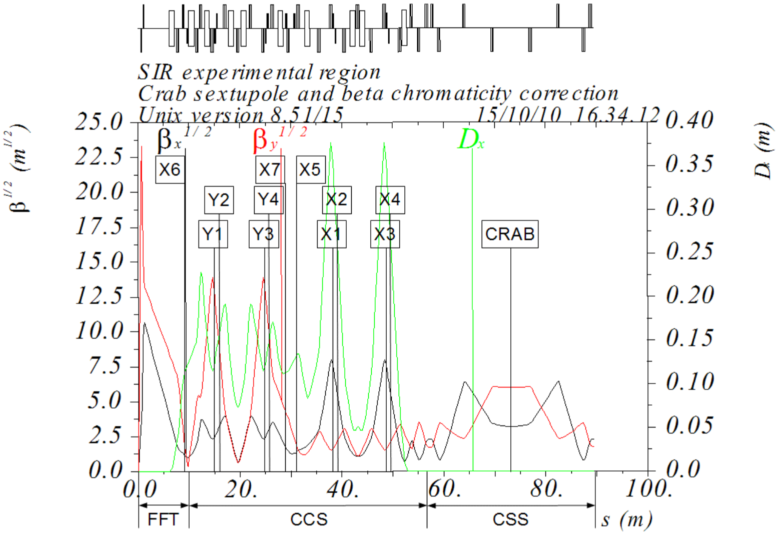
$\beta_x = 0.1$ m
$\beta_y = 0.004$ m
$R_x = 5.3 \cdot 10^{-4}$ m
$R_y = 1.6 \cdot 10^{-4}$ m
$\sigma_x = 3 \cdot 10^{-5}$ m
$\sigma_y = 6 \cdot 10^{-7}$ m

$ksy1 = -330$ T/m^2
$ksx1 = 495$ T/m^2
$ksy2 = -2695$ T/m^2
$ksx2 = 1161$ T/m^2
$ksy3 = -2886$ T/m^2
$ksx3 = 1414$ T/m^2
$ksy4 = -3754$ T/m^2
$ksx4 = 916$ T/m^2
$Ls = 0.1$ m

Medium size: CTau (Novosibirsk)

	CTau			
Energy, GeV	1	1.5	2	2.5
Circumference, m	813.4			
$\varepsilon_x/\varepsilon_y$, nm/pm	8/40			
β_x^*/β_y^*, mm	40/0.8			
Crossing angle, mrad	60			
σ_z, mm	16.5	11	10	10
Piwinski angle φ	27	19	17	17
Beam current, A	1.65			
Beam beam tune shift ξ_y	0.15	0.15	0.12	0.1
Luminosity, $cm^{-2}s^{-1}$	0.6×10^{35}	0.9×10^{35}	1×10^{35}	1×10^{35}

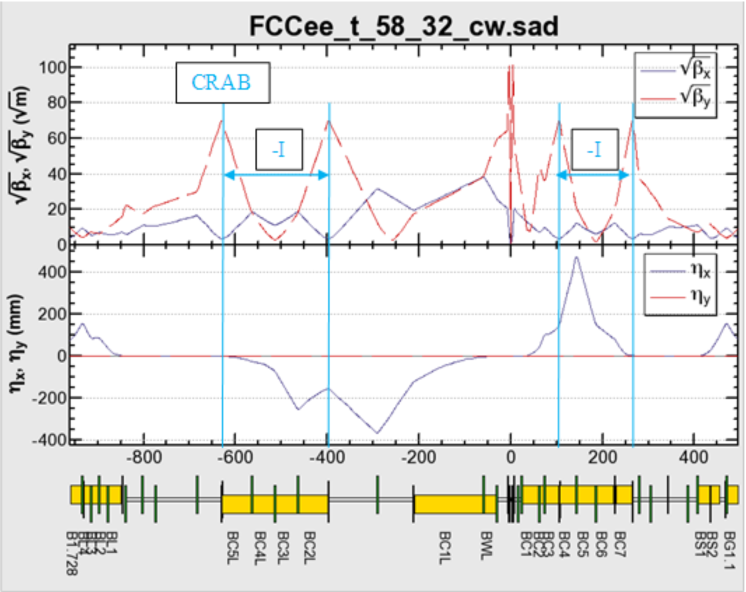
Interaction region CTau



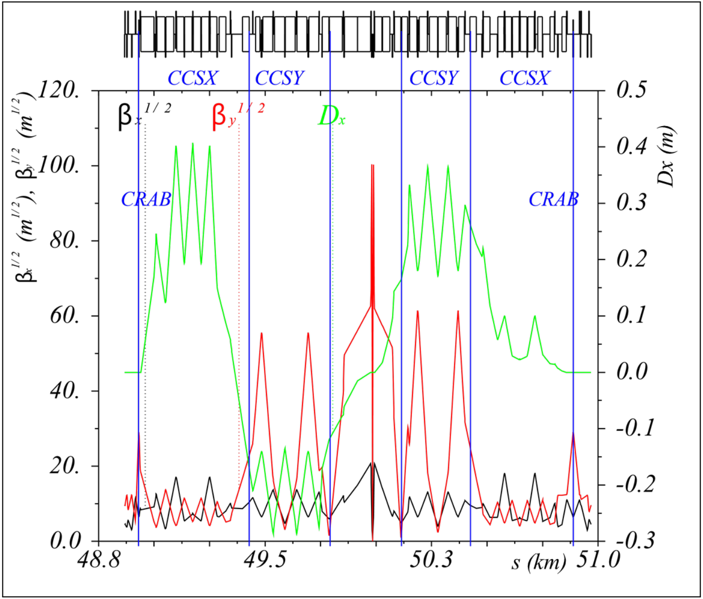
Extra large size: FCCee

	FCC-ee			
Eperiment	Z	W	H	tt
Energy, GeV	45	80	120	175
Circumference, m	100×10^3			
$\varepsilon_x/\varepsilon_y$, nm/pm	0.14/1	0.44/2	1/2	2.1/4.3
β_x^*/β_y^*, mm	500/1			
Crossing angle, mrad	30			
σ_z, mm	5.9	9.1	8.2	6.6
Piwinski angle φ	11	9	6	3
Beam current, A	1.4	1.4	0.3	0.06
Beam beam tune shift ξ_y	0.175	0.187	0.16	0.08
μ_y'	-2805			
Luminosity, $cm^{-2}s^{-1}$	211×10^{34}	36×10^{34}	9×10^{34}	1.3×10^{34}

Interaction region FCC-1 [K. Oide]



Interaction region FCC-2



Upgrade BEPCII: scenario

1. Reduce $\varepsilon_x = 144 \to 30$ nm and $\beta_y^* = 15 \to 5$ mm. Luminosity gain is 8 times, $\xi_y = 0.04 \to 0.1$ acceptable with crab waist.
2. Reduce coupling $\varepsilon_x/\varepsilon_y = 0.015 \to 0.007$. Luminosity gain is 12 times, $\xi_y = 0.04 \to 0.15$ acceptable with crab waist.
3. Increase crossing angle $\theta = 22 \to 30$ mrad. Luminosity gaing is 10 times, $\xi_y = 0.04 \to 0.1$ acceptable with crab waist.
4. Increase bunch population, beam current $0.9 \to 1.3$ A. Luminosity gain is 20 times, $\xi_y = 0.04 \to 0.15$ acceptable with crab waist.

Upgrade BEPCII

BEPC-II	0	1	2	3	4
Energy, GeV	1.89	1.89	1.89	1.89	1.89
Circumference, m	237.53	237.53	237.53	237.53	237.53
$\varepsilon_x/\varepsilon_y$, nm	144/2.2	30/0.45	30/0.2	30/0.2	30/0.2
β_x^*/β_y^*, mm	1000/15	100/5	100/5	100/4	100/4
Crossing angle, mrad	22	22	22	30	30
σ_z, mm	15	16	16	16	16
Piwinski angle φ	0.4	3.3	3.3	4.5	4.5
Beam current, A	0.9	0.9	0.9	0.9	1.3
Beam beam tune shift ξ_y	0.04	0.1	0.15	0.1	0.15
Luminosity, $\times 10^{32}\text{cm}^{-2}\text{s}^{-1}$	8	67	98	83	170

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β_x^*/β_y^*, mm	1000/15	100/5	100/5	100/4	100/4
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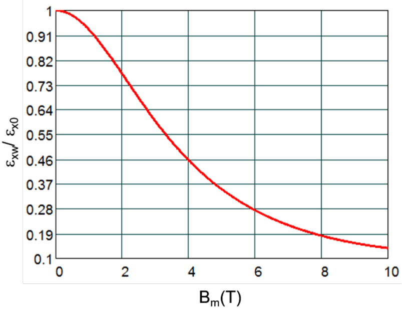
How to reduce emittance 5 times?

Install damping wigglers in the dispersion free section.

$$\frac{\varepsilon_w}{\varepsilon_0} = \frac{1 + i_5/I_5}{1 + i_2/I_2}, \qquad i_2 = \frac{1}{2} h_w^2 L_w, \qquad i_5 = \frac{8}{15} h_w^2 N_w \theta_m^3 \langle \beta_x \rangle,$$

h_w is peak curvature, θ_m is maximum deviation angle, L_w and N_w are wiggler length and number of periods, $\langle \beta_x \rangle$ is average beta function. Two wigglers with $B_m = 7.5$ T, $\lambda_w = 0.164$ m, $L_w = 1.8$ m reduce BEPCII emittance 5 times.



Upgrade BEPCII: issues

1. Arrangement of compact CW IR (BINP has experience).
2. Wigglers will increase energy spread twice.
3. RF system to compensate for additional SR power loss.
4. Place for the damping wigglers, SR.
5. Injector capacity. We believe that these and other problems can be solved if scientific community would show its interest.

Conclusion

1. BEPC II is very close to Crab Waist layout requirements.
2. By moderate (our belief) modification it can be converted to Crab Waist collider factory.
3. Luminosity enhancement for BEPCII-CW is about 20. Study for further luminosity increase is possible.
4. Many accelerator physics and technology aspects needed for CEPC CW mode can be proven at BEPCII-CW (FF quadrupoles, MDI, crab sextupoles dynamics, IR high chromaticity correction, CW scheme DA study and optimization, etc.).
5. Low emittance increases capability of the SR operation mode.
6. High field wiggler extends SR spectrum to the hard X-ray area.