Donuts in XFEL

some conclusions

tracking in XFEL

possible XY - plots (different linear transformations)

possible projections of phase space (different LT)

tracking from gun to start of L2

some conclusions

donuts happen even for the standard case (pencil beam)

they are observable for phase advances μ_x, μ_y from the cathode that fulfill the condition $\mu_x + n\pi = \mu_y + m\pi = \alpha$ (for a particular value/range of α); the necessary condition $\mu_x - \mu_y \approx (n-m)\pi$ is fulfilled in some ranges of the machine

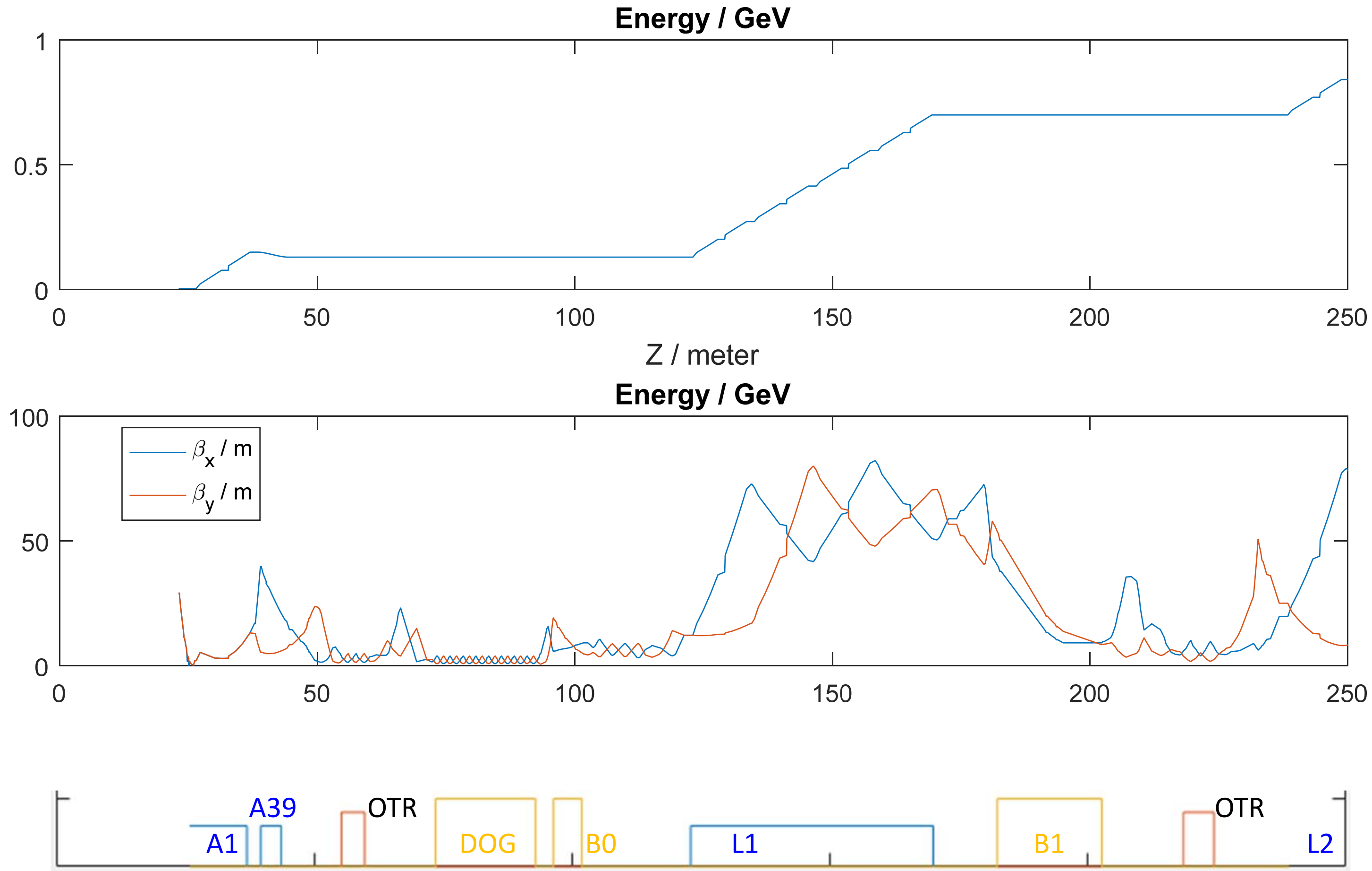
the width of the range of α (to observe donuts) is about 20 deg (54 deg) for the hard uniform (strong ring) distribution;
it was not possible to observe to ring in a wide range (width > 54 deg)

the donut is not very pronounced for the pencil beam, but the effect can be enhanced for donut shaped laser-profiles

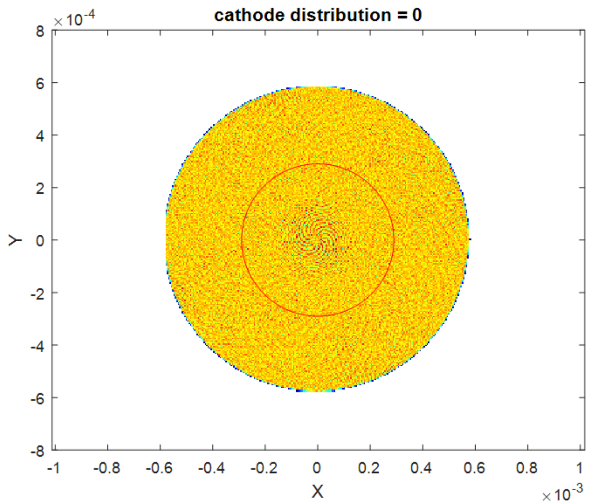
the "cathode picture" reappears later if $\mu_x + n\pi = \mu_y + m\pi = 0$

the phase space projections (for a pencil beam) are by far not gaussian;
usually the core is more populated;
gaussian fits and tail clipping should give smaller emittances!
larger emittances might be explained by non-linear effects (as saturation)

tracking from gun to start of L2



standard case

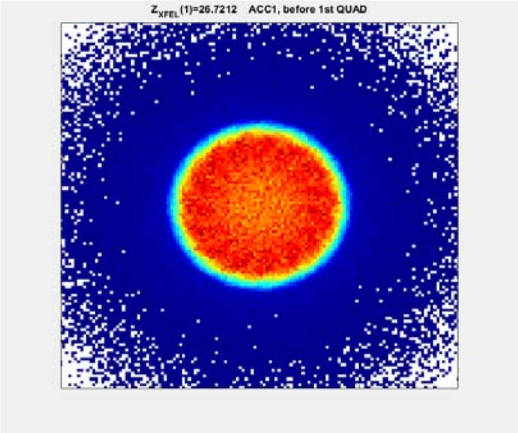


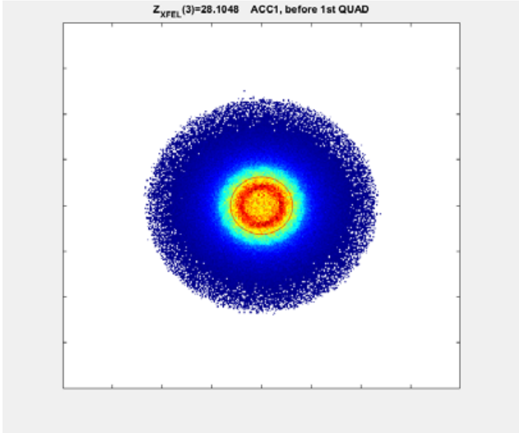
bunch charge = 0.5 nC
rms width in X and Y = 0.29 mm
rms bunch length = 12 psec (3.6 mm)
gaussian distribution
solenoid optimised for this setting
0 --> 2.6 m by Astra
2.6 m --> 216 m by Xtrack (no coupler kicks)

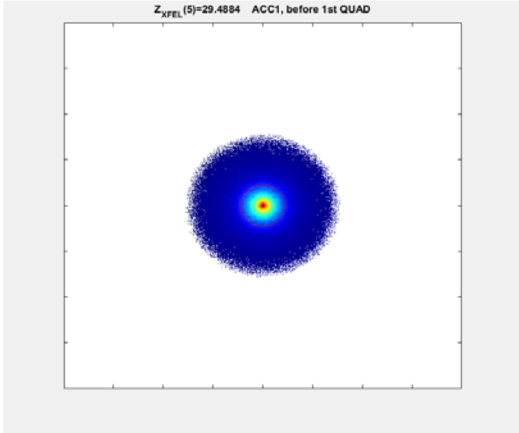
--> many gif files

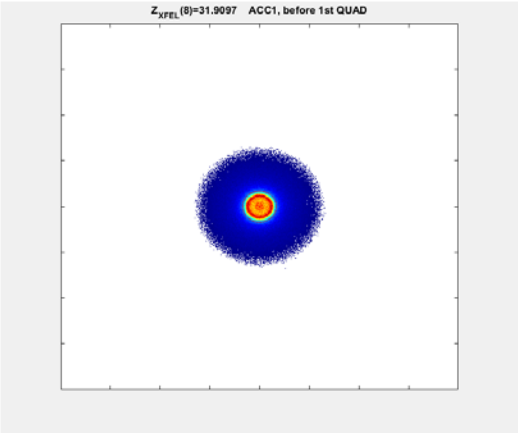
see distribution00/versus_Z

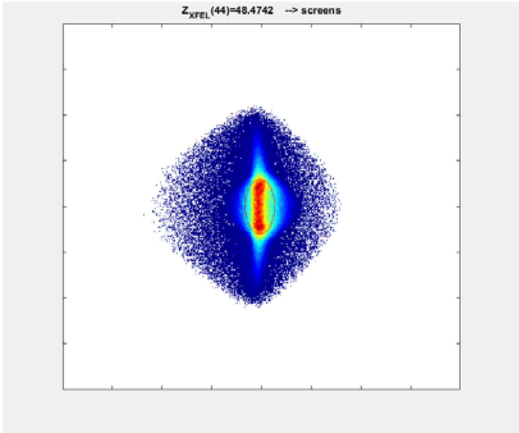
from distribution00/versus_Z

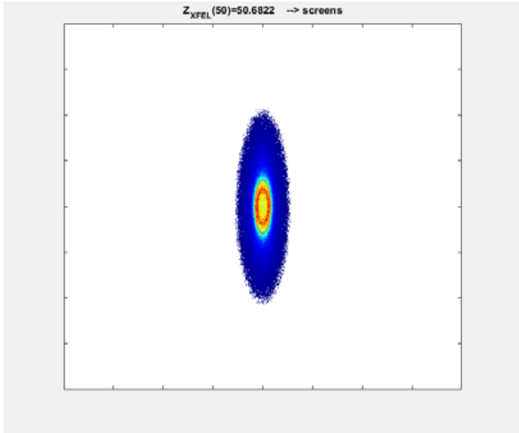


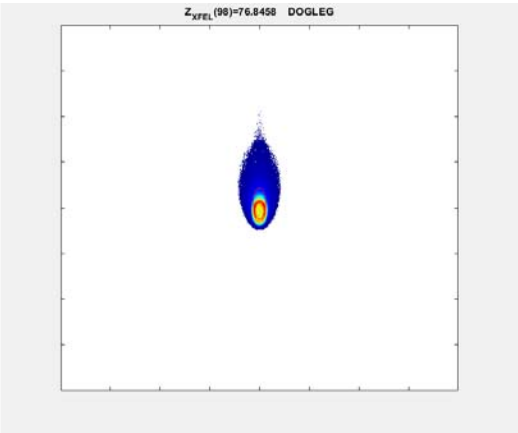












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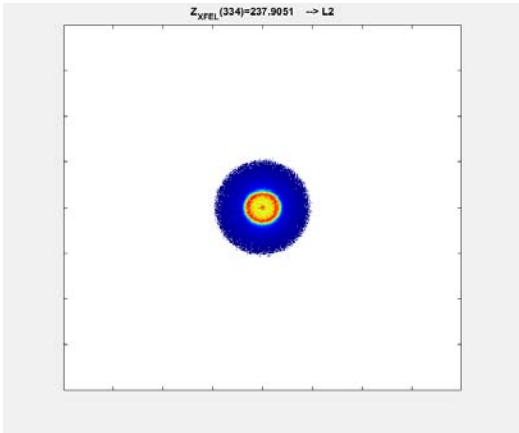
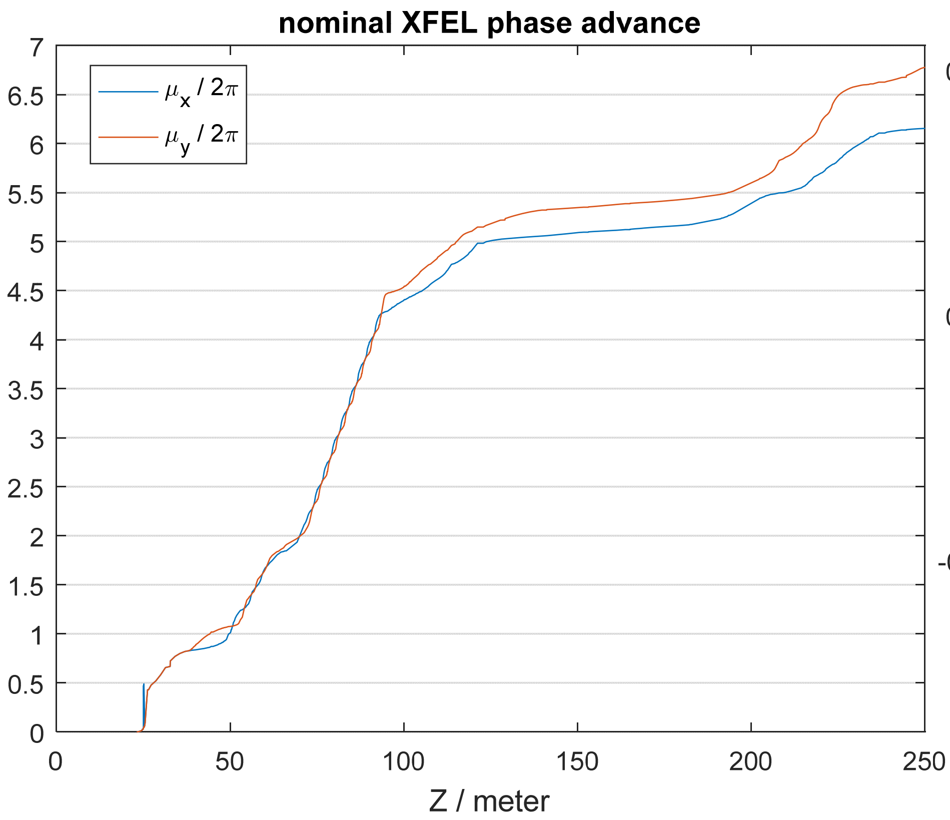
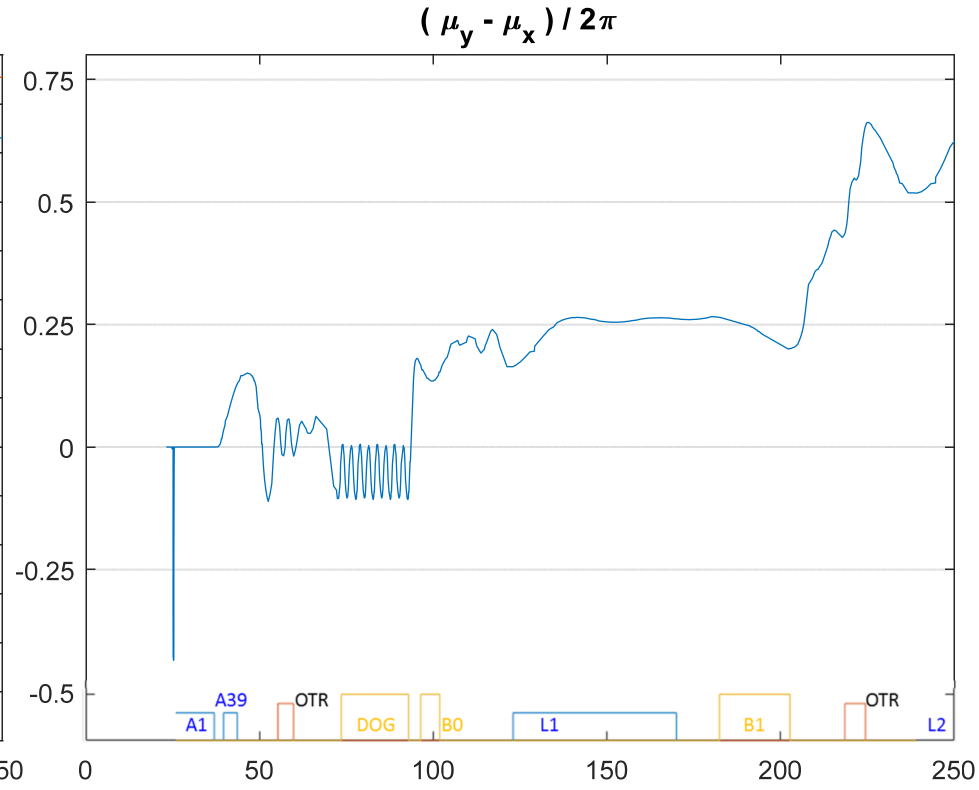


nominal phase advance

(Winnie's data)





possible XY - plots
for different linear transformations of phase space

after ACC (before quads)
at OTR-B (~ 218 m)

--> many gif files

see distribution00/ACC,
distribution00/OTR

linear transformations

drift-transformation $\quad [x, x'] \rightarrow [a, a'] = [x + L_1 x', x']$ $\quad$ with $\quad \langle a, a' \rangle = 0$

$\quad [y, y'] \rightarrow [b, b'] = [y + L_2 y', y']$ $\quad \langle b, b' \rangle = 0$

normalization

$$c = a / \mathrm{rms}(a)$$
$$c' = a' / \mathrm{rms}(a')$$
$$d = b / \mathrm{rms}(b)$$
$$d' = b' / \mathrm{rms}(b)$$

rotation (by angle f1,f2)

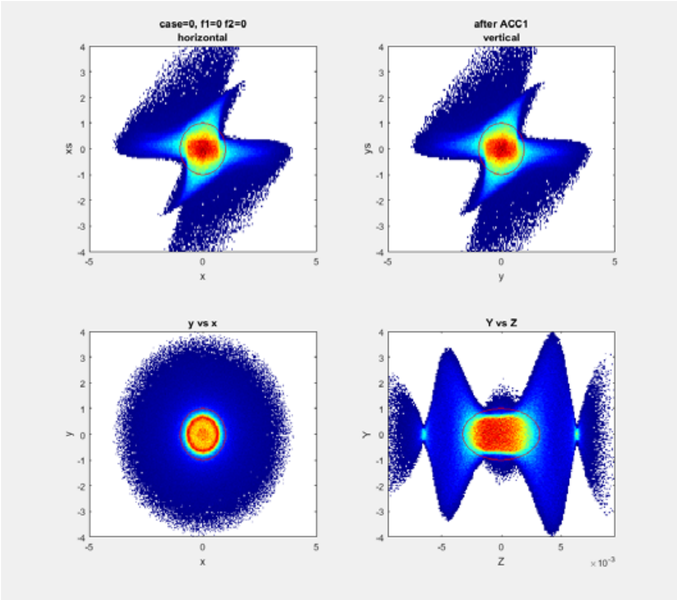
$$[\tilde{x}, \tilde{x}'] = [c, c'] \begin{bmatrix} \cos f_1 & \sin f_1 \\ -\sin f_1 & \cos f_1 \end{bmatrix}$$

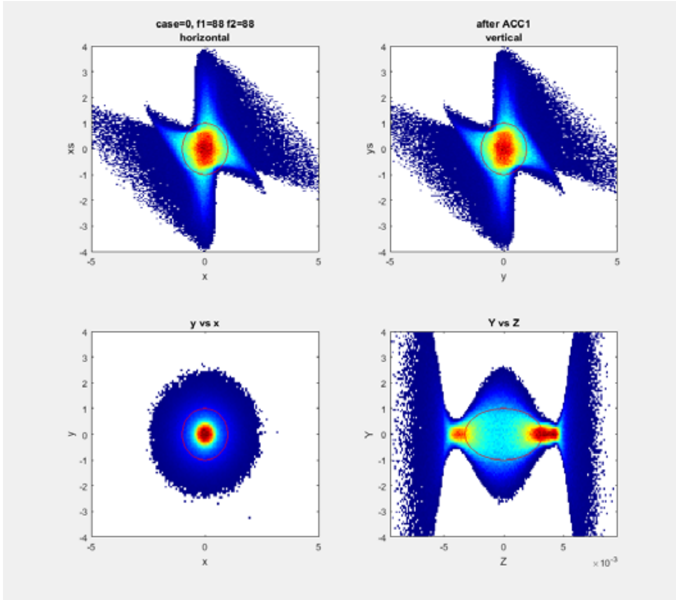
$$[\tilde{y}, \tilde{y}'] = [d, d'] \begin{bmatrix} \cos f_2 & \sin f_2 \\ -\sin f_2 & \cos f_2 \end{bmatrix}$$

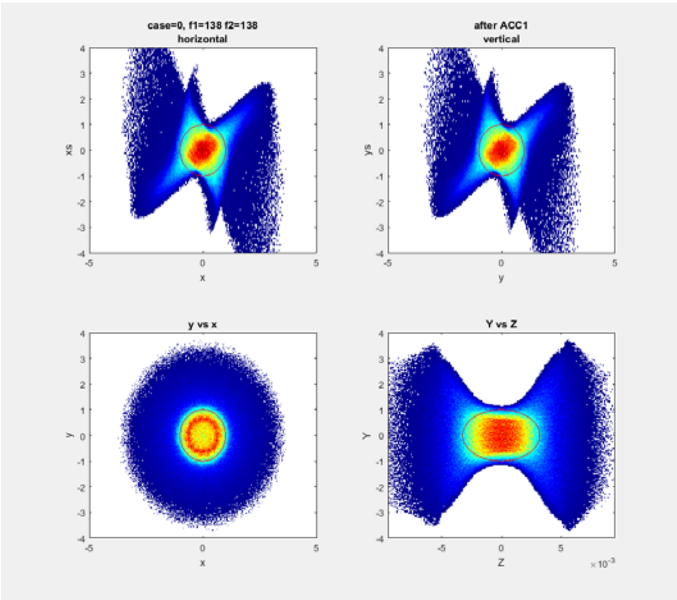
same phase advance from cathode: $\quad f_1 - f_2 = n \cdot \pi / 2$

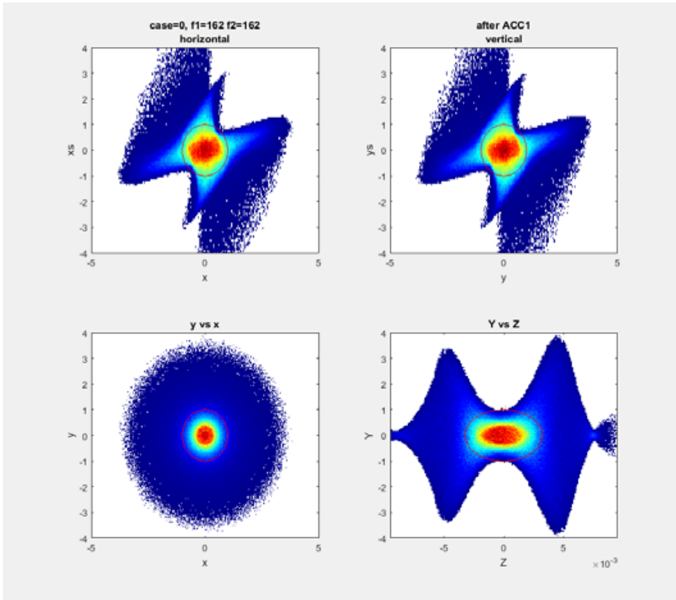
from distribution00/ACC/ACC_00_A

f1 = f2 = 1 ..180 deg

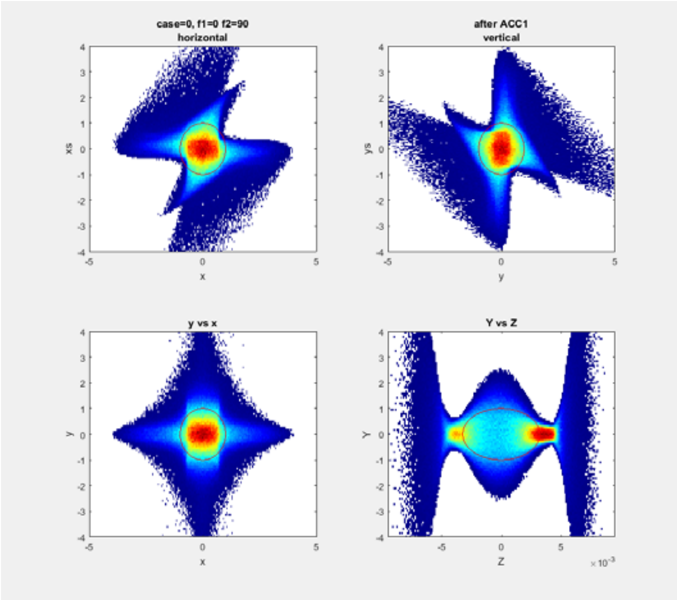


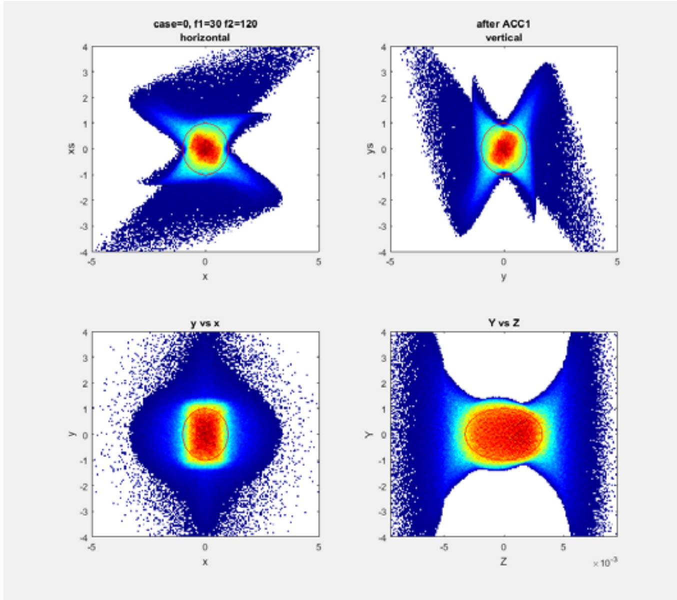


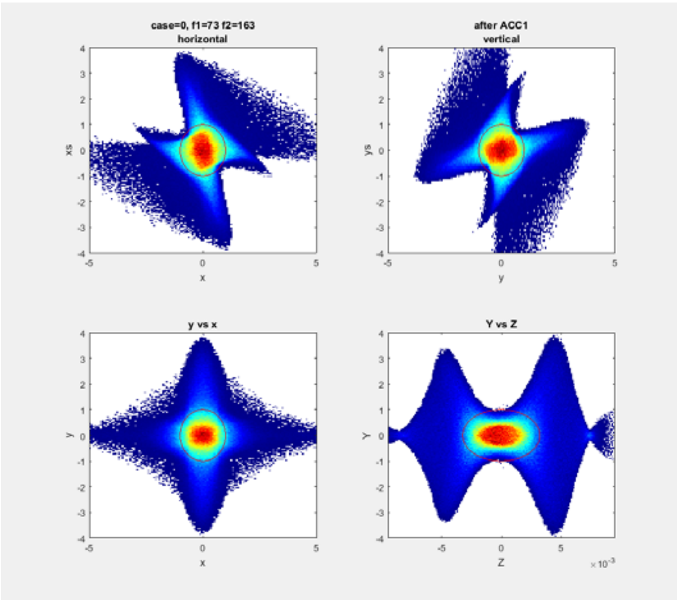


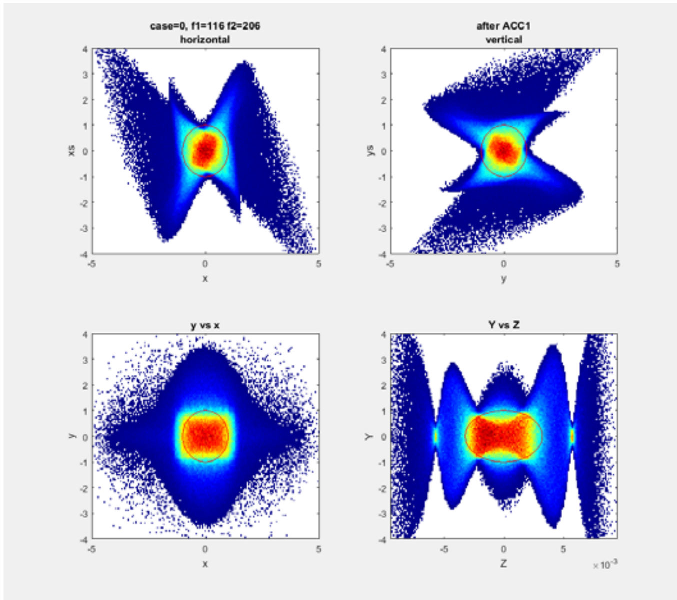


from distribution00/ACC/ACC_00_A_90 f1 = f2-90deg = 1 ..180 deg

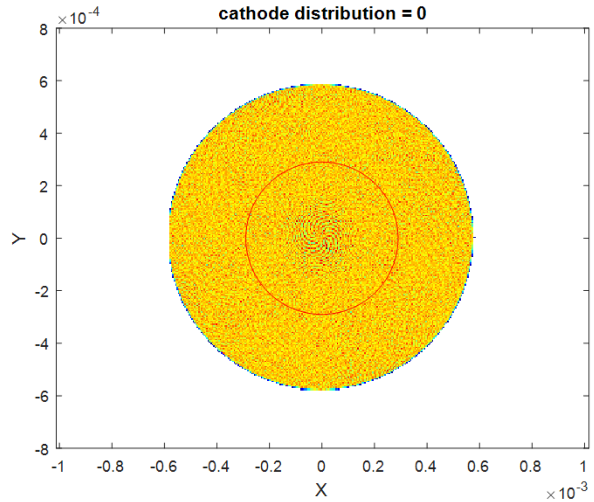




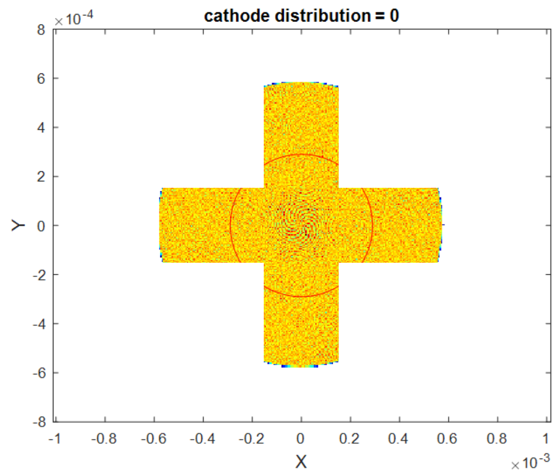




distribution on cathode

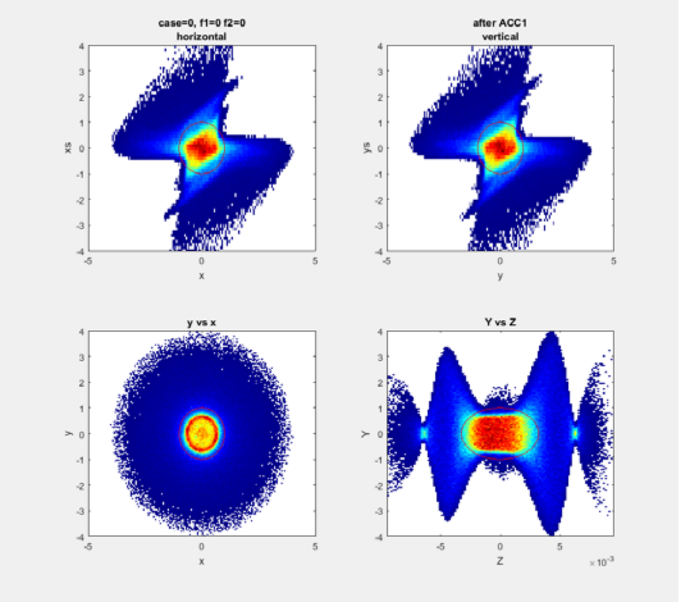


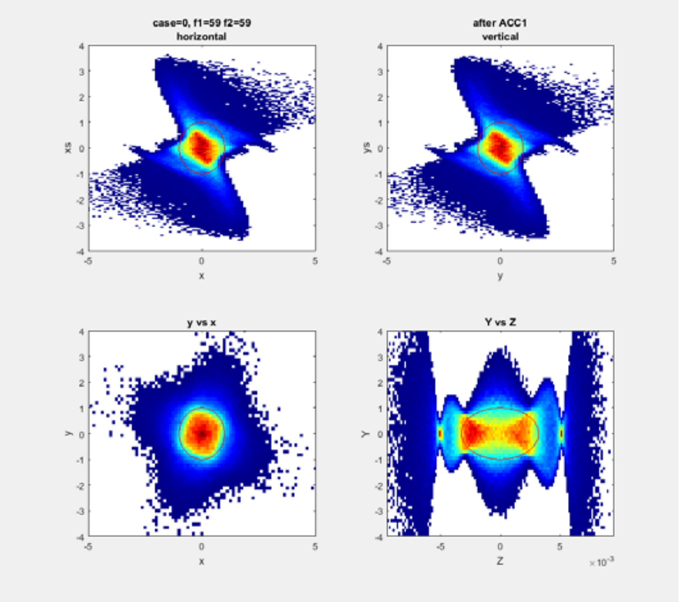
the “plus” particles

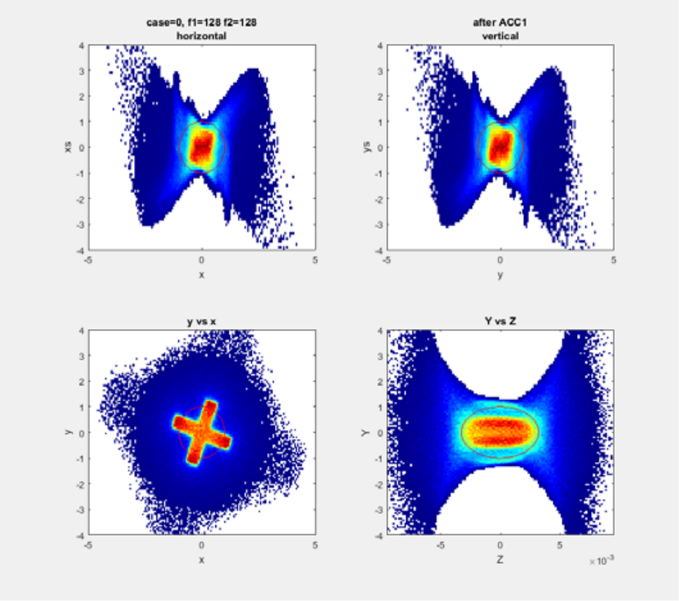


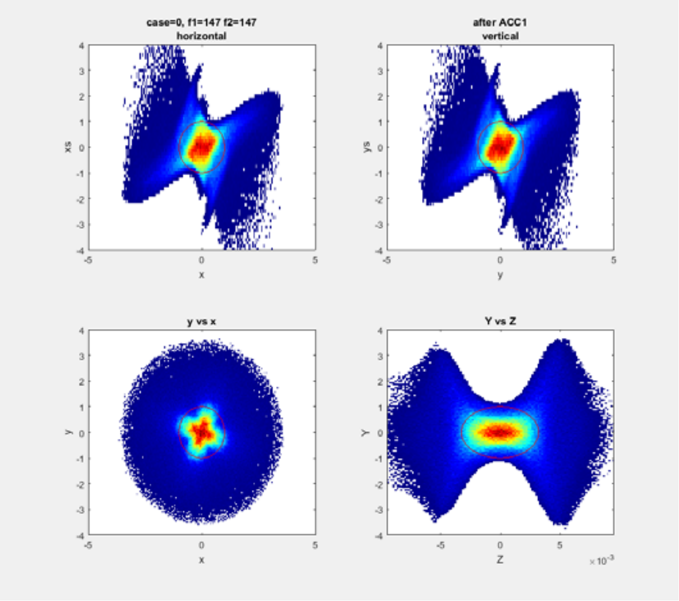
for the following diagrams all particles are tracked, but only “+” particles are plotted from distribution00/ACC/ACC_00_K

f1 = f2 = 1 ..180 deg, only “+” particles



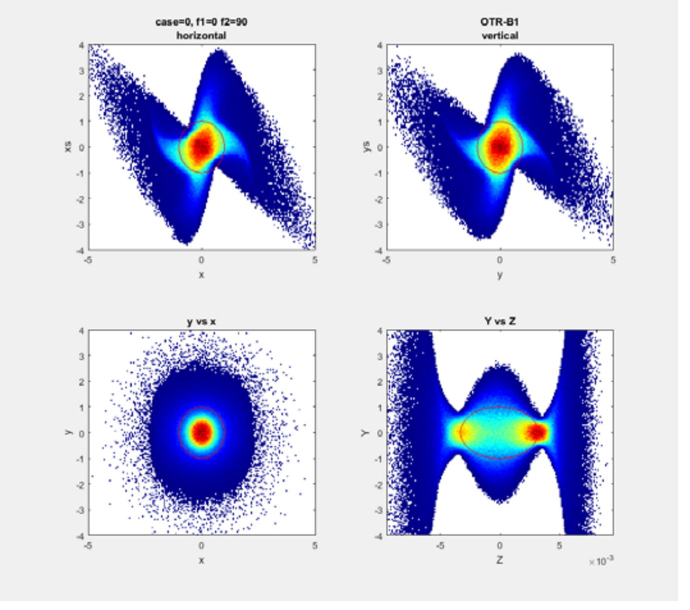


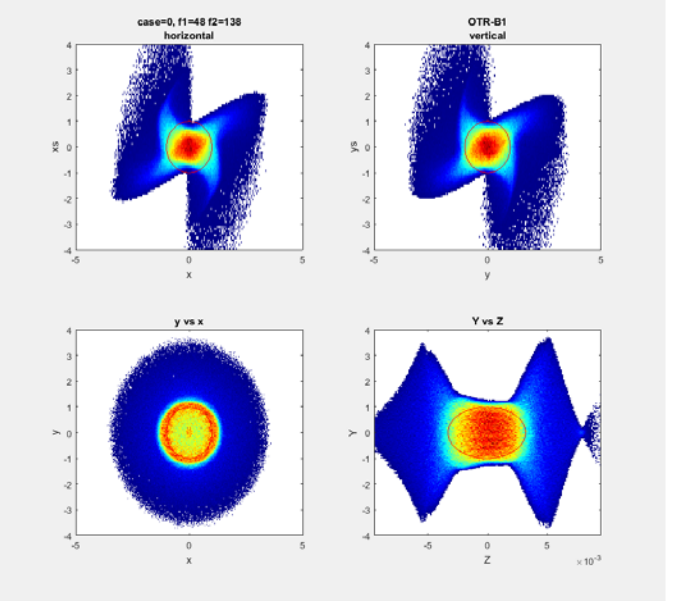


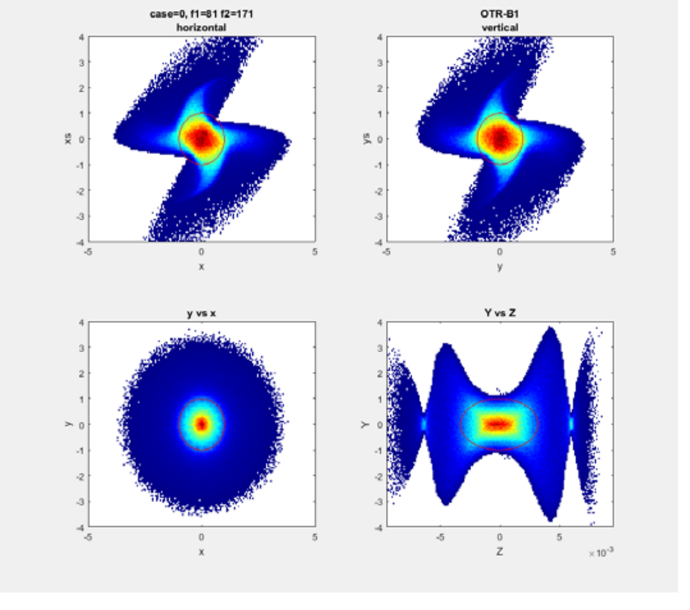


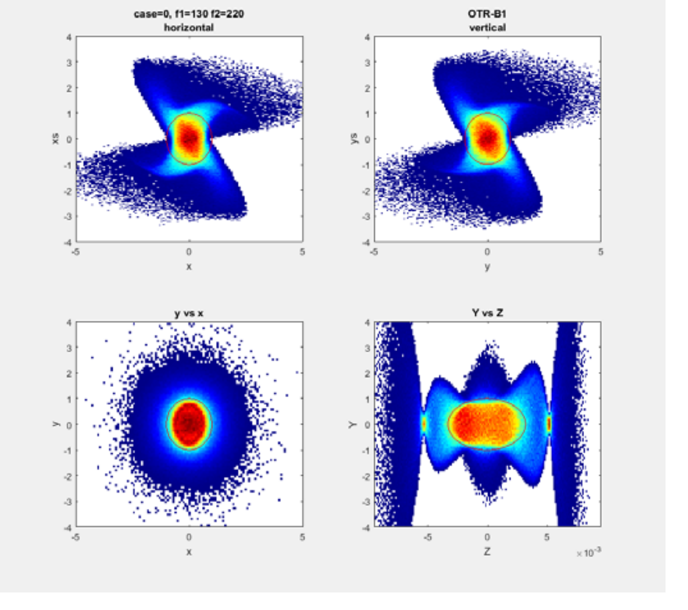
from distribution00/OTR/OTR_00_A

f1 = f2-90deg = 1 ..180 deg



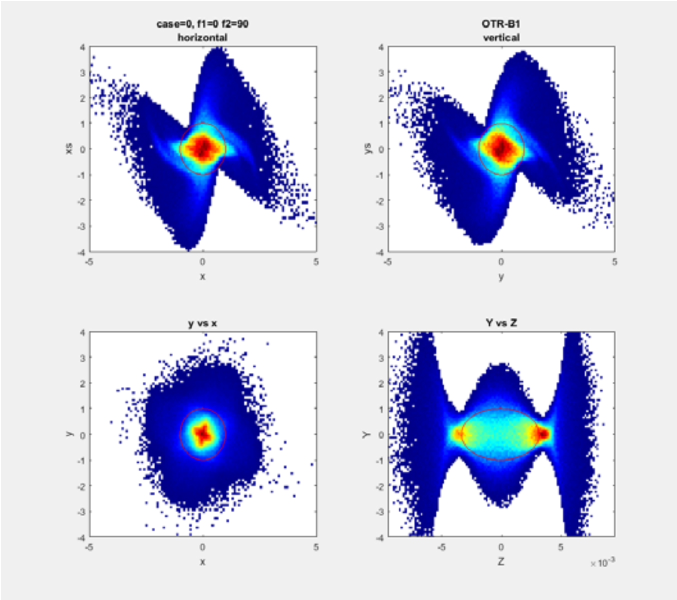


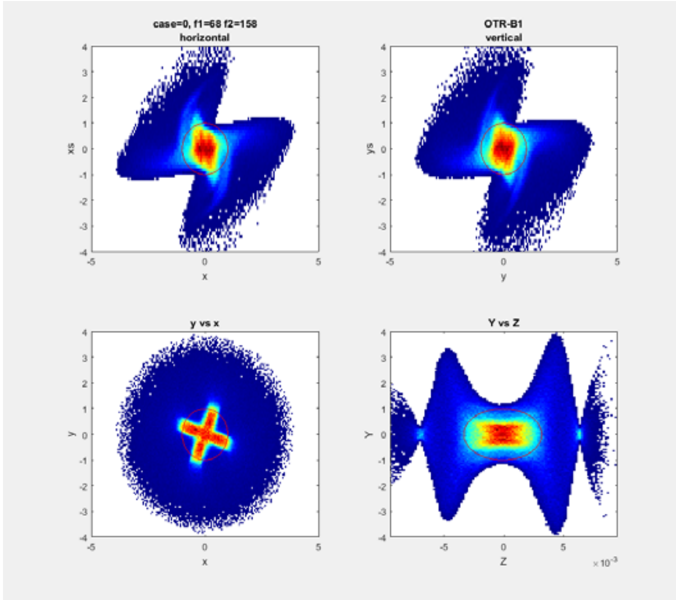


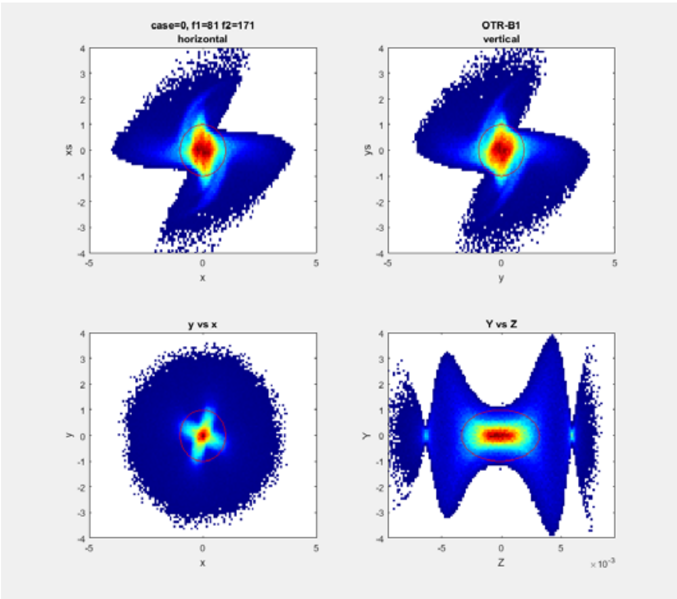


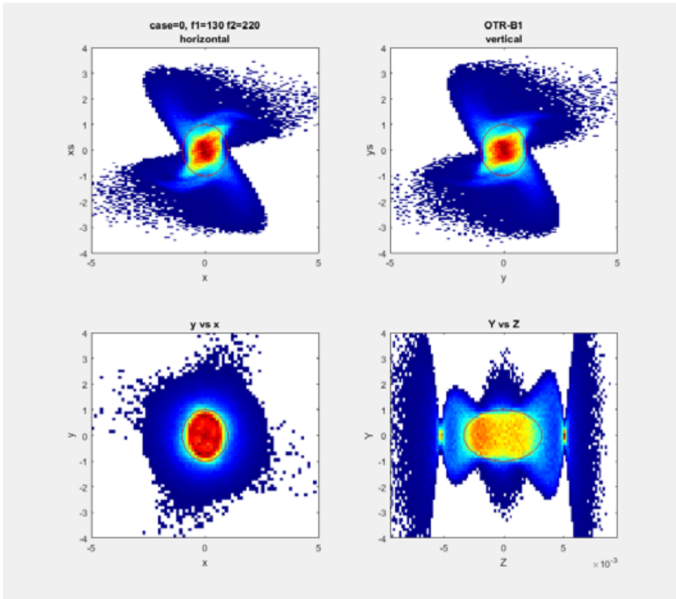
from distribution00/OTR/OTR_00_A

f1 = f2-90deg = 1 ..180 deg, only “+” particles

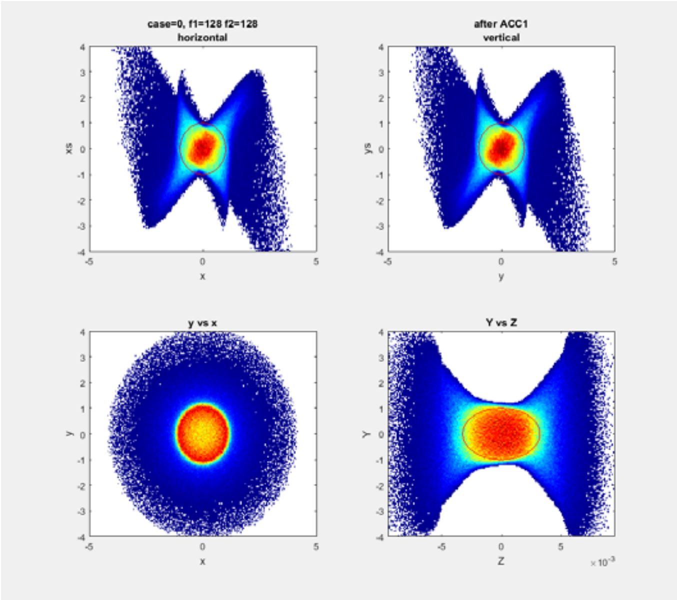




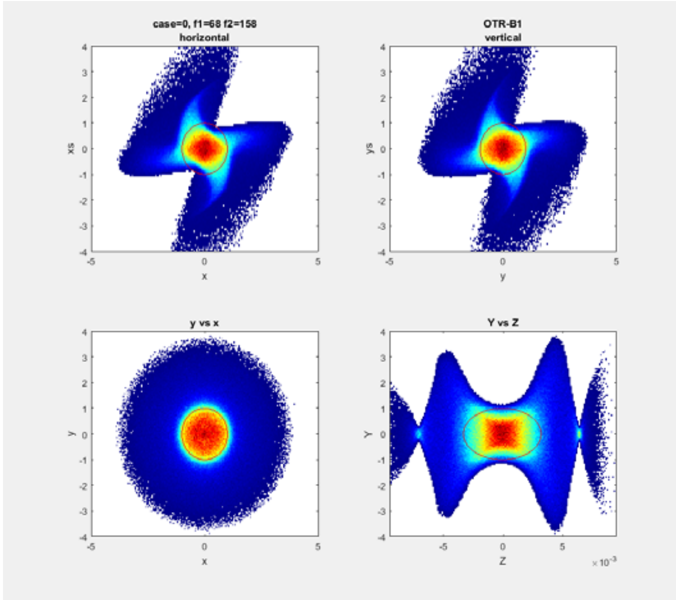




from distribution00/ACC/ACC_00

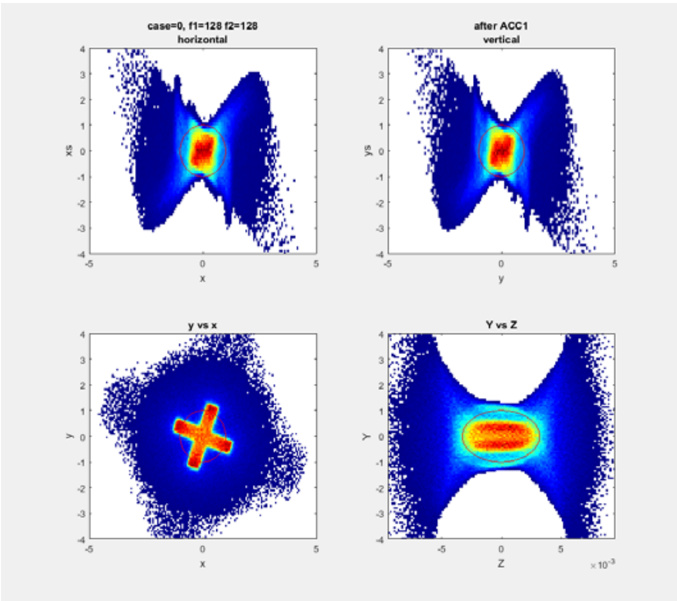


from distribution00/OTR/OTR_00

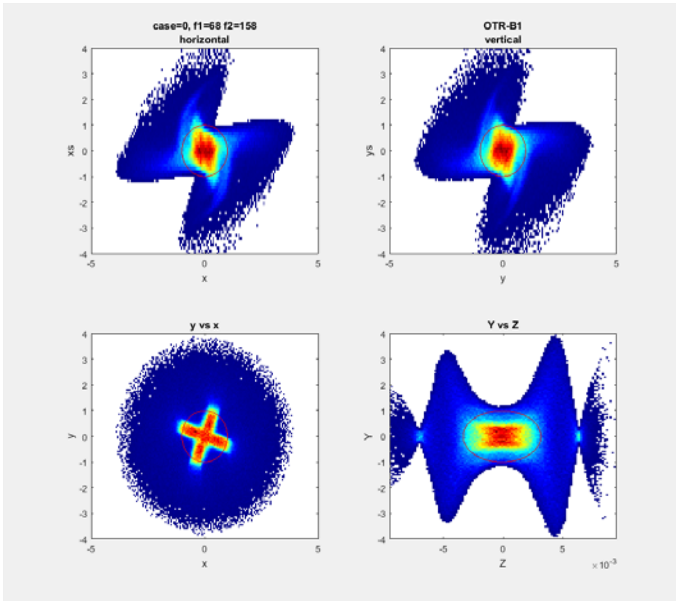


from distribution00/ACC/ACC_00_K

only “+” particles



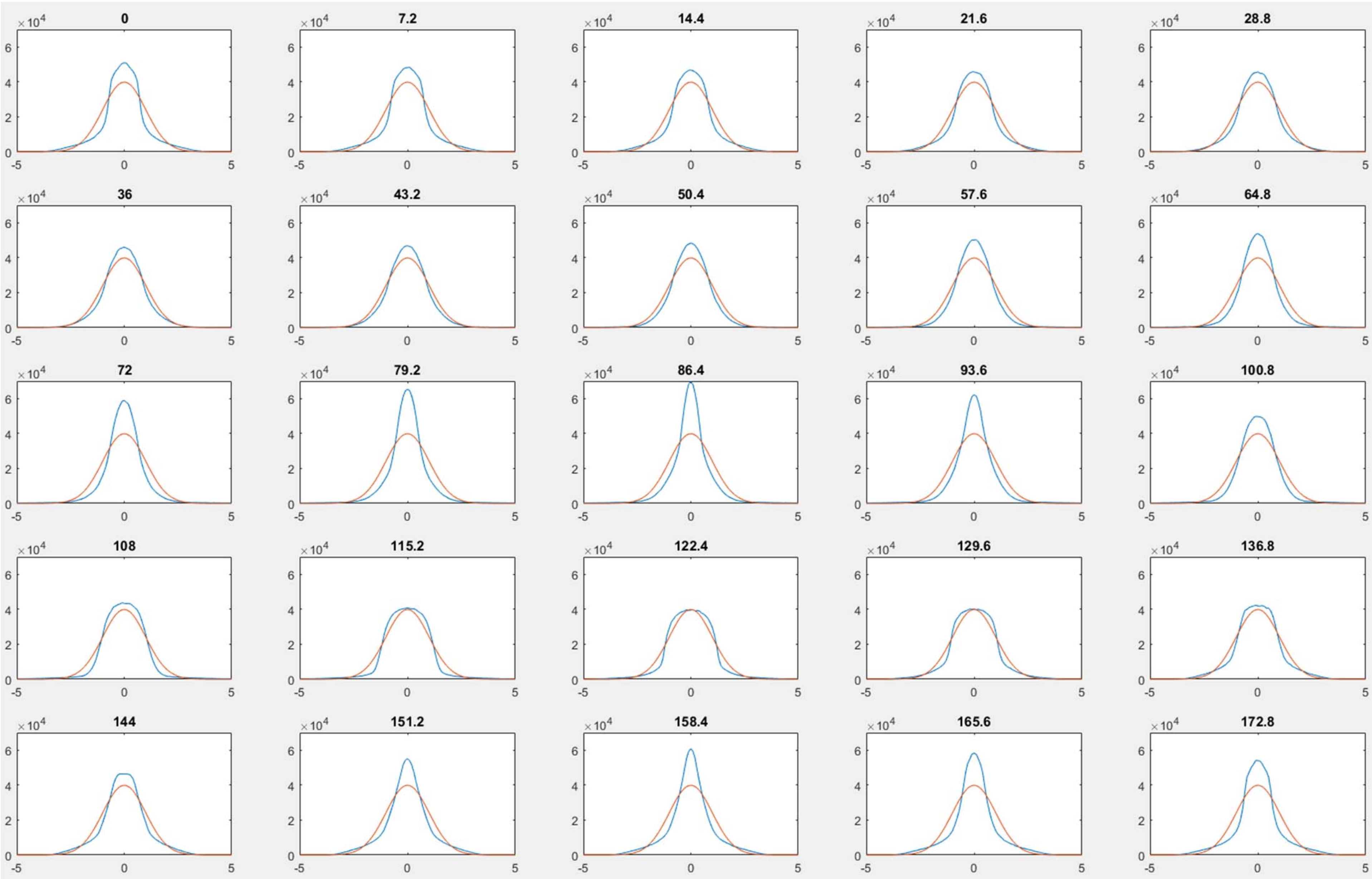
from distribution00/OTR/OTR_00_A



possible projections of phase space

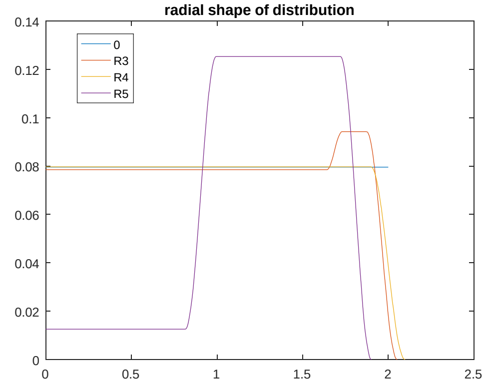
after ACC (before quads)
at OTR-B (~ 218 m)

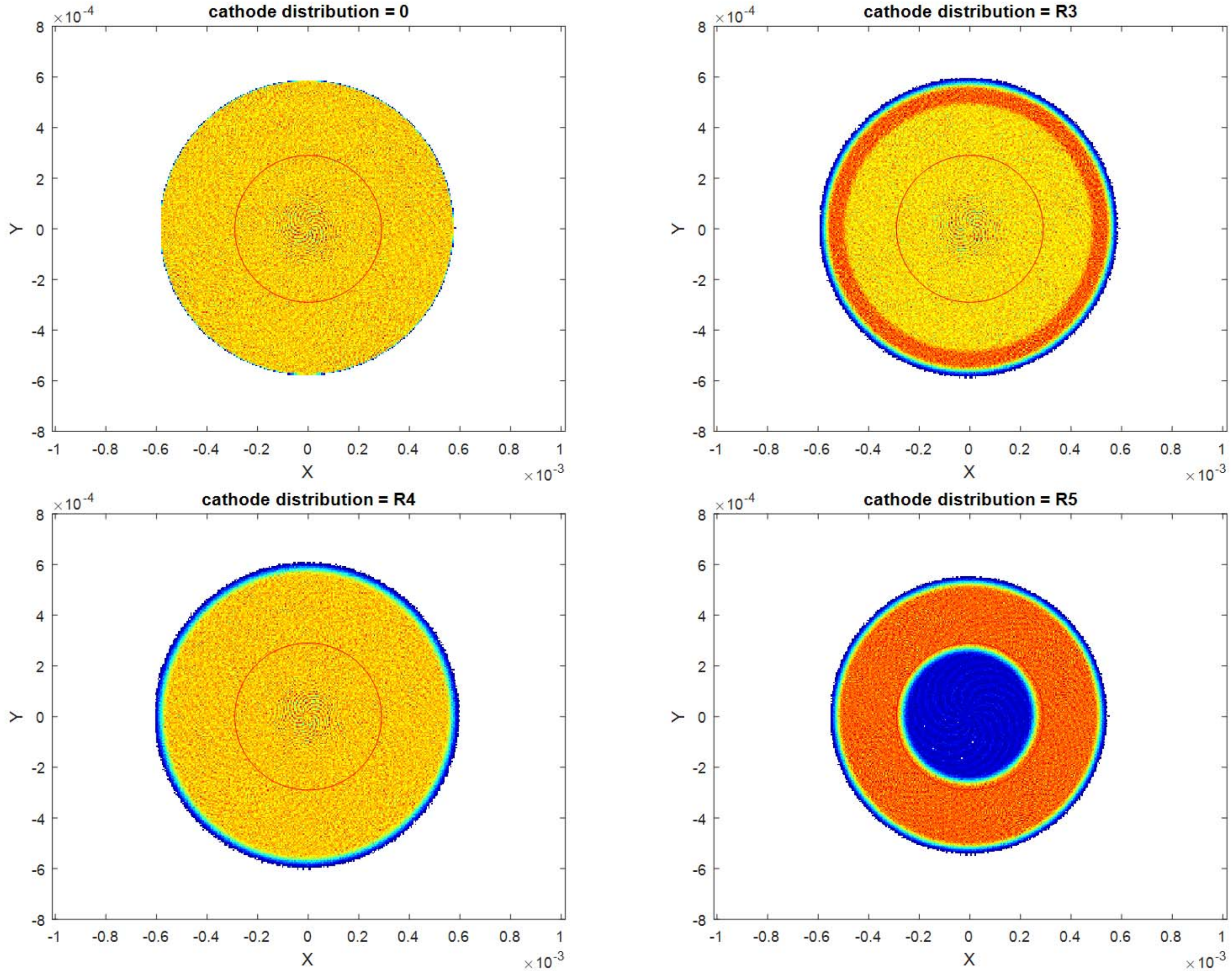
projections of horizontal (and vertical) phase space
ACC, 0 = hard uniform



other distribution functions

0 = hard uniform
R3 = weak ring
R4 = soft uniform
R5 = strong ring



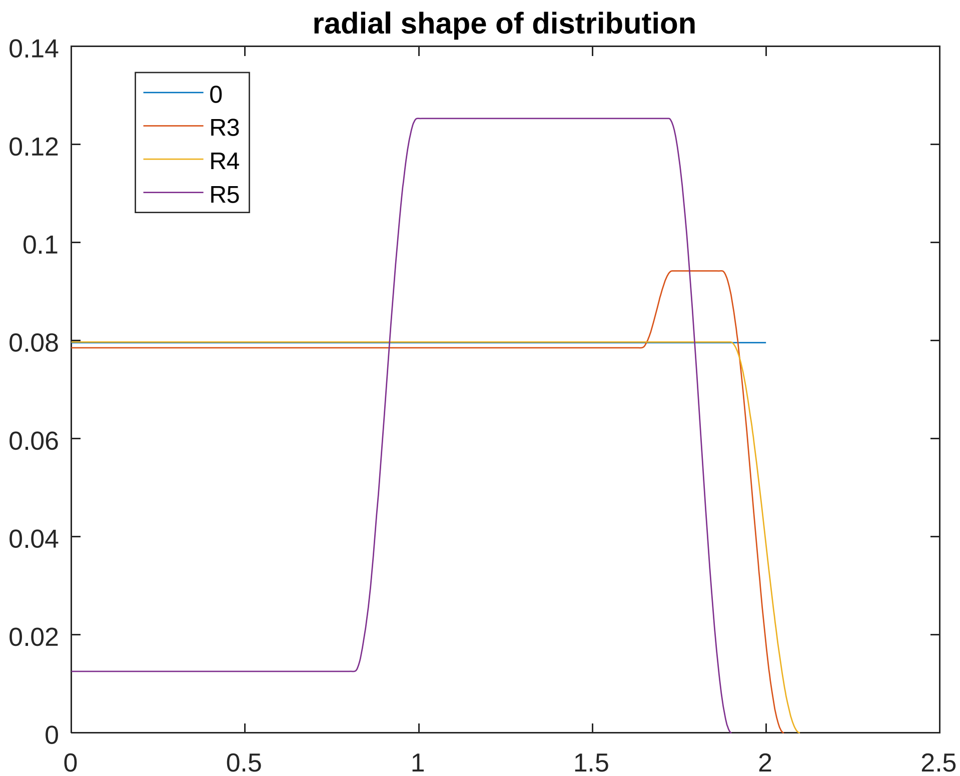


0 = hard uniform

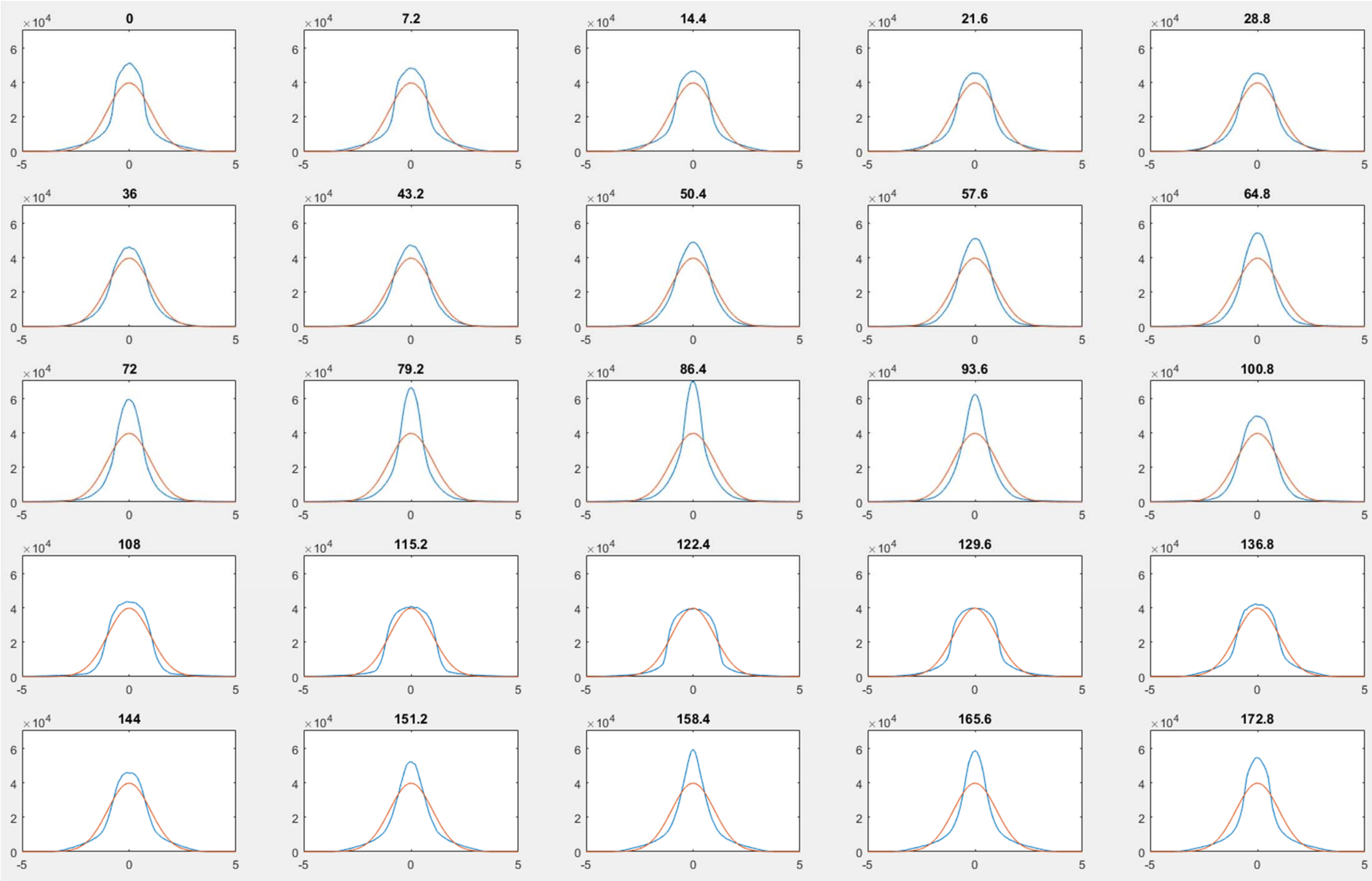
R3 = weak ring

R4 = soft uniform

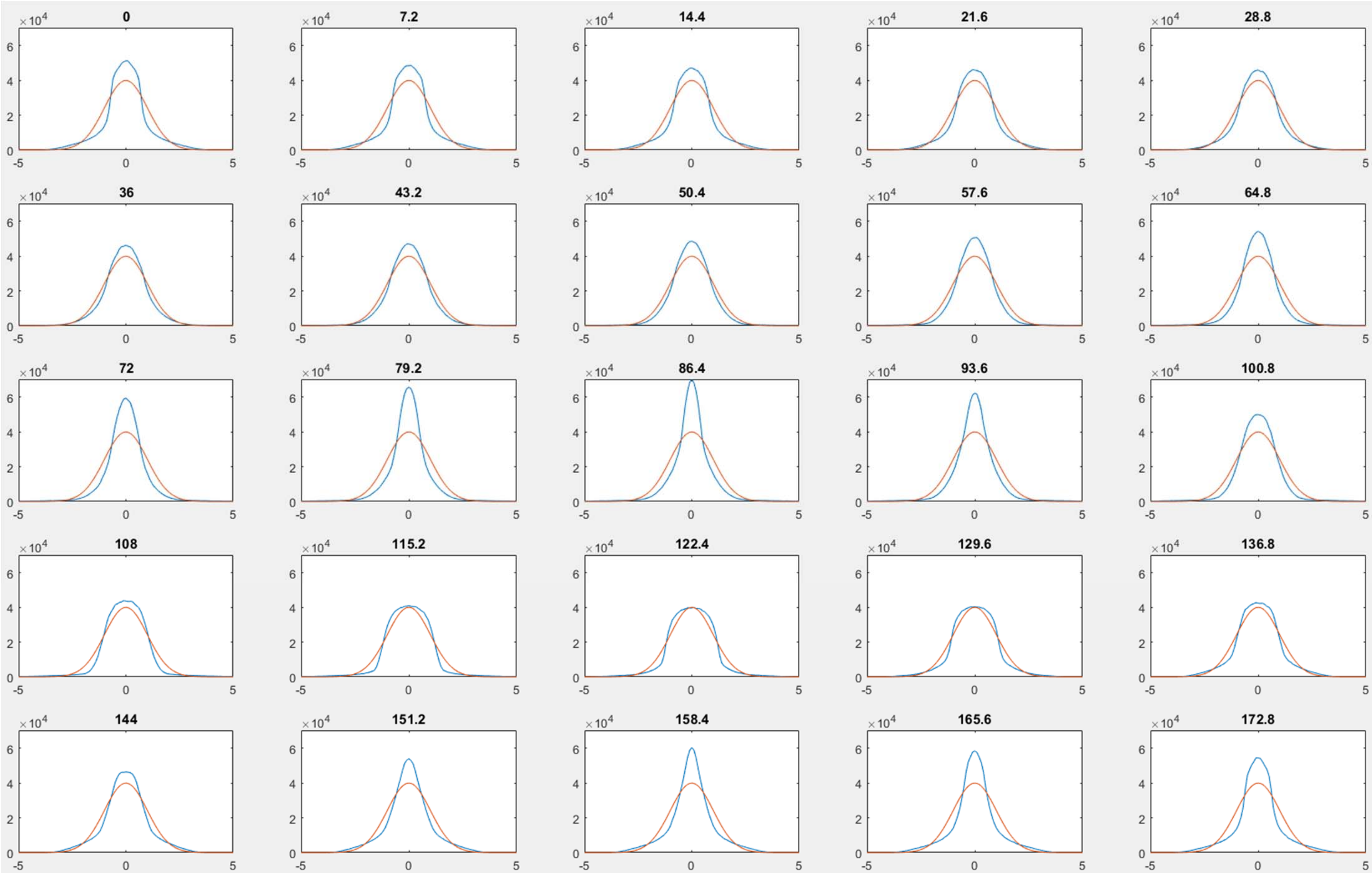
R5 = strong ring



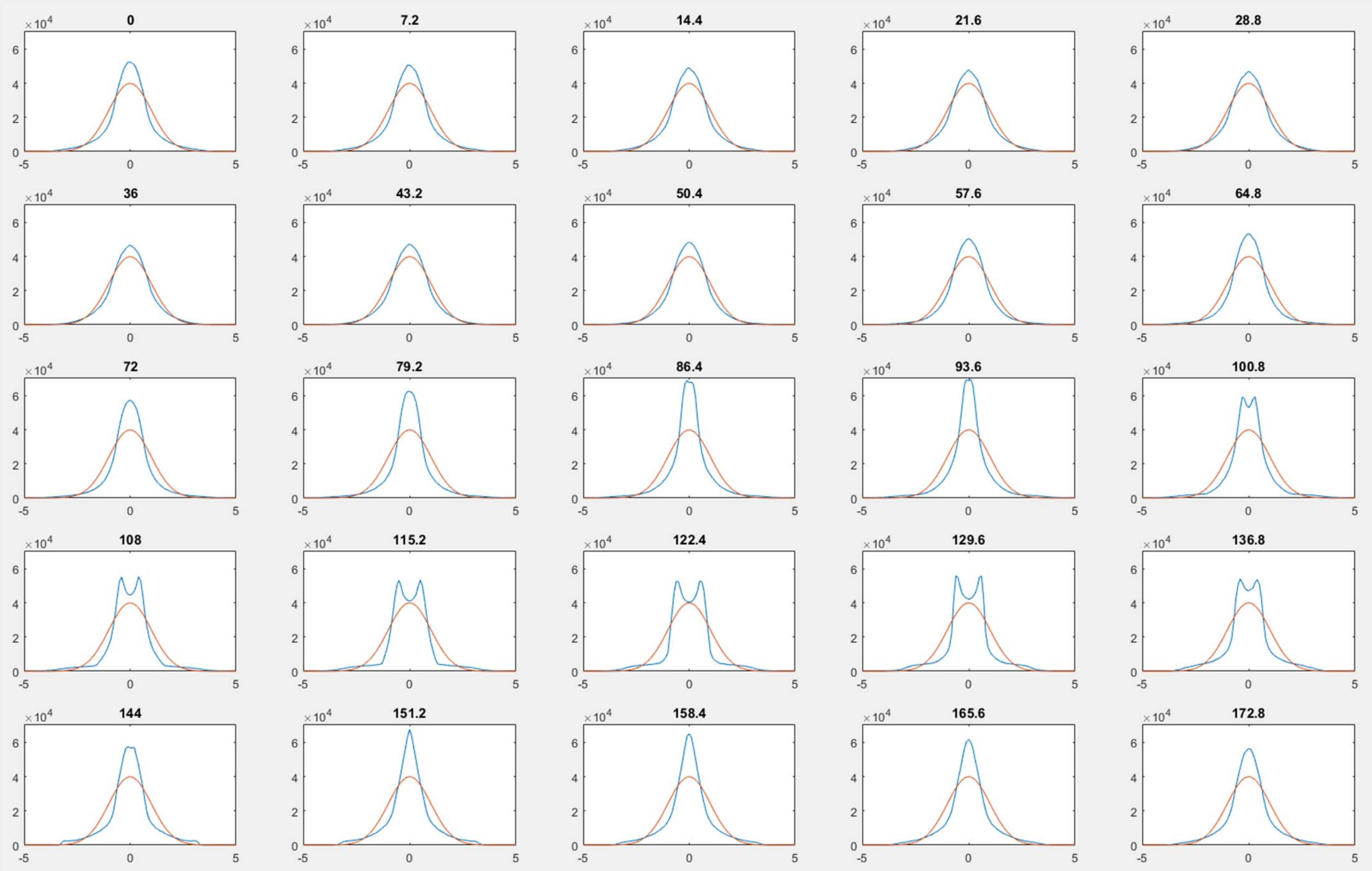
projections of horizontal (and vertical) phase space
ACC, R3 = weak ring



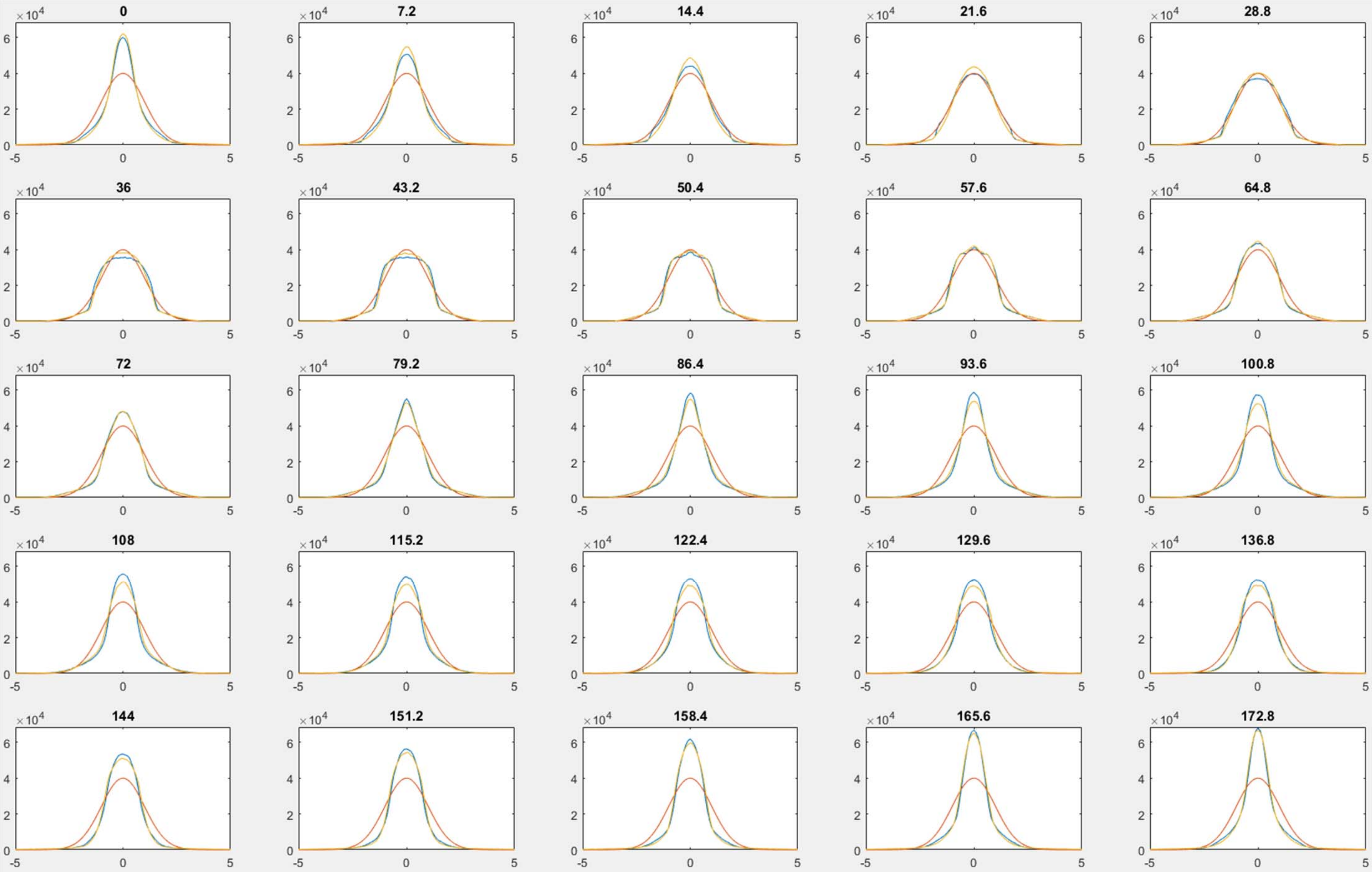
projections of horizontal (and vertical) phase space
ACC, R4 = soft uniform



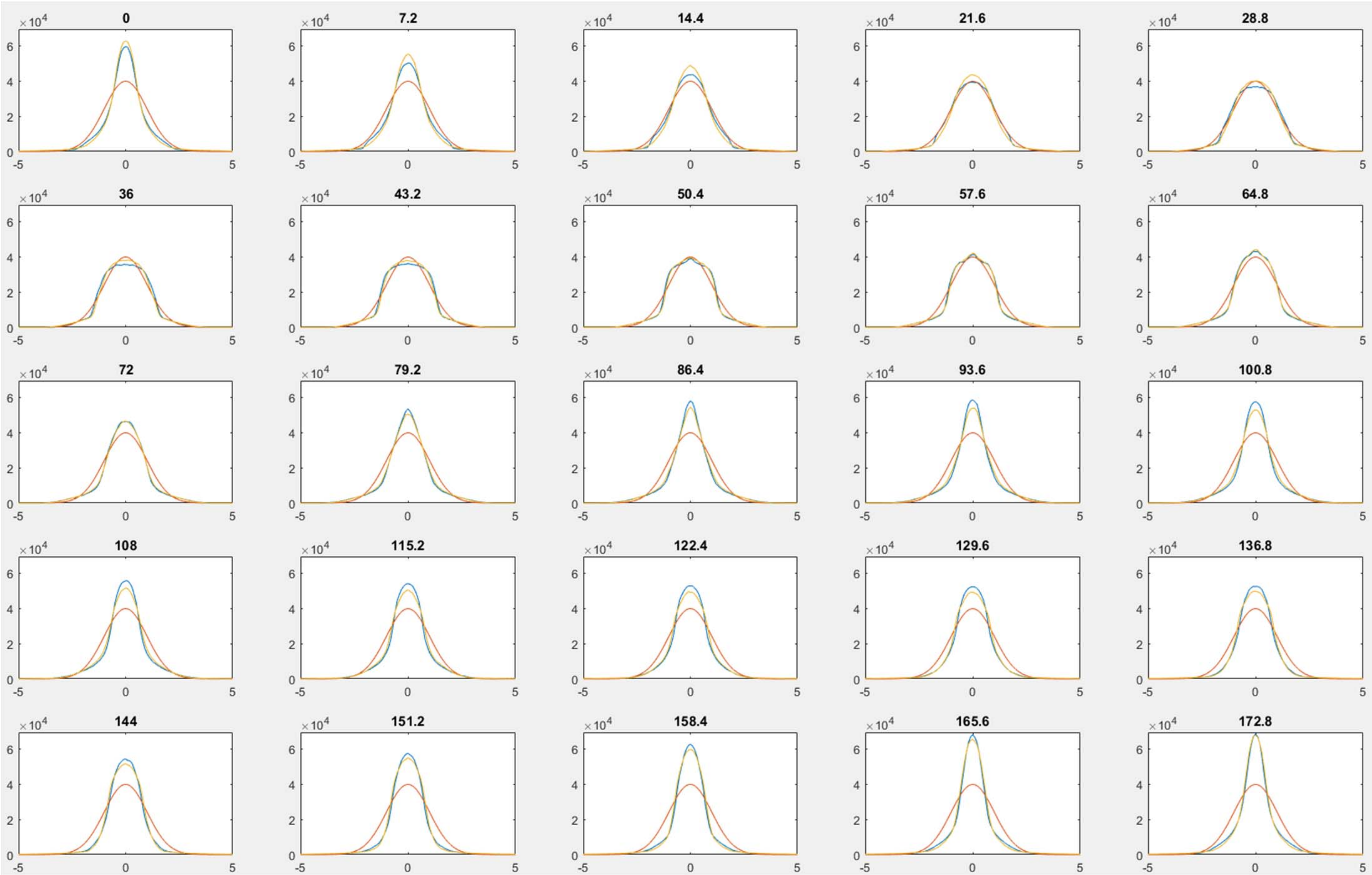
projections of horizontal (and vertical) phase space
ACC, R5 = strong ring



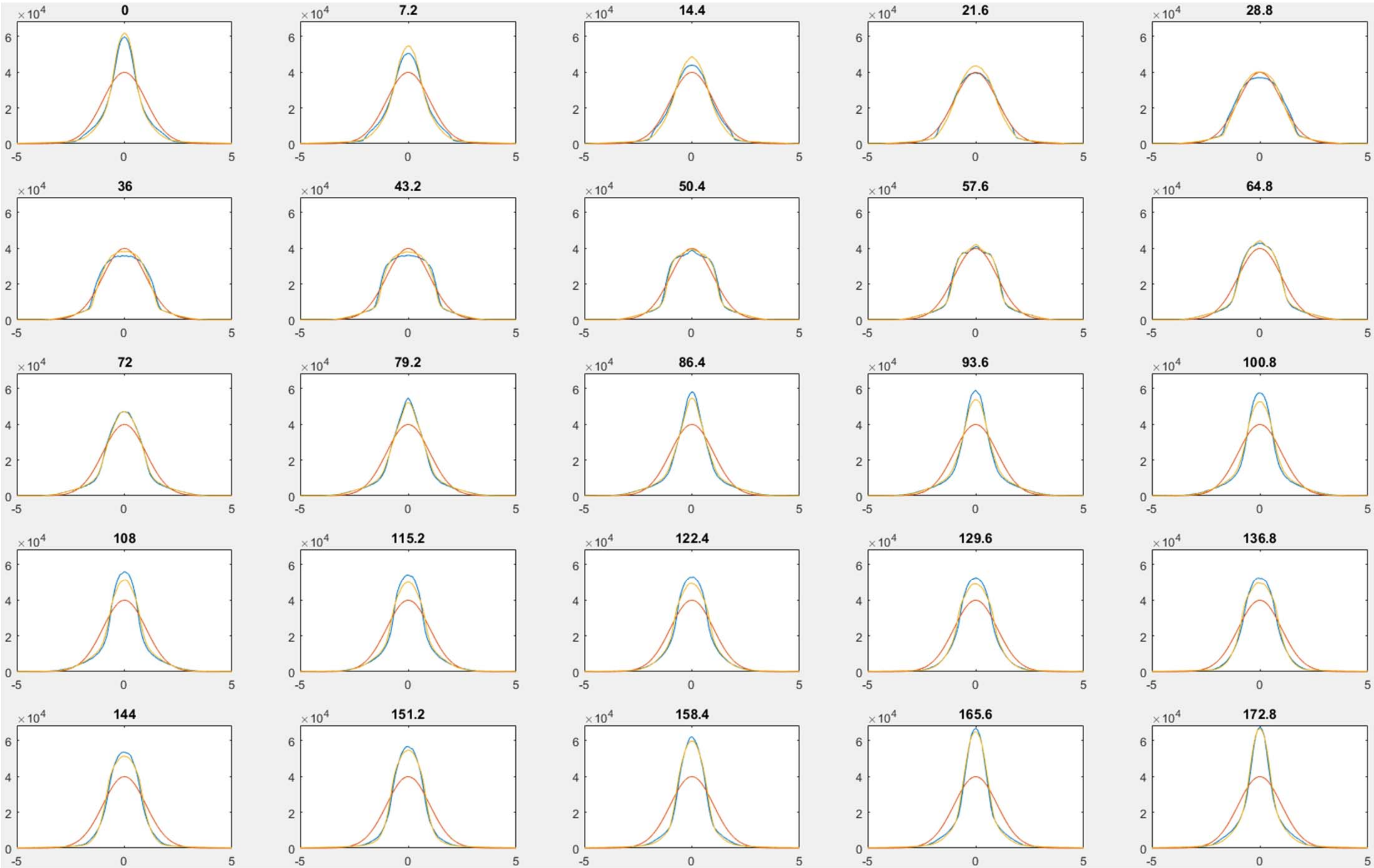
projections of horizontal and vertical phase space
OTR, 0 = hard uniform (f2 = f1-90)



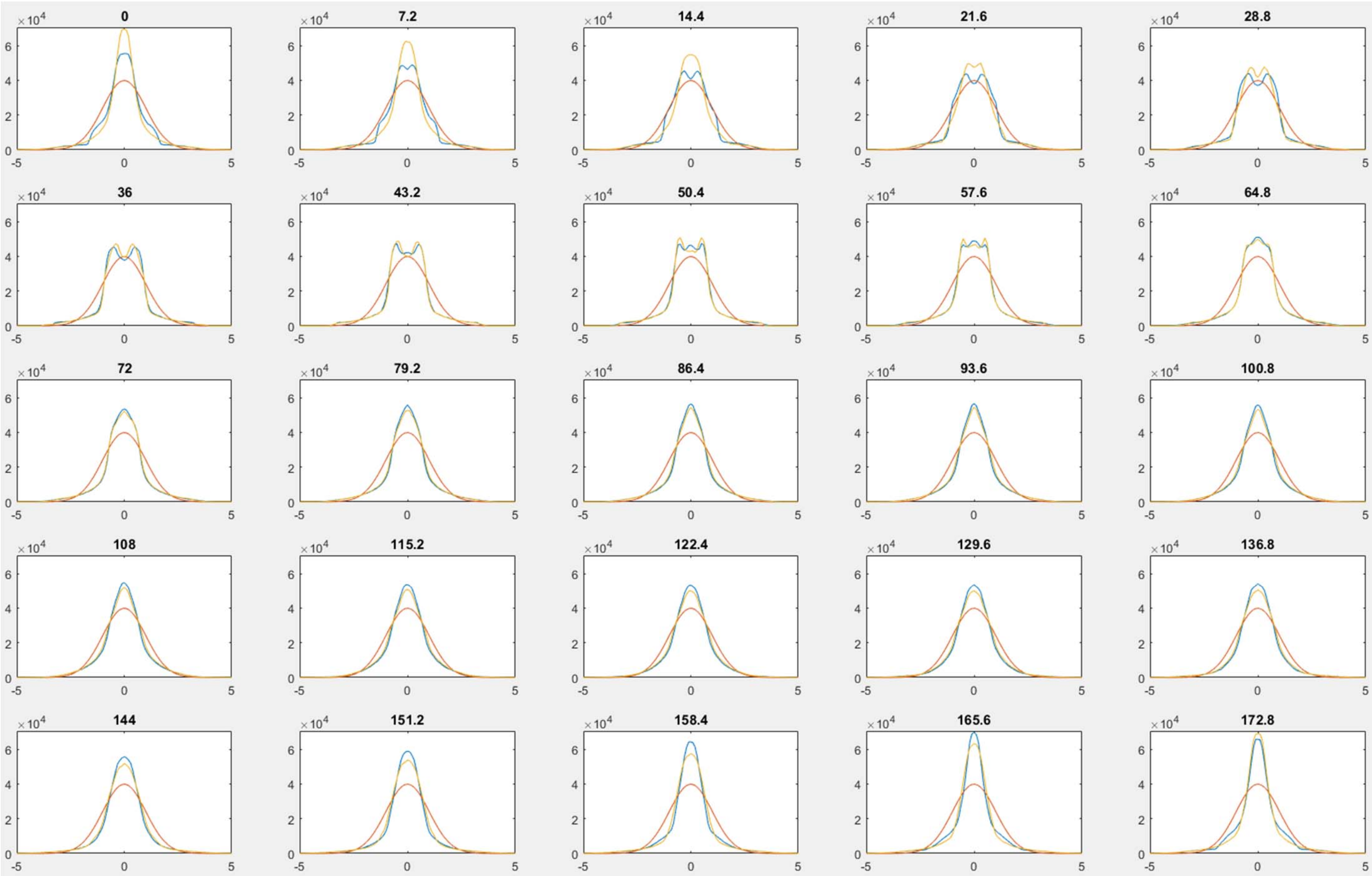
projections of horizontal and vertical phase space
OTR, R3 = weak ring



projections of horizontal and vertical phase space
OTR, R4 = soft uniform



projections of horizontal and vertical phase space
OTR, R5 = strong ring



projections of horizontal and vertical phase space
OTR, 0 = hard uniform, with spatial dependent part of CK (f2 = f1-90)