Crab Cavity in PTC

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Crab Cavity Multipoles

High order multipoles for different crab cavities models.

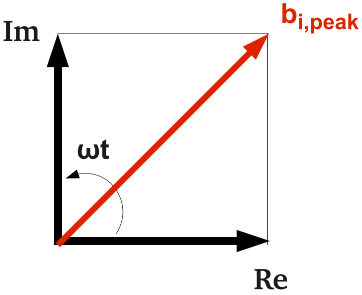
	PB400		ODUCAV		SRHW		KEKCAV	
	Re	Im	Re	Im	Re	Im	Re	Im
V_z[kV]	0	0	0	0	-2.1	-2.5	-4	1378
V_x[MV]	5	0	5	0	5	0	5	0
b_2[mTm/m]	0	0	0	0	0	-0.04	-32.7	-0.1
b_3[mTm/m^2]	0	0	1250	0	229	0	250	0
b_4[mTm/m^3]	0	0	0	0	0	0	266	-5

	UKCAV		QWAVE		LQW	
	Re	Im	Re	Im	Re	Im
V_z[kV]	0	0	-28	1519	7	1357
V_x[MV]	5	0	5	0	5	0
b_2[mTm/m]	0.02	0	-12.2	0	-244	-14
b_3[mTm/m^2]	2452	-0.5	612.4	-0.1	3282	549
b_4[mTm/m^3]	0	0	11425	9	-43775	-8512

Courtesy of Alexej Grudiev

Crab Cavity Multipoles

The previous multipoles oscillate with ωt. For the results presented next the *peak* value for each case is used.



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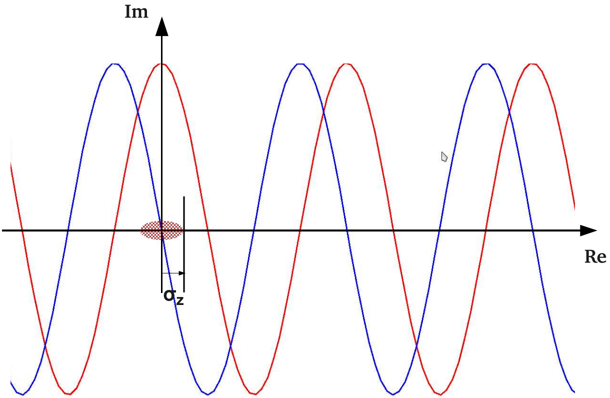


Aberrations induced by crab cavity multipoles

Just for reference.
Tune shift,

$$\Delta Q_{x,y} = \frac{1}{4\pi}\beta_{x,y} b_{2,cc}.$$

Tune shift with amplitude,

$$\Delta Q/J_x = \frac{3}{8\pi}\beta_x^2 b_{4,cc}.$$

Chromaticity shift,

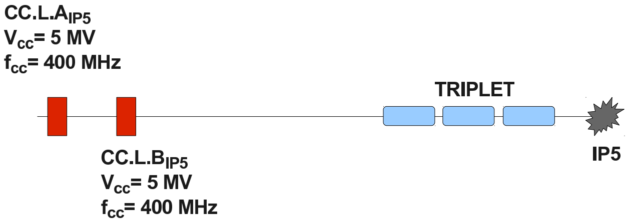
$$\Delta\xi_{x,y} = \pm\frac{1}{4\pi} D_x b_{3,cc}\beta_{x,y}.$$

Coupling,

$$\Delta Q_{min} = \sqrt{\beta_x\beta_y} b_{3,cc} D_y \sigma_\delta.$$

Linear tuneshift due to crab cavity multipoles

Evaluated at IP5 for beam 1 (both IPs $\rightarrow$ results x2). Case f_{cc}=400 MHz and V_{cc}= 10 MV. CCs located at D2 position,



	PB400	ODUCAV	SRHW	KEKCAV
$\lvert\Delta Q_x\rvert$	0.0	0.0	$2.35{\cdot}10^{-6}$	$1.92{\cdot}10^{-3}$
$\lvert\Delta Q_y\rvert$	0.0	0.0	$2.23{\cdot}10^{-6}$	$1.82{\cdot}10^{-3}$

	UKCAV	QWAVE	LQW
$\lvert\Delta Q_x\rvert$	$1.18{\cdot}10^{-6}$	$7.17{\cdot}10^{-4}$	$1.44{\cdot}10^{-2}$
$\lvert\Delta Q_y\rvert$	$1.11{\cdot}10^{-6}$	$6.80{\cdot}10^{-4}$	$1.36{\cdot}10^{-2}$

Non-linear aberrations induced by crab cavity multipoles

Evaluated at IP5 for beam 1 (both IPs → results x2). Case f_{cc}=400 MHz and V_{cc}= 10 MV. CCs located at D2 position,

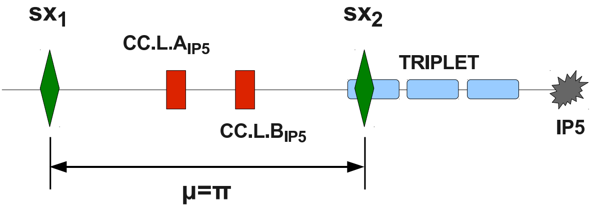
	PB400	ODUCAV	SRHW	KEKCAV
$\|\Delta Q_x^{3\sigma}\|$	0.0	0.0	0.0	$2.68{\cdot}10^{-6}$
$\|\Delta\xi_x\|$	0.0	$1.54{\cdot}10^{-3}$	$2.82{\cdot}10^{-4}$	$3.08{\cdot}10^{-4}$
$\|\Delta\xi_y\|$	0.0	$1.45{\cdot}10^{-3}$	$2.66{\cdot}10^{-4}$	$2.91{\cdot}10^{-4}$
$\|\Delta Q_{min}\|$	0.0	$1.31{\cdot}10^{-4}$	$2.39{\cdot}10^{-5}$	$2.61{\cdot}10^{-5}$

	UKCAV	QWAVE	LQW
$\|\Delta Q_x^{3\sigma}\|$	0.0	$1.15{\cdot}10^{-4}$	$4.49{\cdot}10^{-4}$
$\|\Delta\xi_x\|$	$3.02{\cdot}10^{-3}$	$7.54{\cdot}10^{-4}$	$4.10{\cdot}10^{-3}$
$\|\Delta\xi_y\|$	$2.85{\cdot}10^{-3}$	$7.13{\cdot}10^{-4}$	$3.87{\cdot}10^{-3}$
$\|\Delta Q_{min}\|$	$2.56{\cdot}10^{-4}$	$6.40{\cdot}10^{-5}$	$3.48{\cdot}10^{-4}$

Possible correction of CC multipoles

Due to the orbit distortion induced by the crab cavity, the trajectory passes off-center in the final triplet. Sextupolar components will produce a ΔQ to compensate the effect of the crab cavity.

$$\frac{1}{4\pi} R_{12} \Delta x'(z) b_3 \beta_{sext} = \Delta Q_{cc}$$

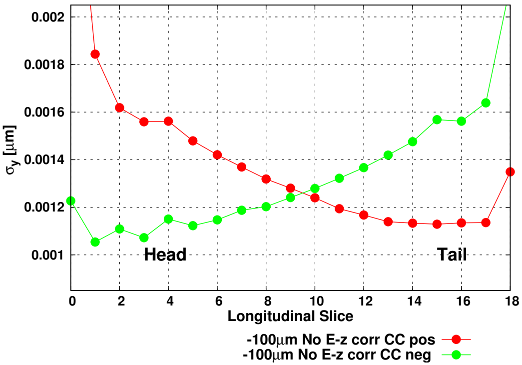


Nevertheless stability issues like dynamic aperture degradation should be addressed in further studies.

Traveling Waist Scheme at CLIC Final Focus

Recently it was observed in simulations a loss of luminosity of $\Delta\mathcal{L}/\mathcal{L}_{headon}$ ~-5% when comparing head on collisions with crab collisions.

Reason was a longitudinal displacement of the beam waist along the bunch, the so-called traveling waist scheme, due to off-center passage through final doublet sextupoles. For the current crossing scheme $\theta_c/2 = 10$ mrad the evolution of the traveling waist was from tail to head in opposition to the collision process.



MAPCLASS

Mapclass updated for longitudinal dependence on traverse emittance.

$$<x_f^2> = \sum_{jklmnq} X^2_{jklmnq} \Gamma\left(\frac{1+2j}{2}\right)\Gamma\left(\frac{1+2k}{2}\right)\Gamma\left(\frac{1+2l}{2}\right)\Gamma\left(\frac{1+2m}{2}\right)$$

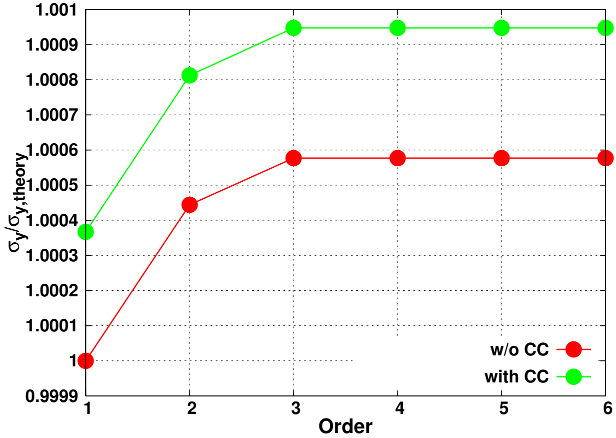
$$\frac{2^{j+k+l+m-2n}}{(2n+1)\pi^2}\sigma_x^{2j}\sigma_{p_x}^{2k}\sigma_y^{2l}\sigma_{p_y}^{2m}\Delta_\delta^{2n} z_0^{2q} + \sum_{jklmnq>j'k'l'm'n'q'} 2X_{jklmnq}X_{j'k'l'm'n'q'}$$

$$\Gamma\left(\frac{1+j+j'}{2}\right)\Gamma\left(\frac{1+k+k'}{2}\right)\Gamma\left(\frac{1+l+l'}{2}\right)\Gamma\left(\frac{1+m+m'}{2}\right)$$

$$\times\frac{2^{[(j+k+l+m+n+j'+k'+l'+m'+n)/2]-n-n'}}{(n+n'+1)\pi^2}\sigma_x^{j+j'}\sigma_{p_x}^{k+k'}\sigma_y^{l+l'}\sigma_{p_y}^{m+m'}\Delta_\delta^{n+n'} z_0^{q+q'}$$

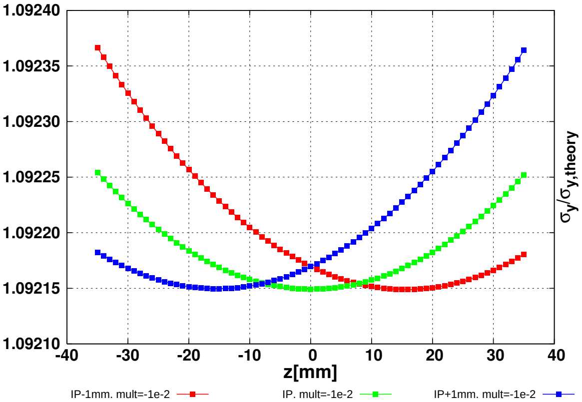
MAPCLASS studies in LHC

Beam size calculated using Maps terms up to 6th order using MAPCLASS.



MAPCLASS studies in LHC

Aberrations in positions with $z \neq 0$ are negligible with respect to $z = 0$.



Conclusions

- Different crab cavities were evaluated against linear and non-linear aberrations.
- Linear tune shift due to quadrupolar aberrations seems to be a main limitation for some of the types. On the other hand non-linear seems to be negligible.
- Non-linear optimization code for beam lines, MAPCLASS, updated to provide transverse beam sizes for different longitudinal positions.
- A possible configuration to correct ΔQ_{cc} including a pair of sextupoles should be evaluated with respect to stability issues.