Beam-beam compensation in an e^+e^- or eA collid

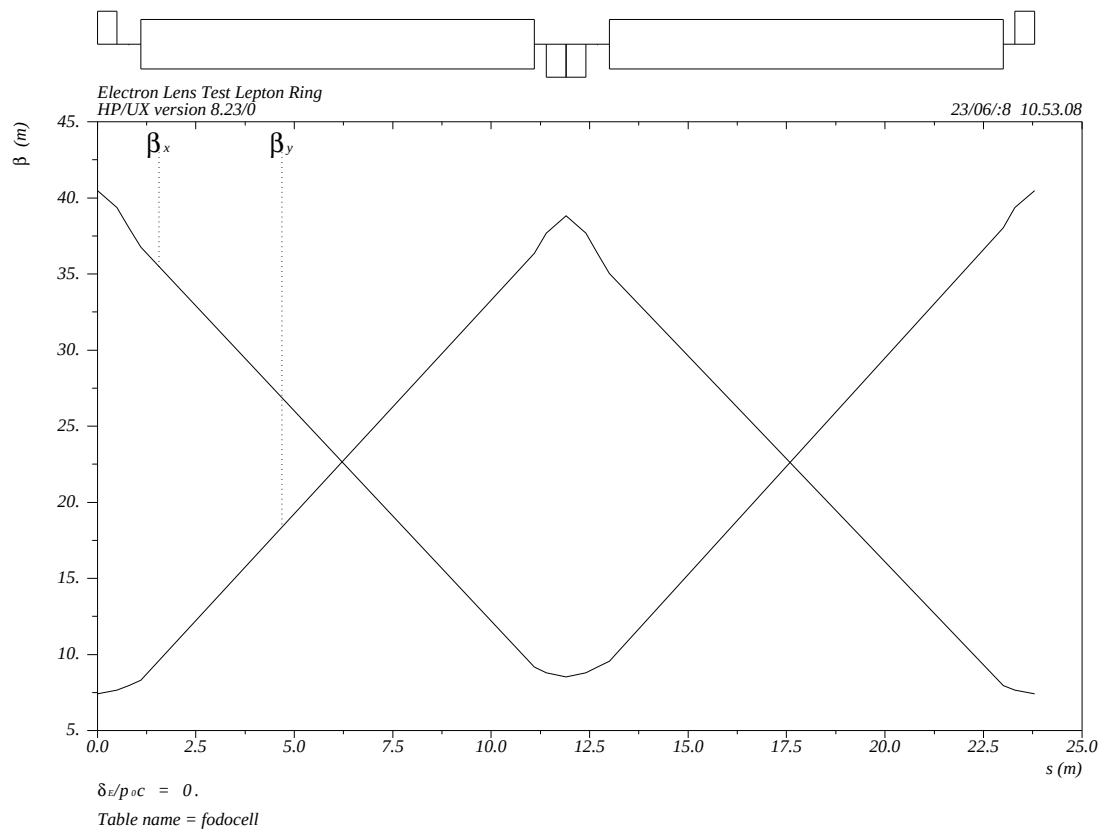
Parameter table

No. of FODO cells	N_{FODO}	50
Phase advance/cell (hor./vert.)	$\Delta\Phi_x/\Delta\Phi_y$	$79.7^\circ/89.0^\circ$
Chromaticity (hor./vert.)	ξ_x/ξ_y	$+2/+2$
β-function at IP and elens	β_x/β_y	0.19 m, 0.26 m
No. of protons/bunch	N_p	$4 \cdot 10^{11}$
rms beam size at IP and elens	σ_x/σ_y	$101\,\mu$m/$50.5\,\mu$m
Lorentz factor	γ	19560
damping times	$\tau_x/\tau_y/\tau_z$	1740/1740/870 turns

IP and electron lens on opposite sides of the ring; 25 FODO cells (with sextupoles) in-between

Ideal phase advance between IP and e-lens: $m \cdot \pi$, achieved by rotation matrices

One FODO cell



Dynamic tune and β-function

One-turn matrices:

$$\begin{aligned} M^{\circ}_{\mathrm{IP}} &= M_{\mathrm{IP}\to\mathrm{elens}} \cdot M_{\mathrm{elens}} \cdot M_{\mathrm{elens}\to\mathrm{IP}} \cdot M_{\mathrm{IP}} \\ M^{\circ}_{\mathrm{elens}} &= M_{\mathrm{elens}\to\mathrm{IP}} \cdot M_{\mathrm{IP}} \cdot M_{\mathrm{IP}\to\mathrm{elens}} \cdot M_{\mathrm{elens}} \end{aligned}$$

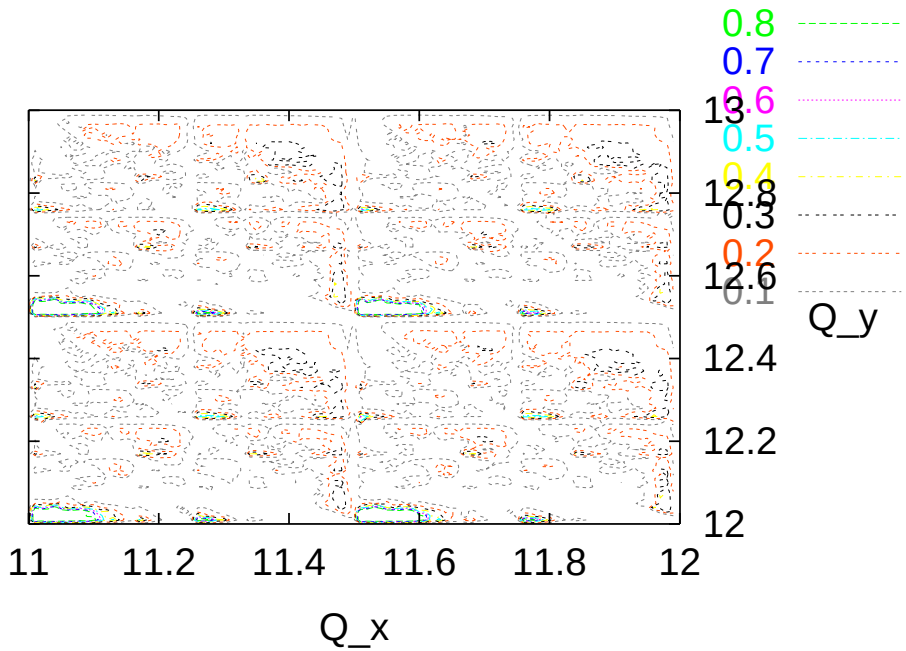
Tune:

$$\cos Q^* = \frac{1}{2}\mathrm{Tr}(M^{\circ}_{\mathrm{IP}}) = \frac{1}{2}\mathrm{Tr}(M^{\circ}_{\mathrm{e-lens}})$$

β-functions, from matrix elements M_{12}:

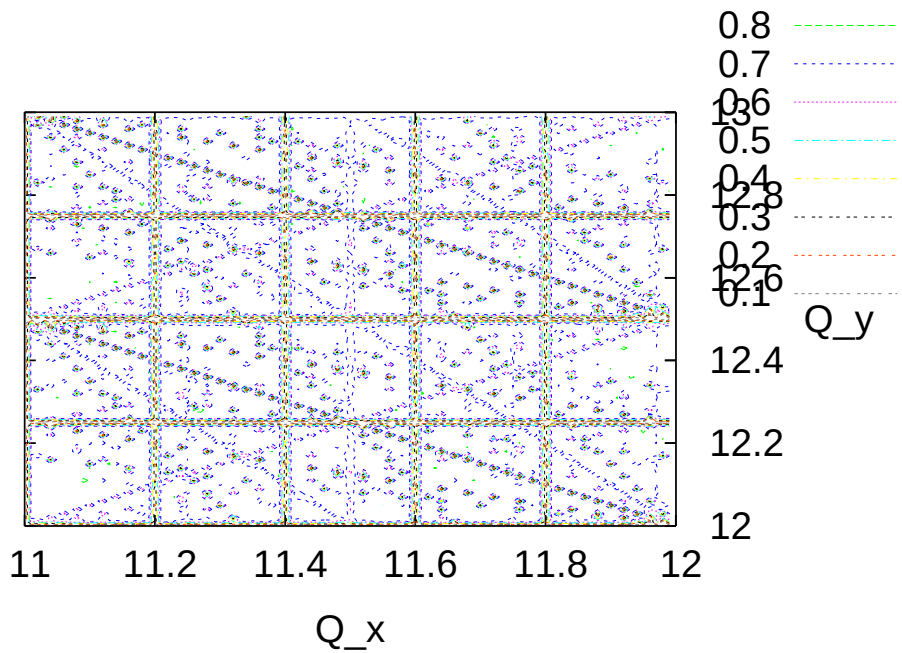
$$\begin{aligned} \beta^*_{\mathrm{IP}} &= M^{\circ}_{\mathrm{IP}}|_{12} \,/\, \sin(2\pi Q^*) \\ \beta^*_{\mathrm{elens}} &= M^{\circ}_{\mathrm{elens}}|_{12} \,/\, \sin(2\pi Q^*) \end{aligned}$$

Tune scan without beam-beam compensation



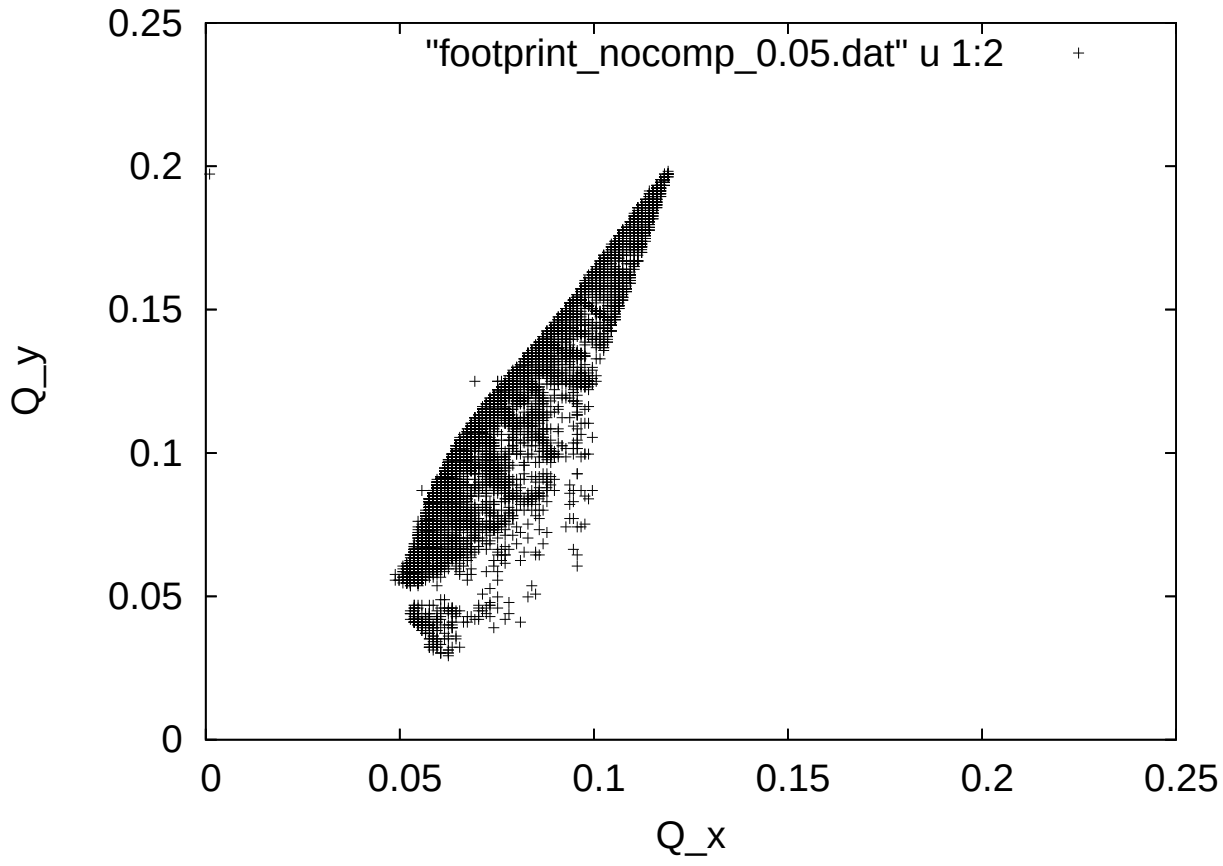
High luminosity just above (half) integer tunes due to dynamic focusing

Tune scan with ideal beam-beam compensation



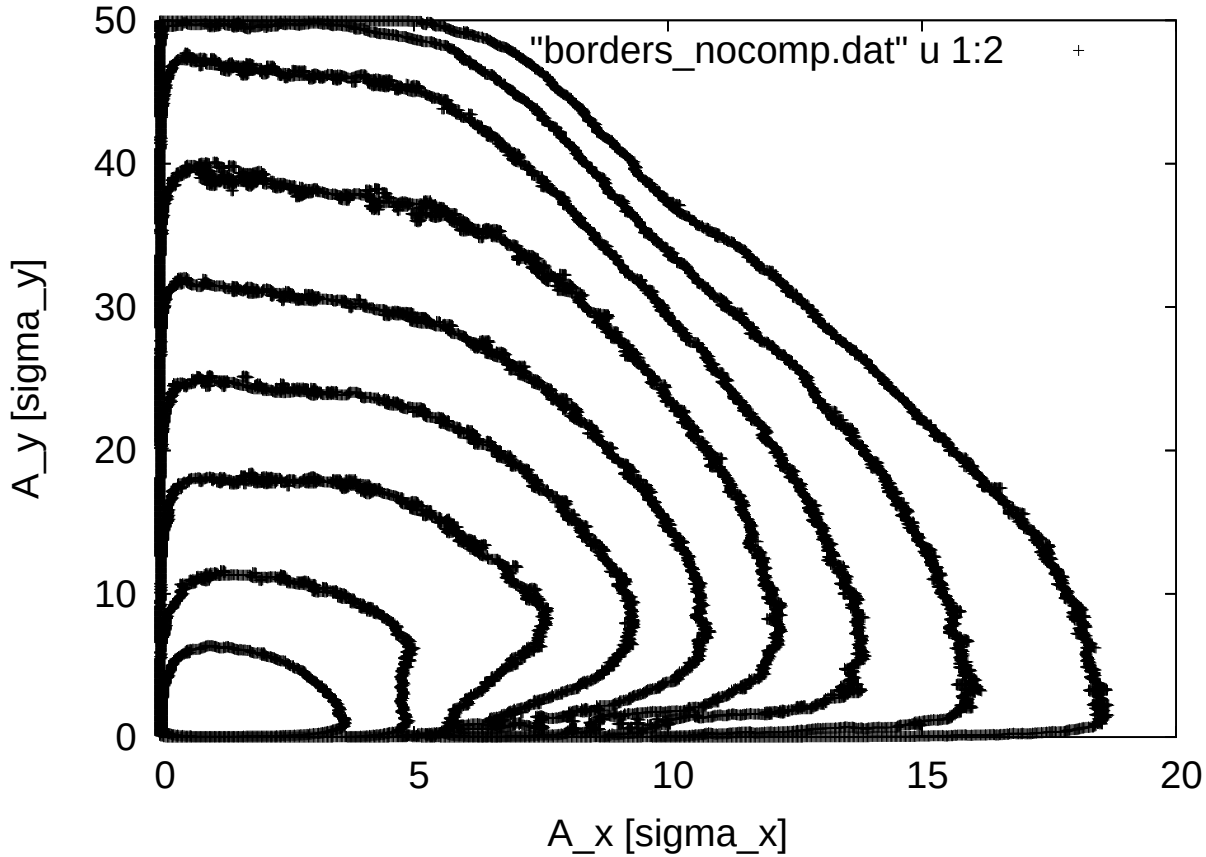
High luminosity, rather insensitive to working point

Tune footprint without compensation



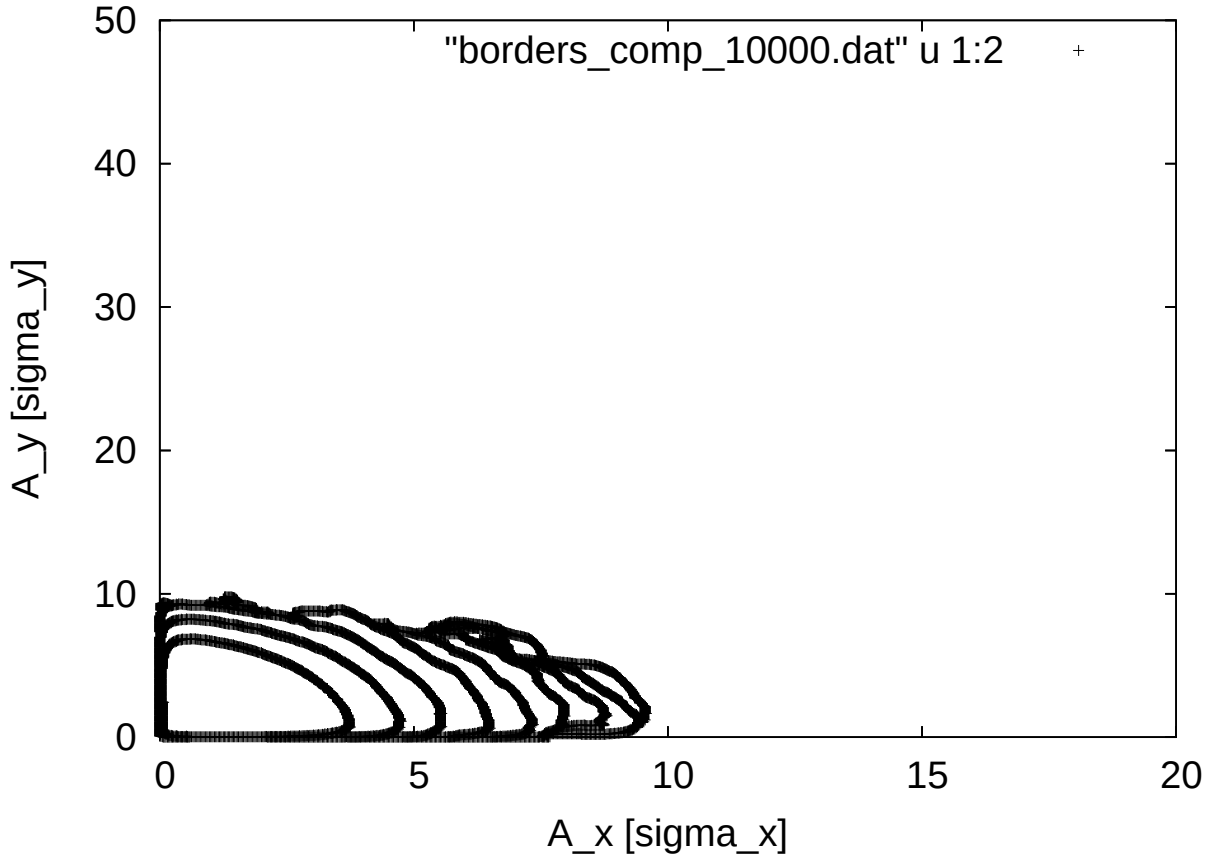
With ideal compensation, the footprint shrinks to a point - at least on this scale

Transverse electron distribution without compensation



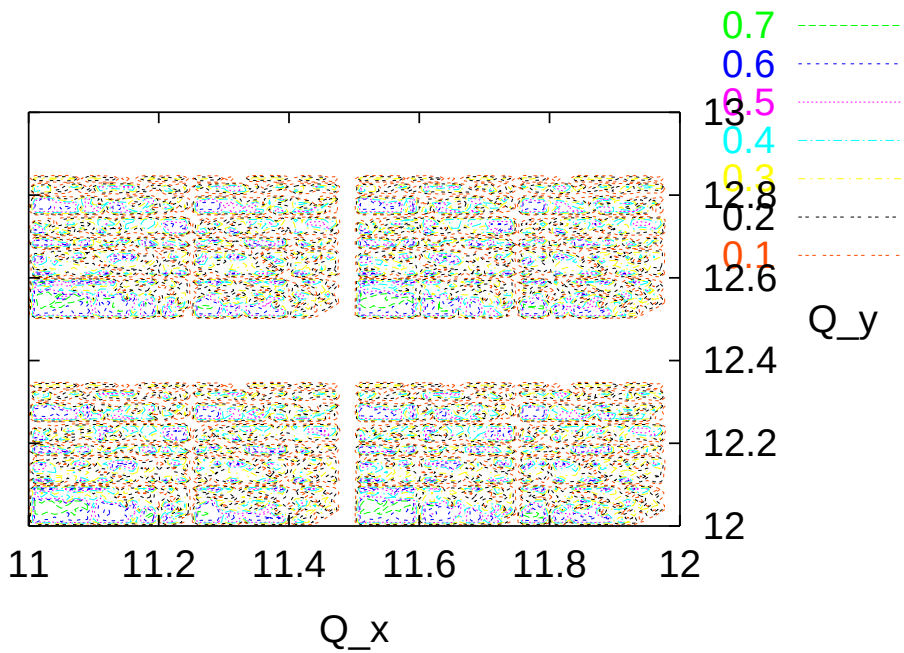
Tunes (.05,.05)
Density drops by factor ten between contour lines

Transverse electron distribution with ideal compensation



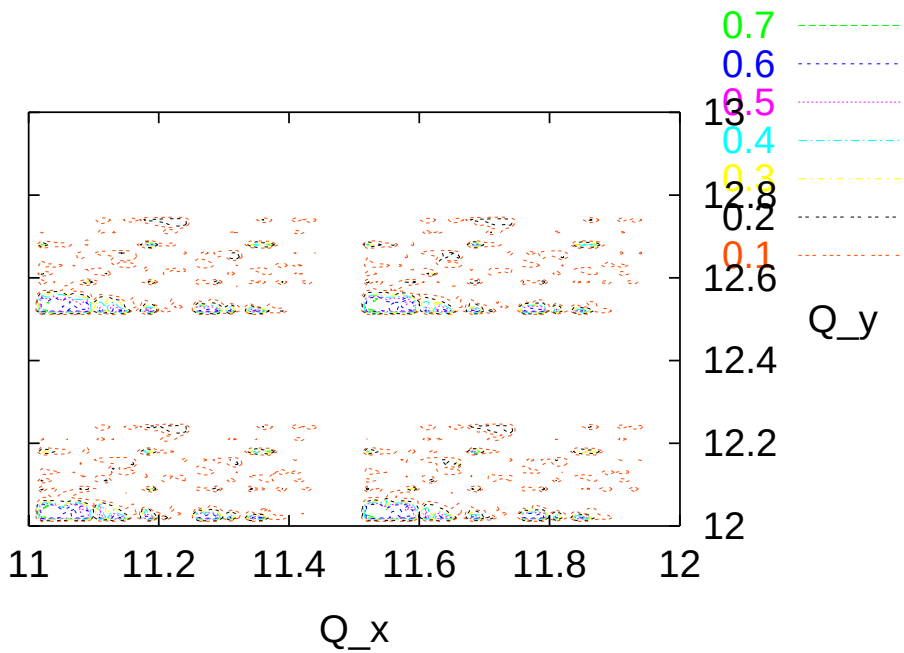
Tunes (.05,.05)
Density drops by factor ten between contour lines

Tune scan with phase advance off by $+0.01 \cdot 2\pi$



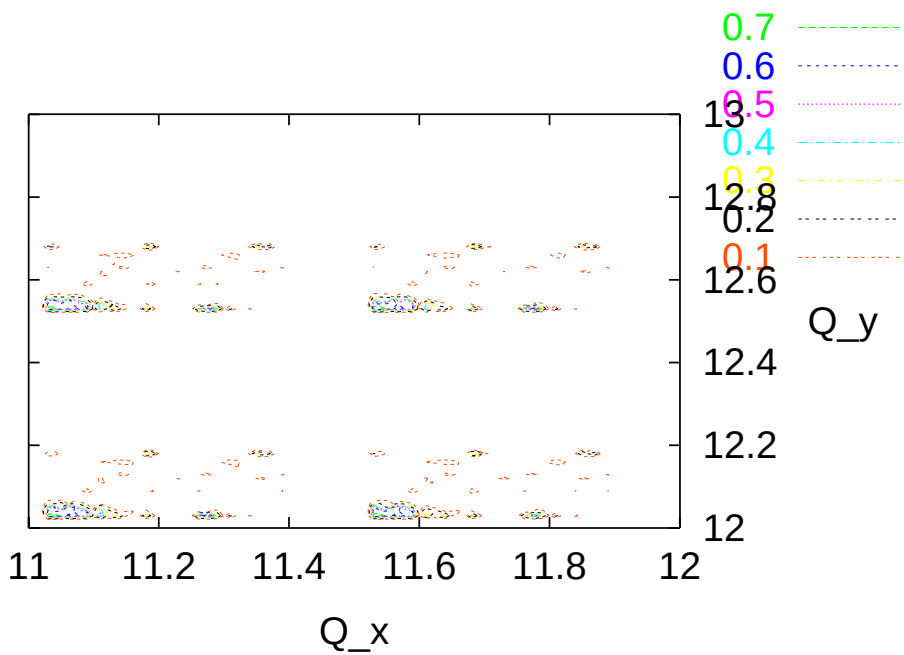
Already quite sensitive to working point

Tune scan with phase advance off by $+0.02 \cdot 2\pi$



Getting worse...

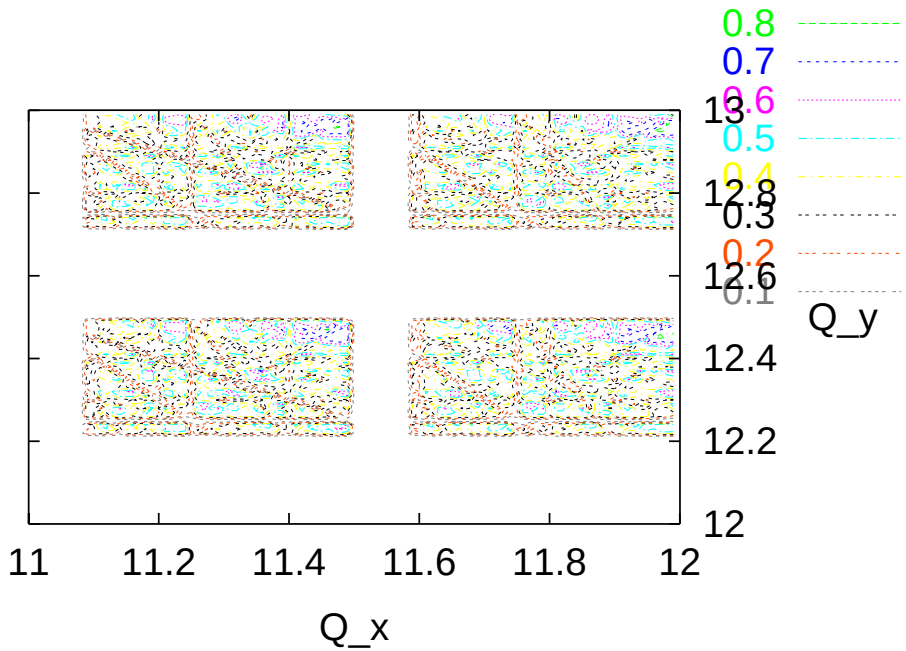
Tune scan with phase advance off by $+0.03 \cdot 2\pi$



...and worse...

$\Delta\phi = +0.005$ still running, but seems ok

Size mismatch: e-lens at 85 percent of p-beam size



e-lens defocusing takes over, highest lumi below (half) integer

e-lens at 1.15 percent of p-beam size

Still running...

e-lens intensity scan

Still running...

Plans:

Apply all errors simultaneously, perform tune scan and calculate transverse tails