

Study of Crab-Waist Scheme

Y. Ohnishi

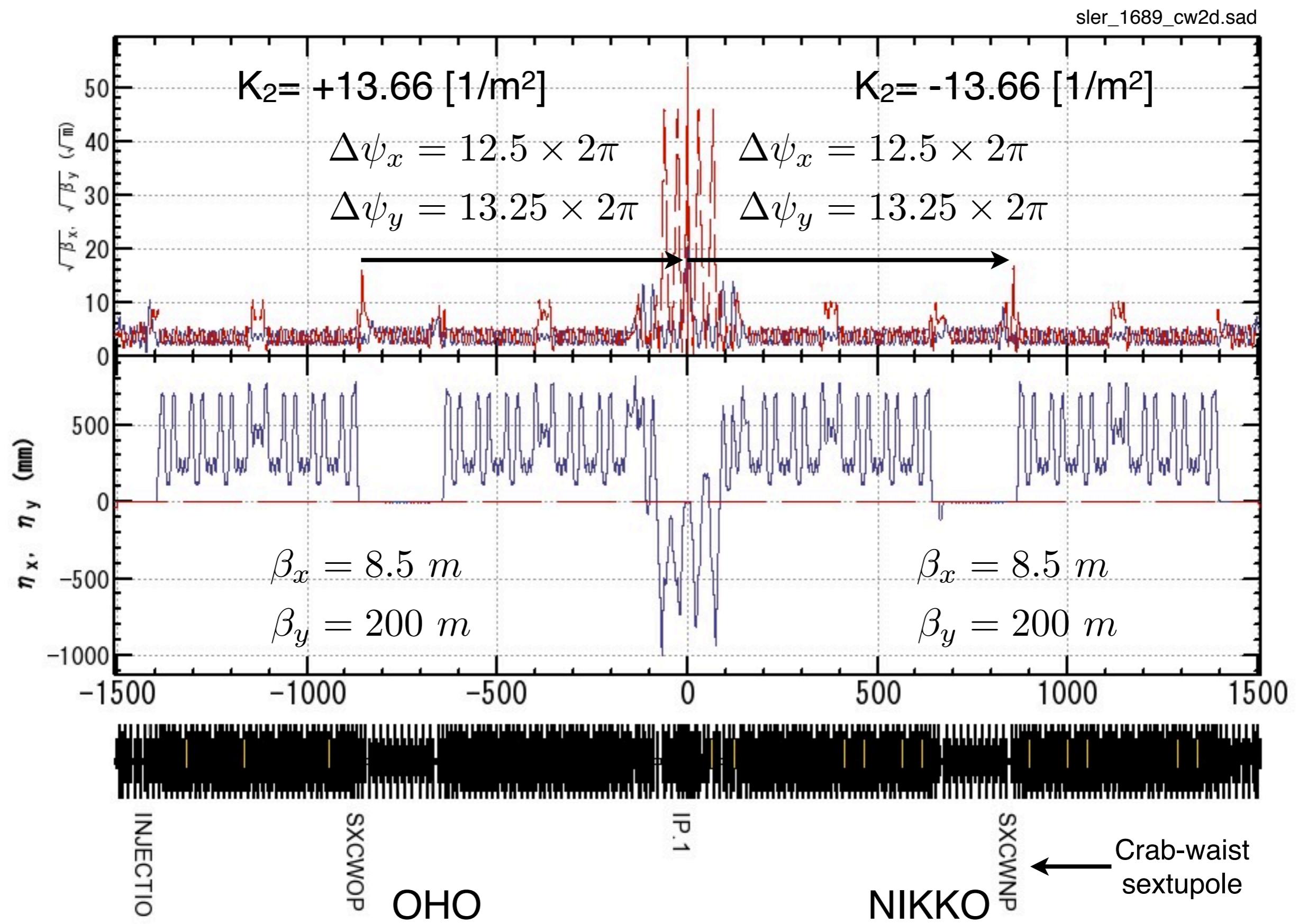
	LER	Unit
Emittance	3.2	nm
Horizontal Beta at IP	32	mm
Vertical Beta at IP	0.270	mm
Half crossing angle	41.5	mrad
Horizontal Beta at crab-waist sextupole	8.5	m
Vertical Beta at crab-waist sextupole	200	m
Horizontal phase advance between IP and crab-waist sextupole	25π	rad
Vertical phase advance between IP and crab-waist sextupole	26.5π	rad
Nominal $ K_2 $ for crab-waist sextupole	13.66	$1/m^2$

$$|K_2| = \frac{1}{\tan 2\phi_x \beta_{y,s} \beta_y^*} \sqrt{\frac{\beta_x^*}{\beta_{x,s}}}$$

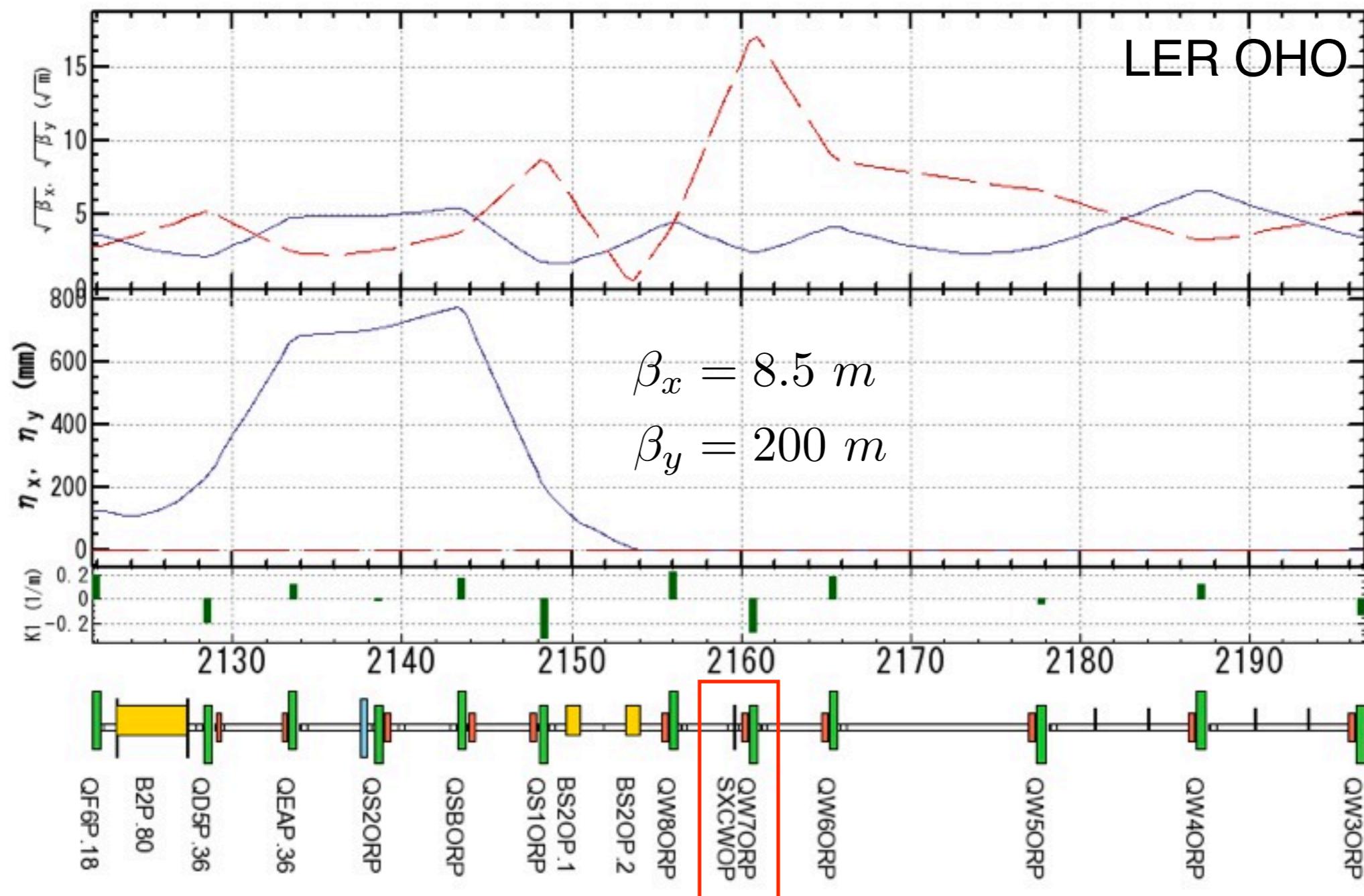
$$H_s = c_3 x^{*3} + c_{cw} x^* p_y^{*2}$$

$$|c_3| = 9854$$

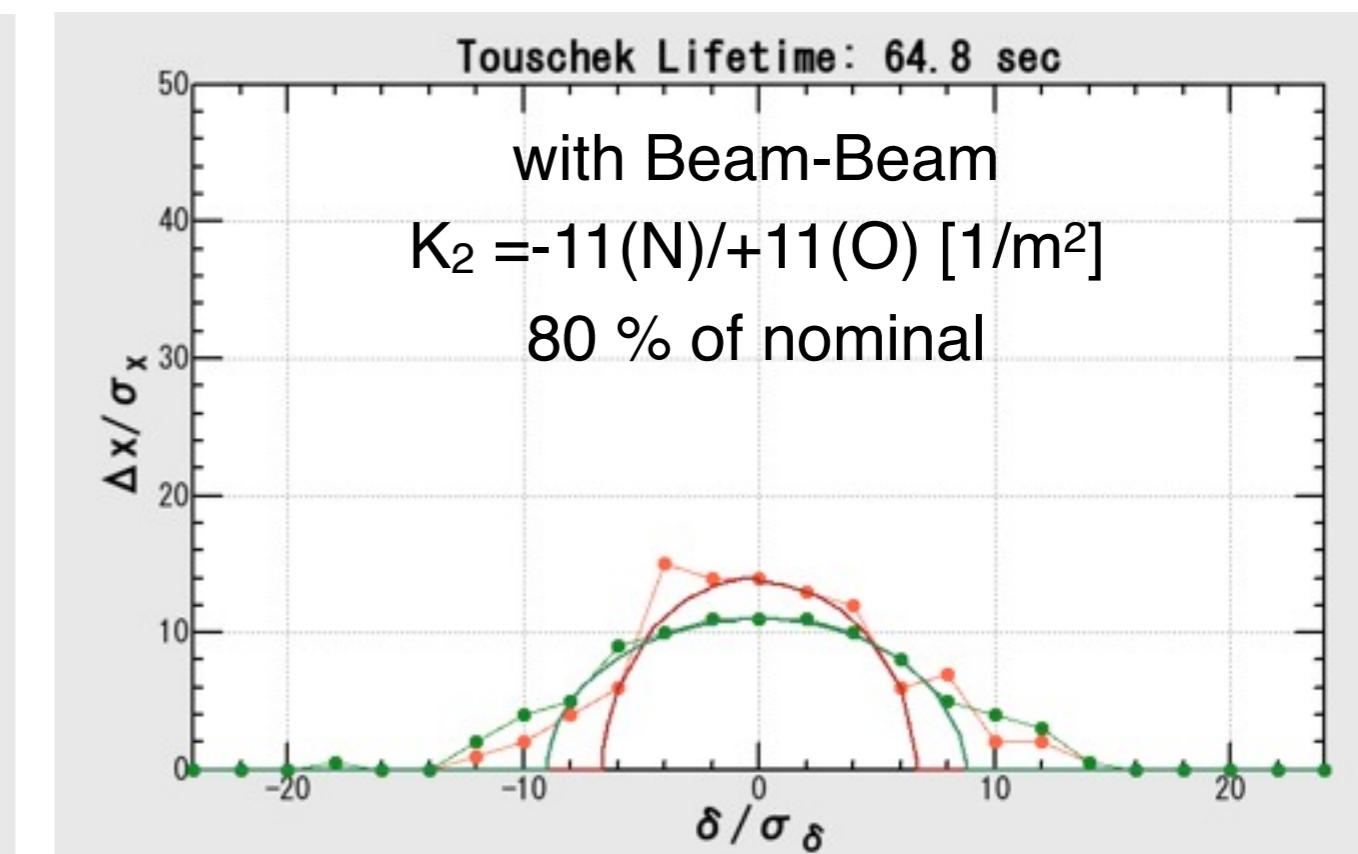
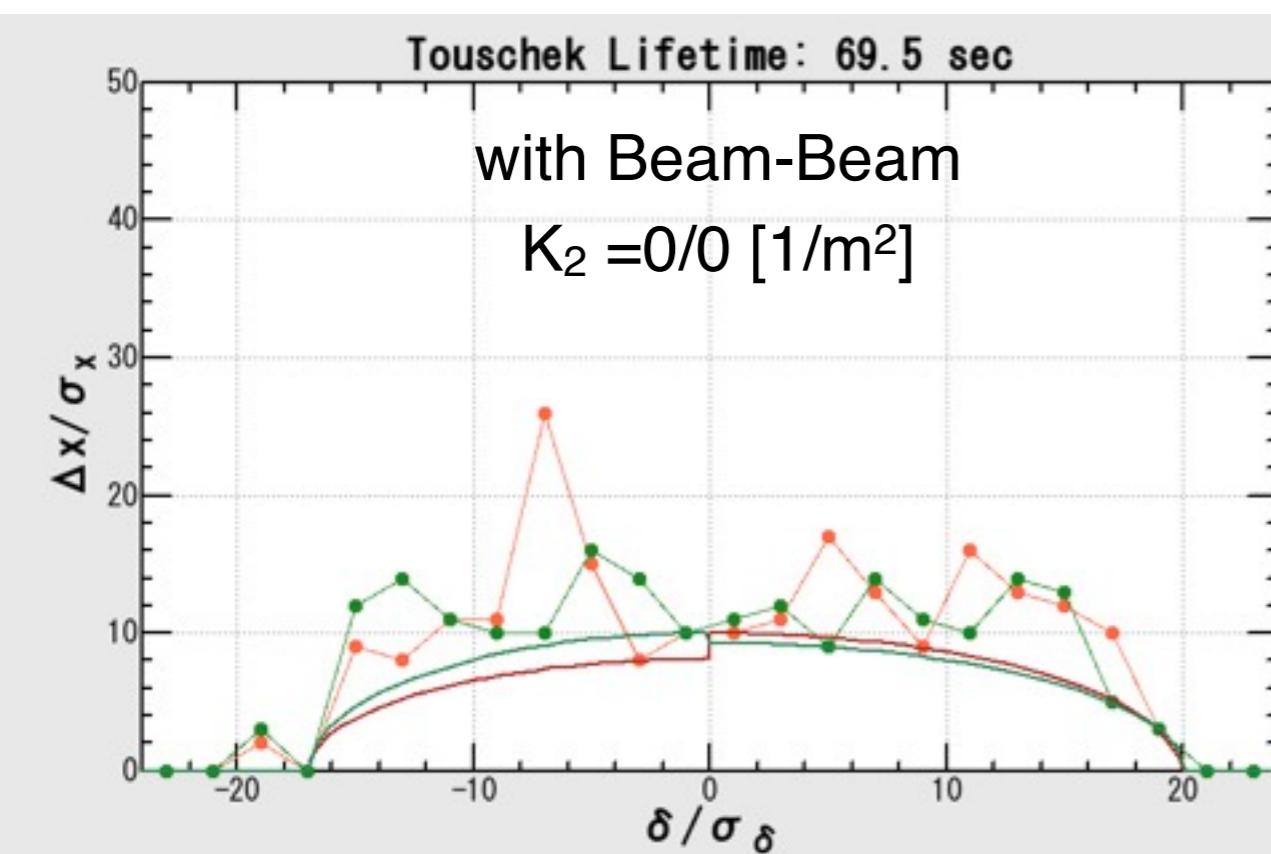
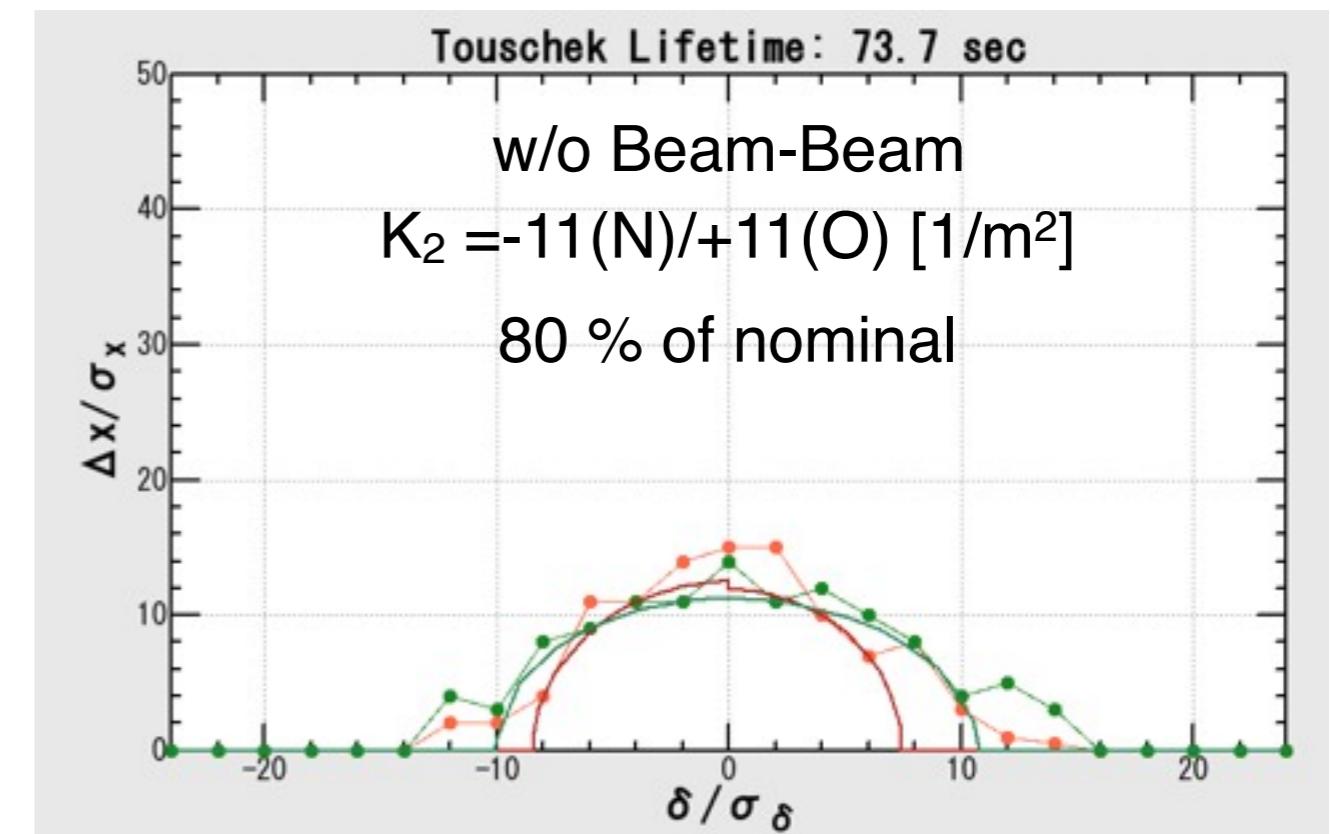
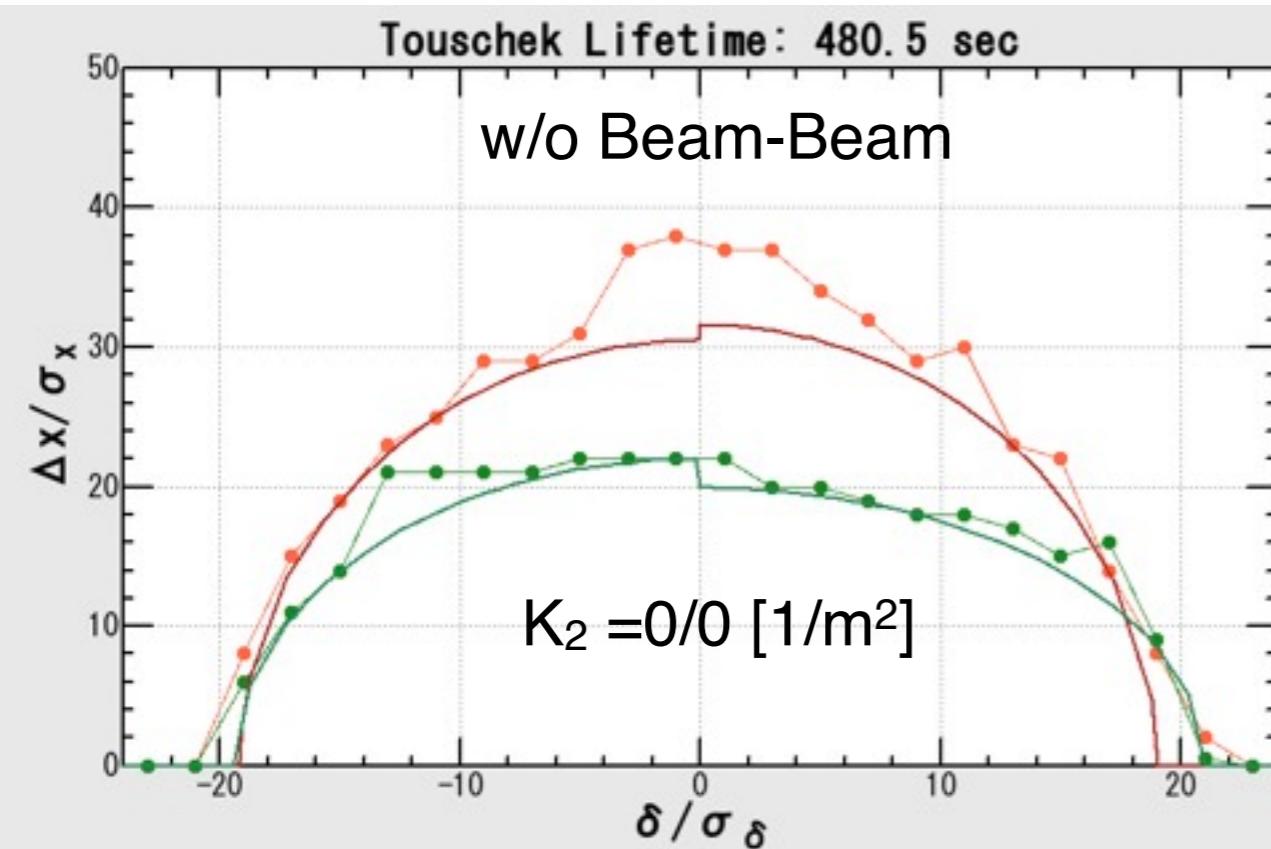
$$|c_{cw}| = 6$$



Crab-Waist sextupole: SXCWOP/SXCWNP (thin lens)



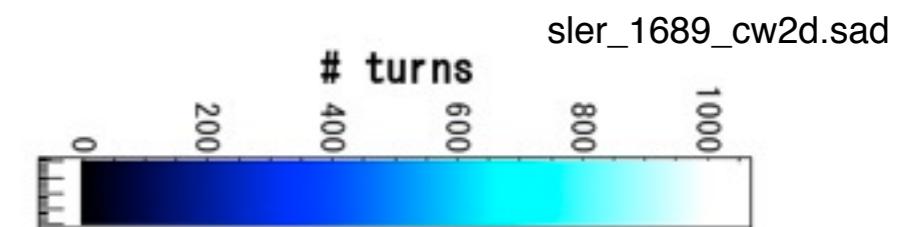
QS1OP, QSBOP, QS2OP -> (QS1OP, QSBOP, QS2OP) and (QS1OLP, QSBOLP, QS2OLP)
 Add 3 magnet power supplies for each.



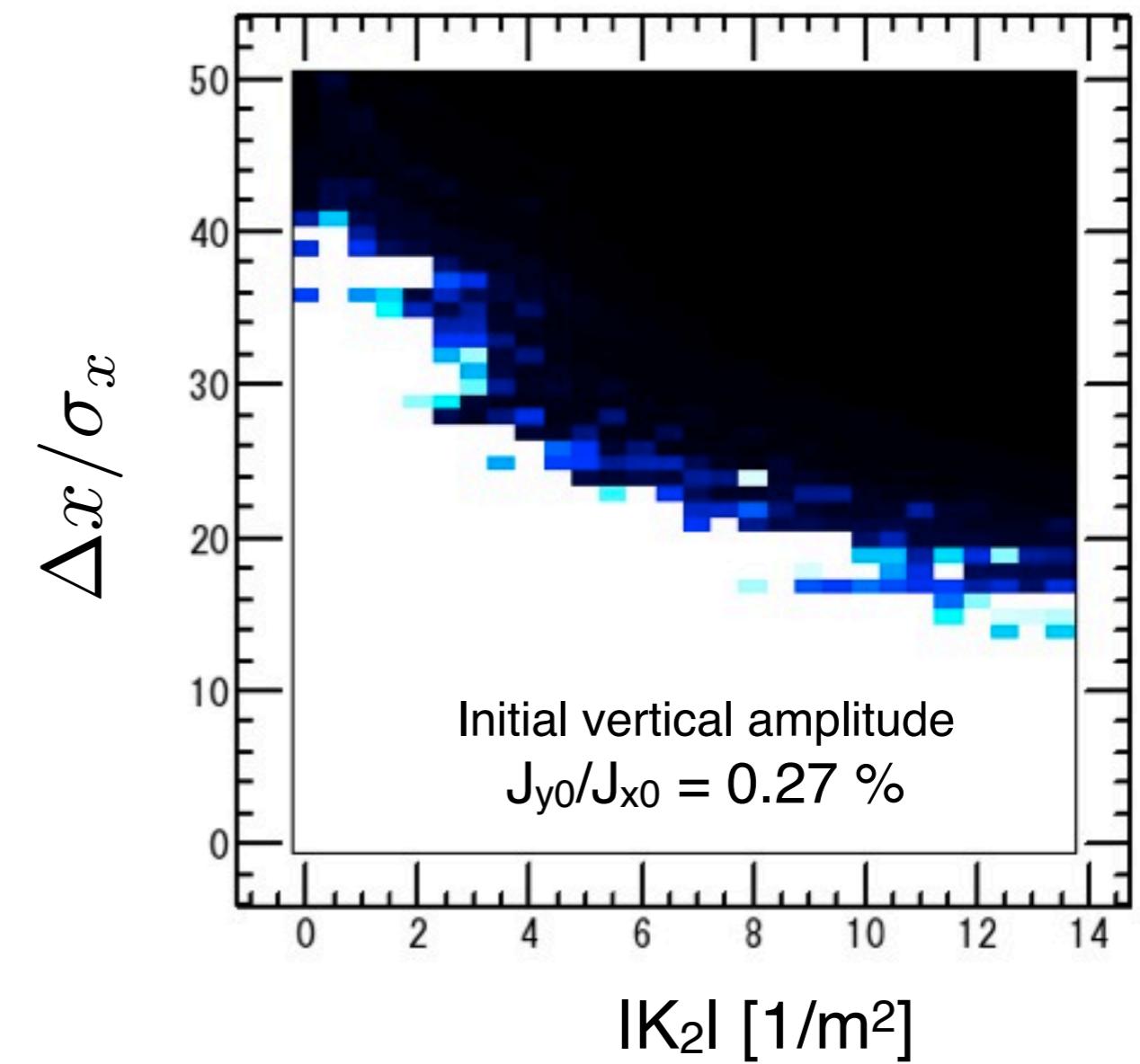
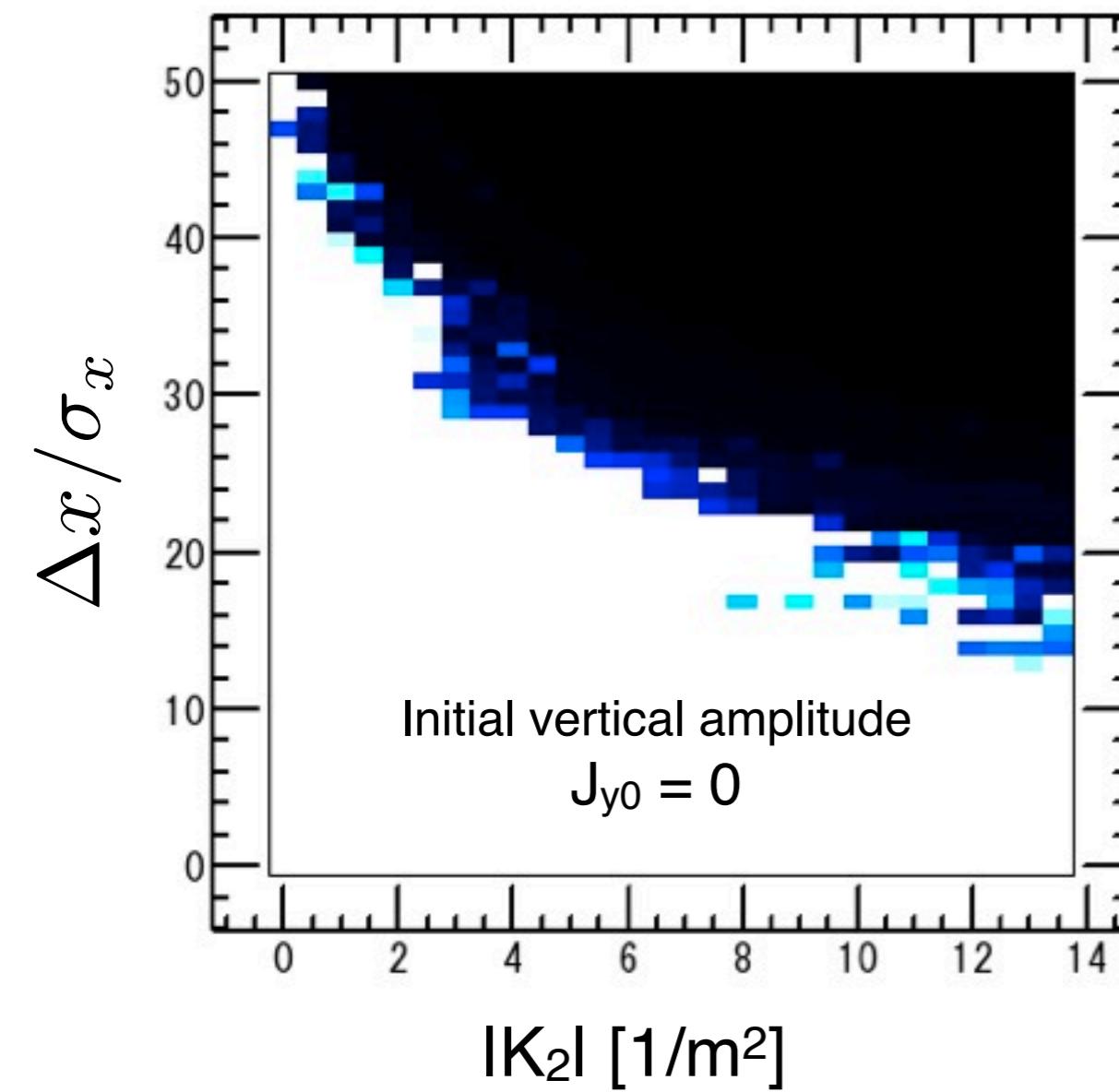
Transverse Aperture for Crab-Waist Scheme

Initial momentum deviation

$$\delta_0 = \Delta p / p_0 = 0$$



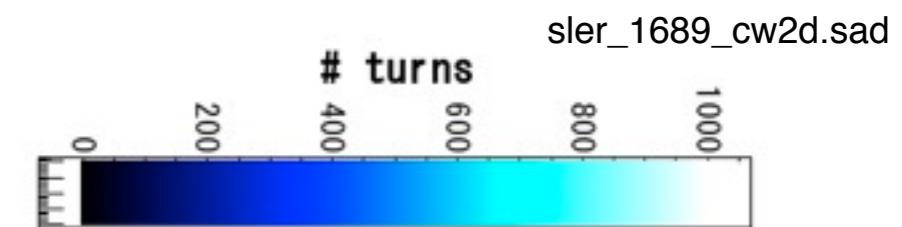
without Beam-Beam



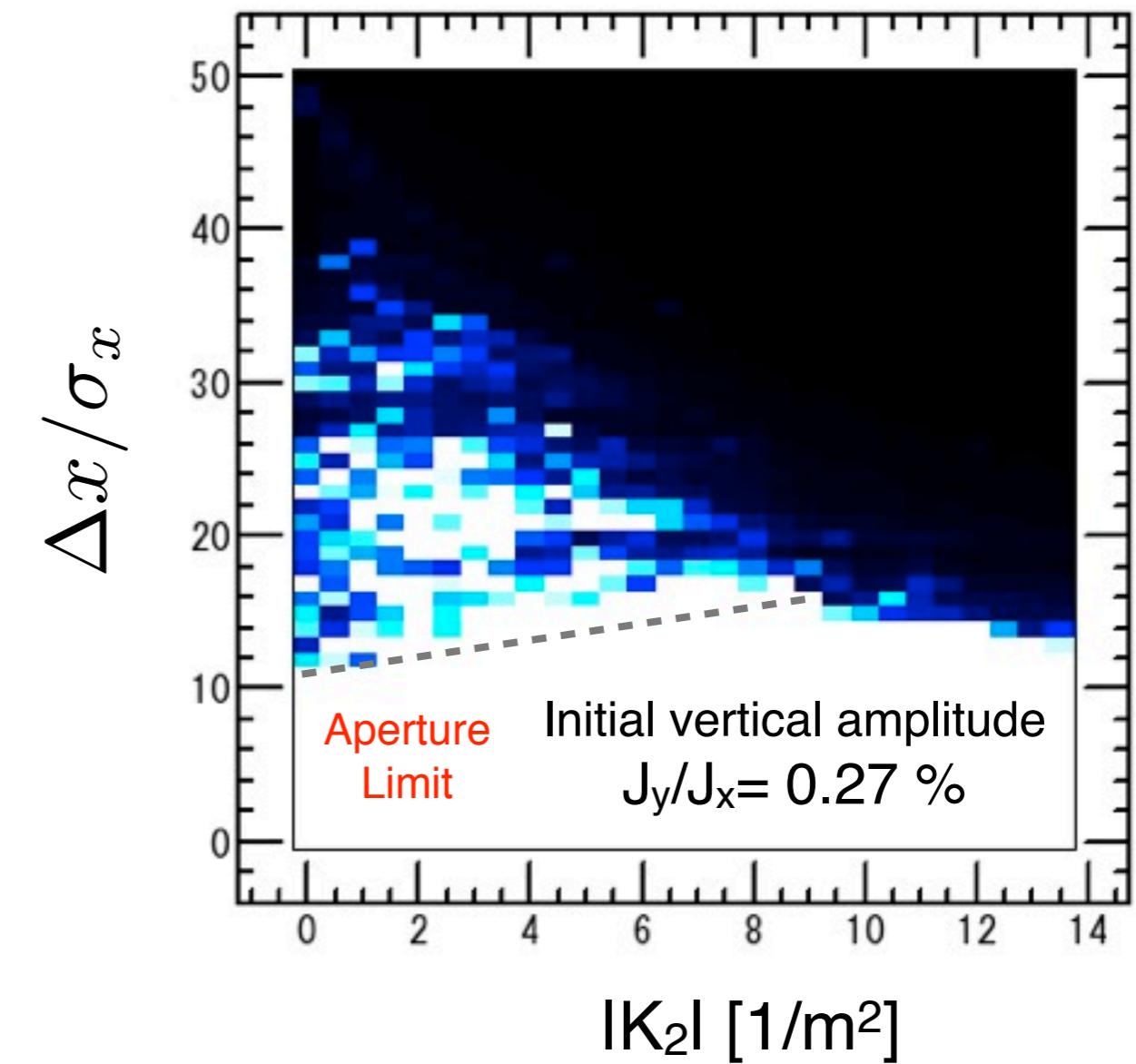
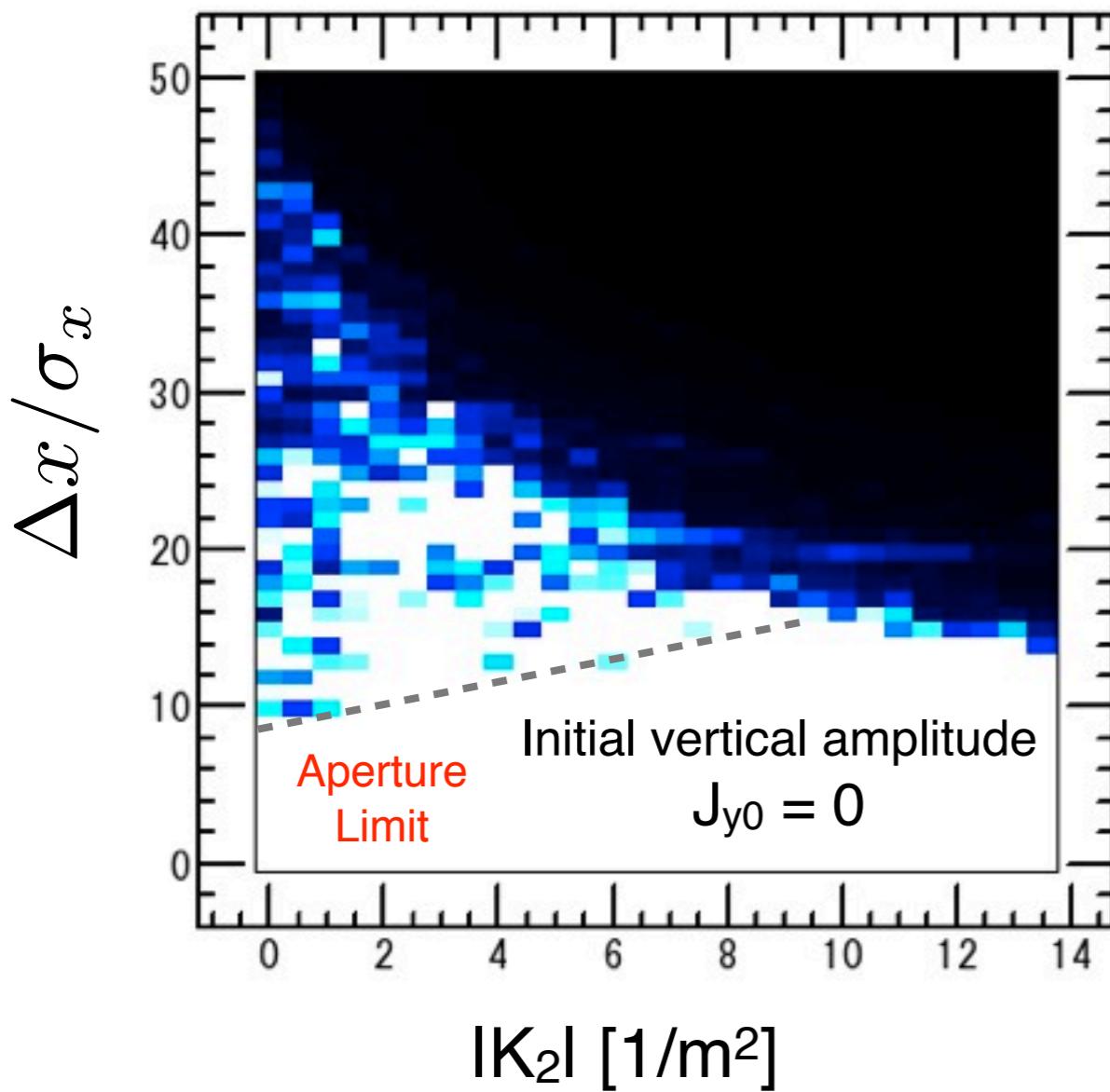
Transverse Aperture for Crab-Waist Scheme

Initial momentum deviation

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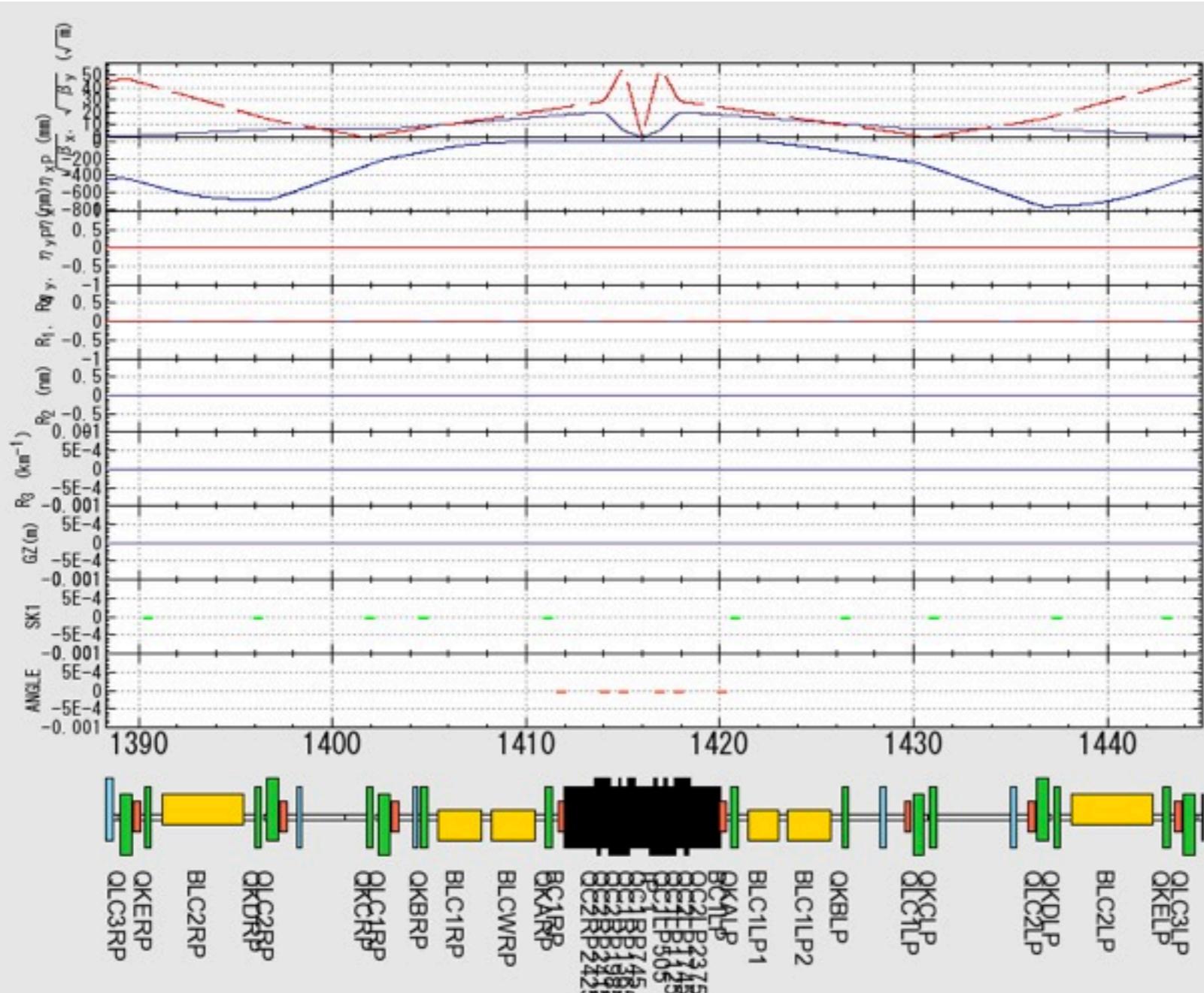


with Beam-Beam



No X-Y coupling and No vertical dispersion in IR

sler_1689_cw3_5e.sad



- No solenoid ($ES^* BZ = 0$)
- No offset of quads
- $Z\{HV\}QC^* K0 = 0$
- No skew sextupole field
- No higher order multipoles for $EC^*/QC\{12\}^*$
- No octupole field

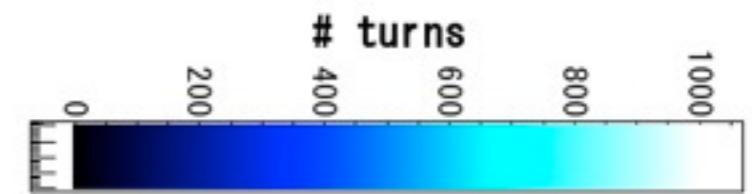
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{ -8.E-17, -6.E-15, -1.0000, 2.8E-11},
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Simple IR for Crab-Waist Scheme

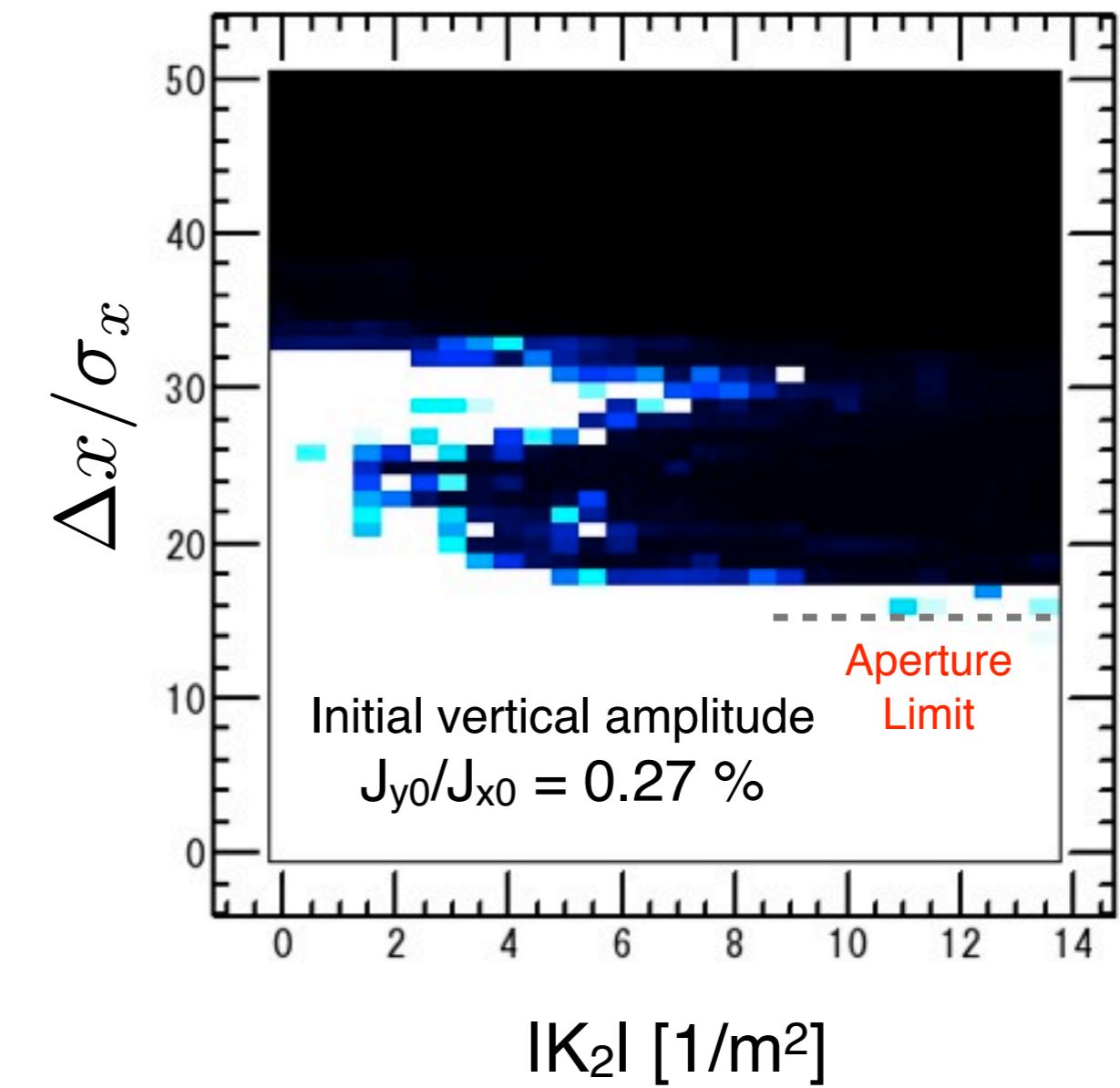
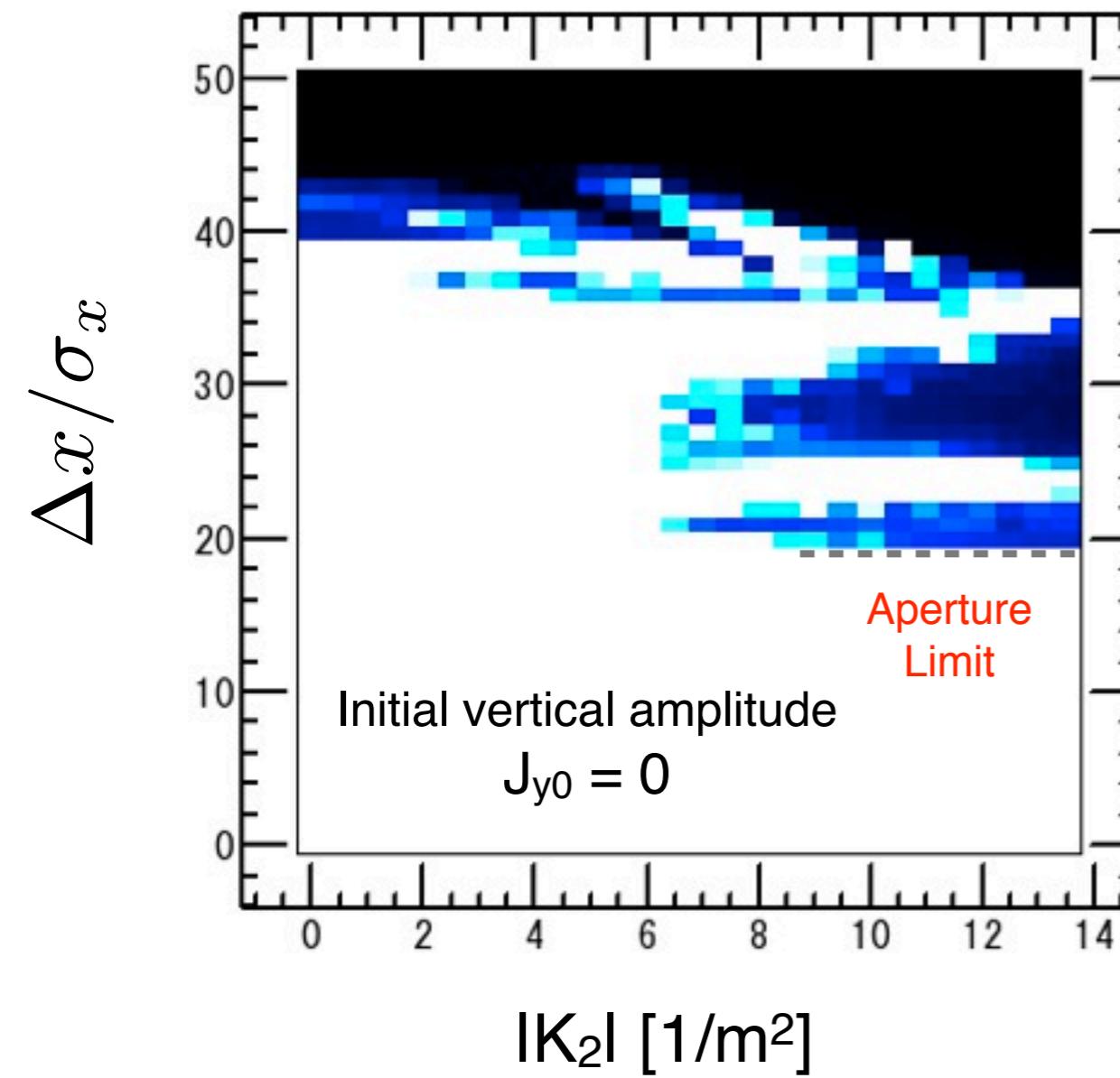
slr_1689_cw3_5e.sad

Initial momentum deviation

$$\delta_0 = \Delta p / p_0 = 0$$

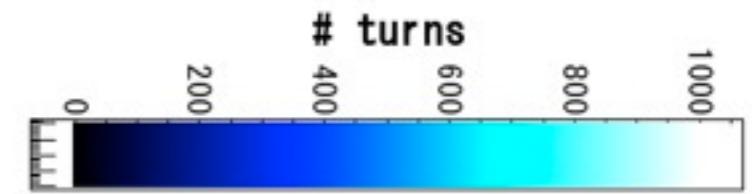


Simple IR optics w/o Beam-Beam

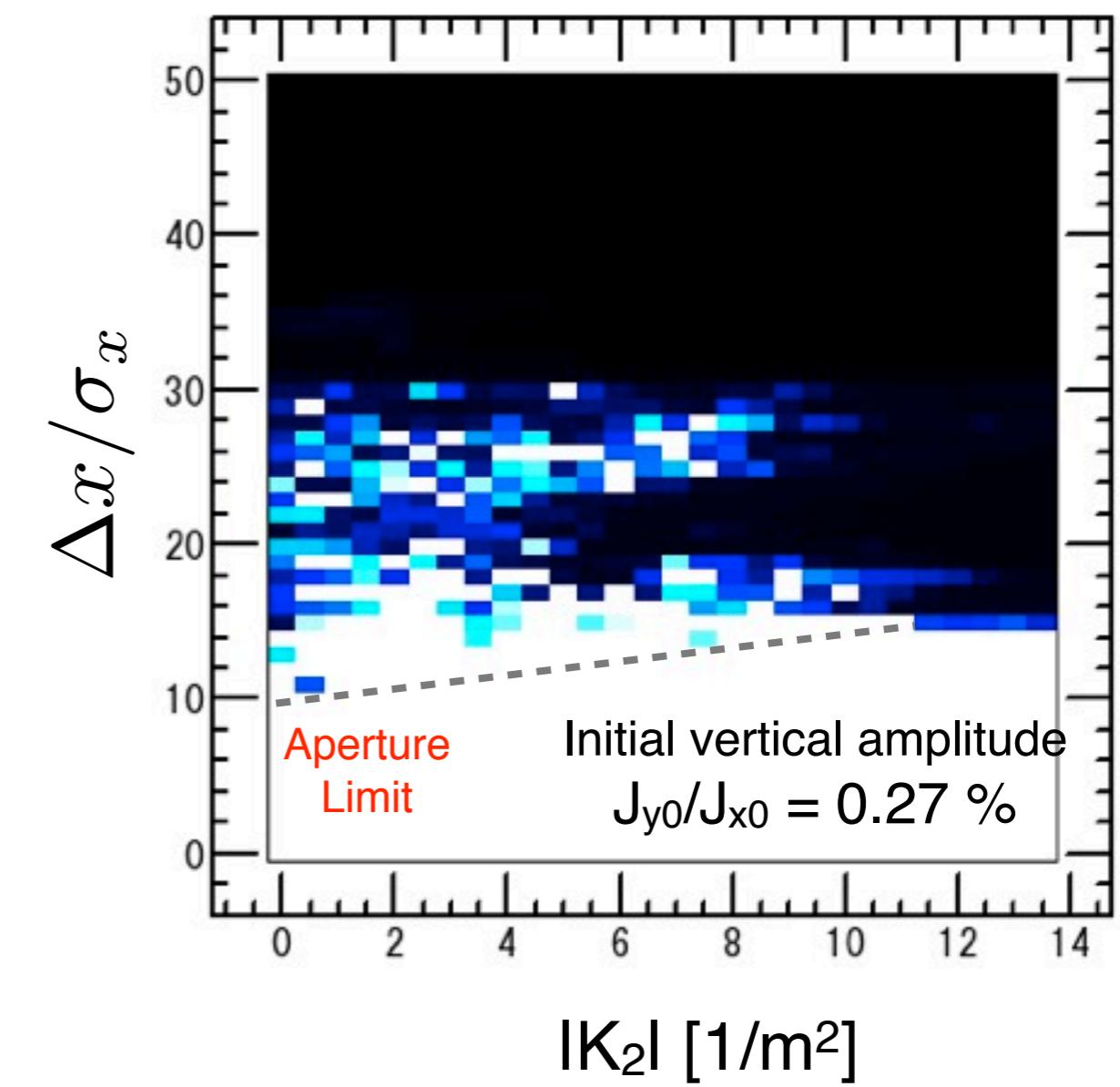
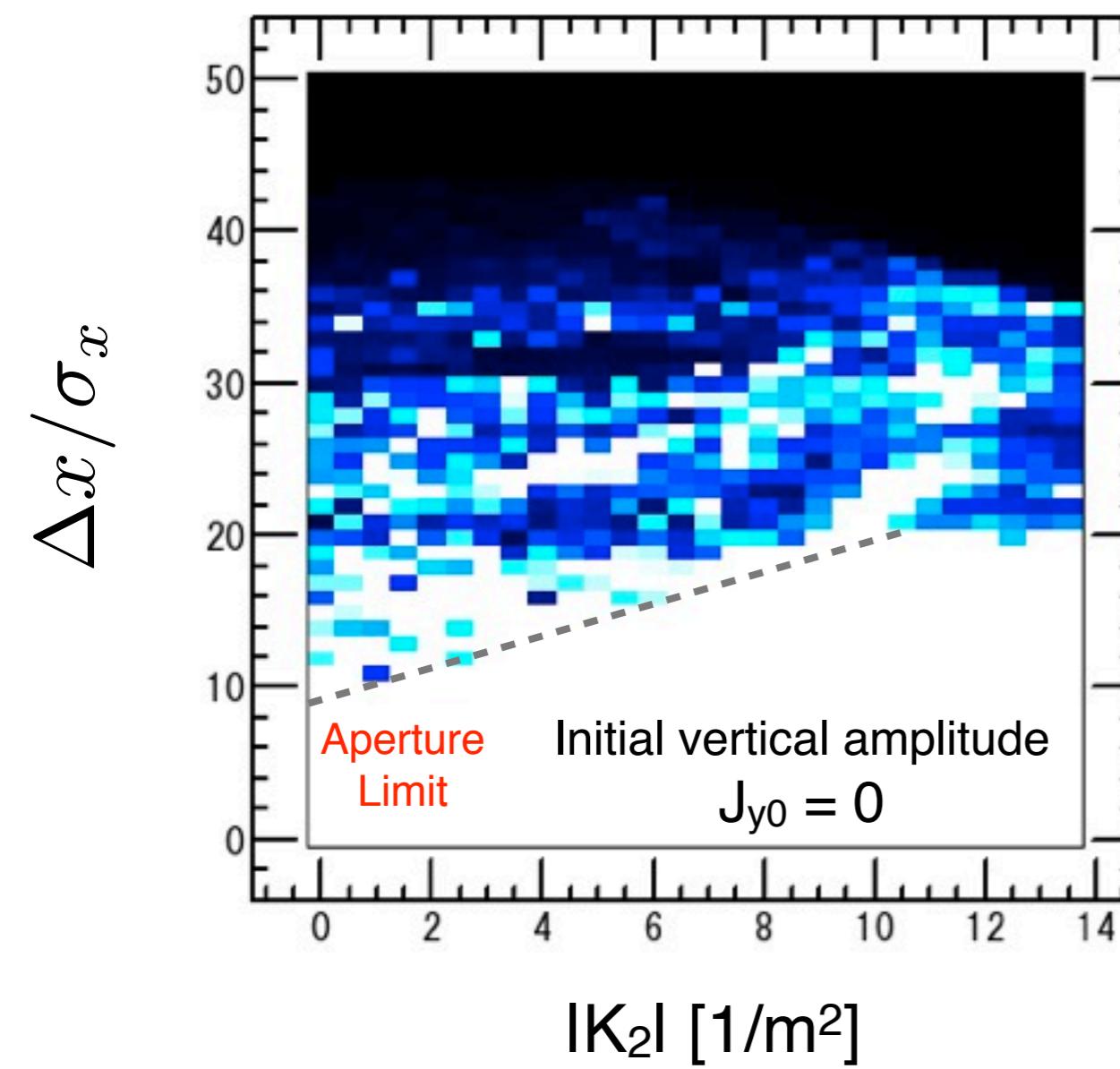


Initial momentum deviation

$$\delta_0 = \Delta p / p_0 = 0$$



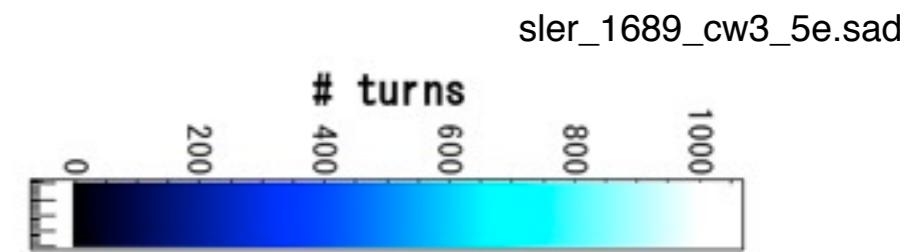
Simple IR optics with Beam-Beam



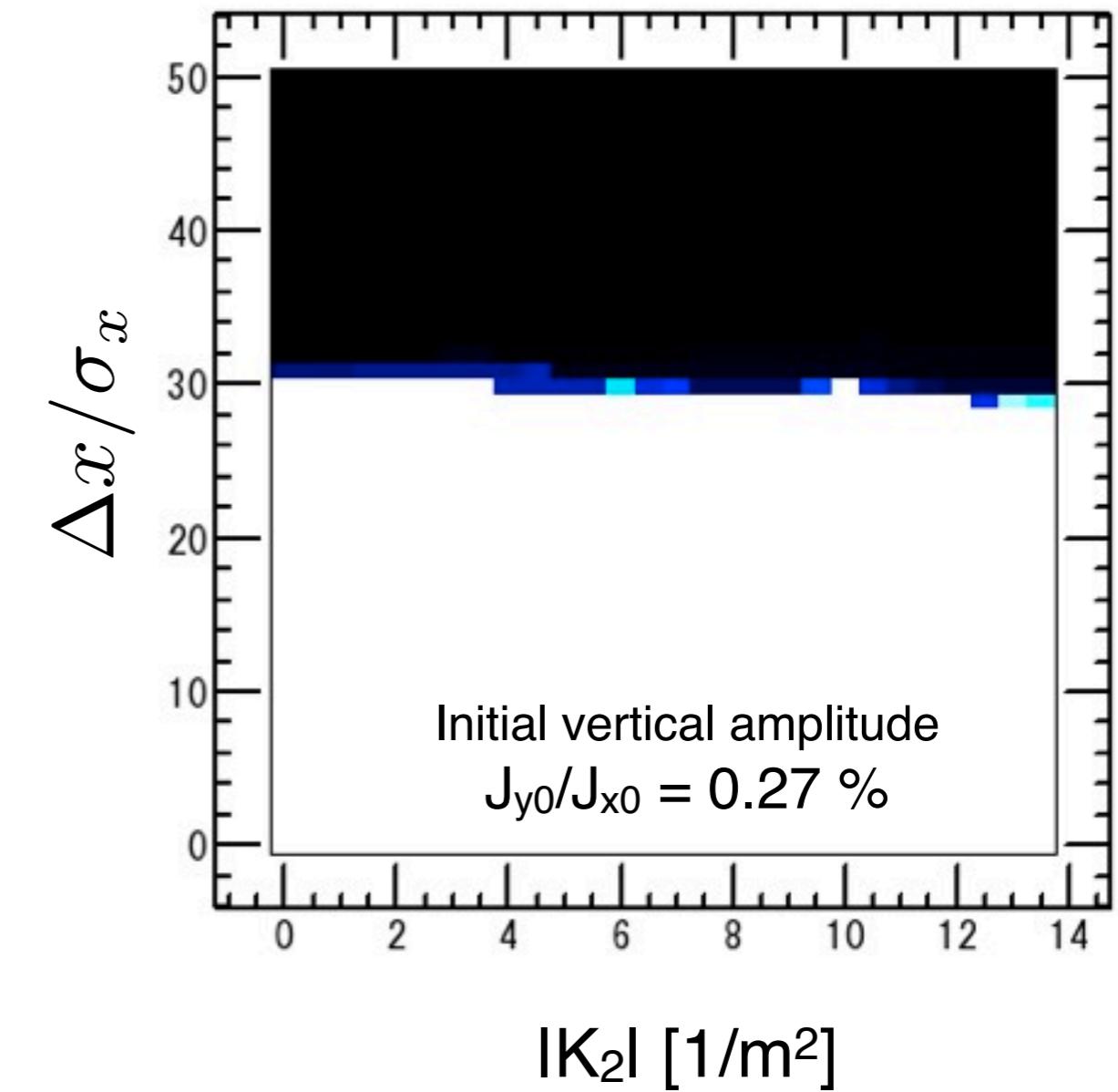
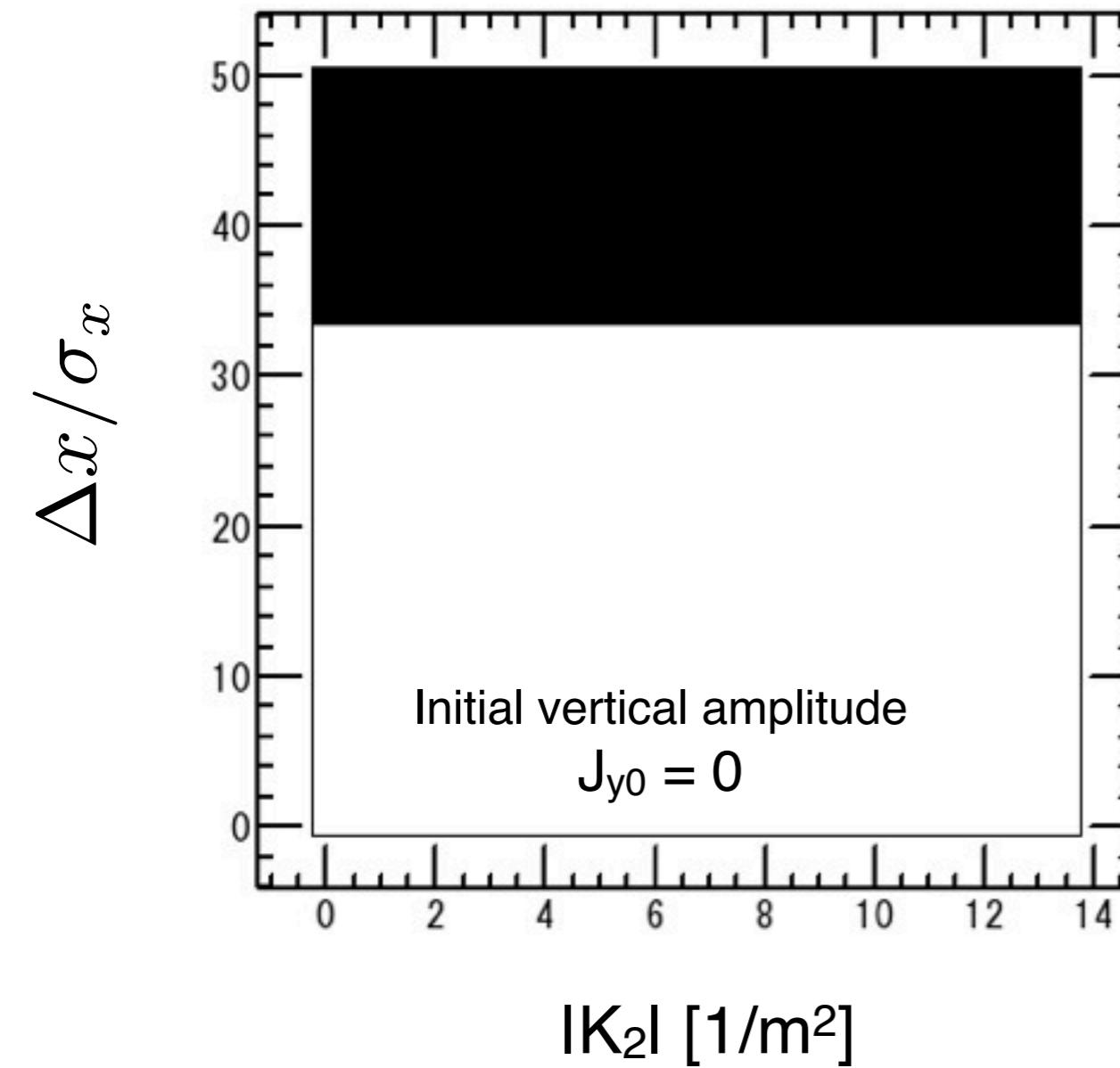
w/o nonlinear Maxwellian fringe for QC1/QC2

Initial momentum deviation

$$\delta_0 = \Delta p / p_0 = 0$$



Simple IR optics w/o Beam-Beam

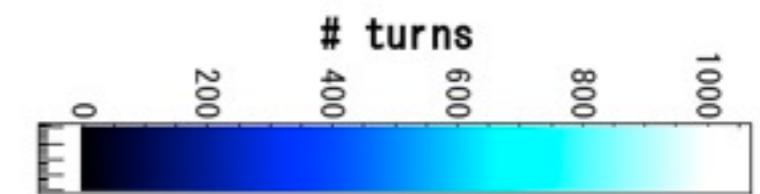


w/o nonlinear Maxwellian fringe for QC1/QC2

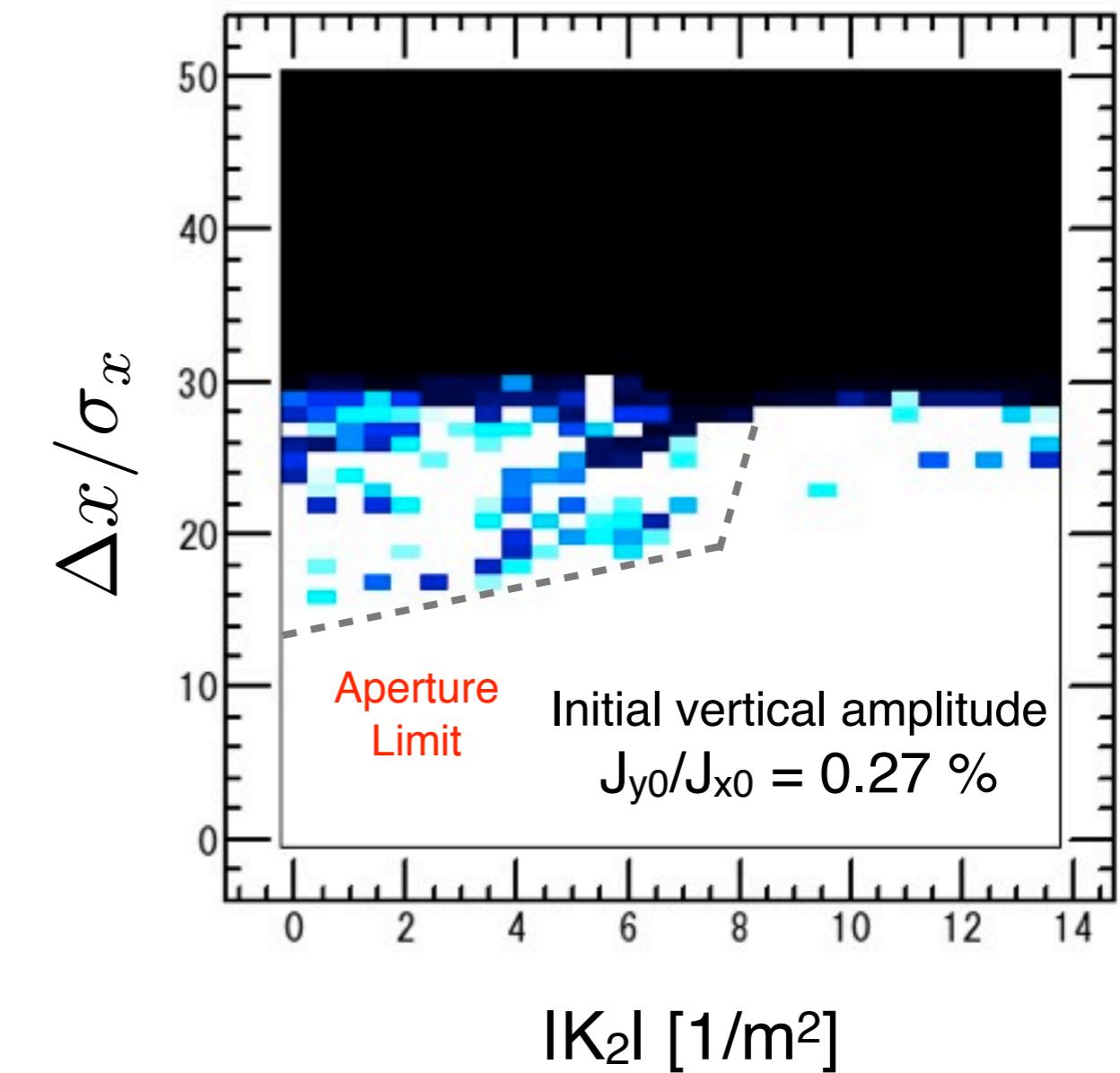
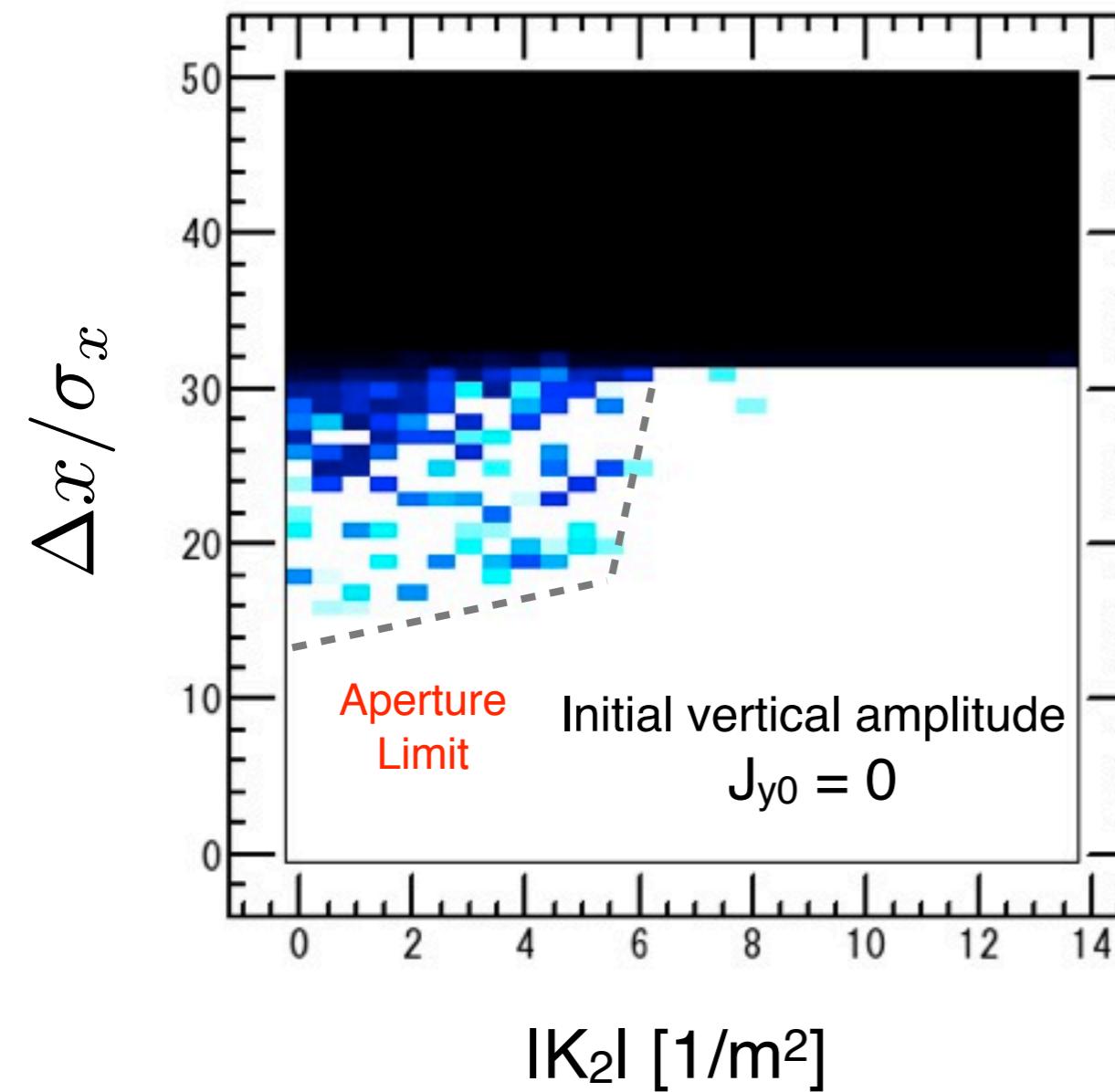
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Initial momentum deviation

$$\delta_0 = \Delta p / p_0 = 0$$



Simple IR optics with Beam-Beam

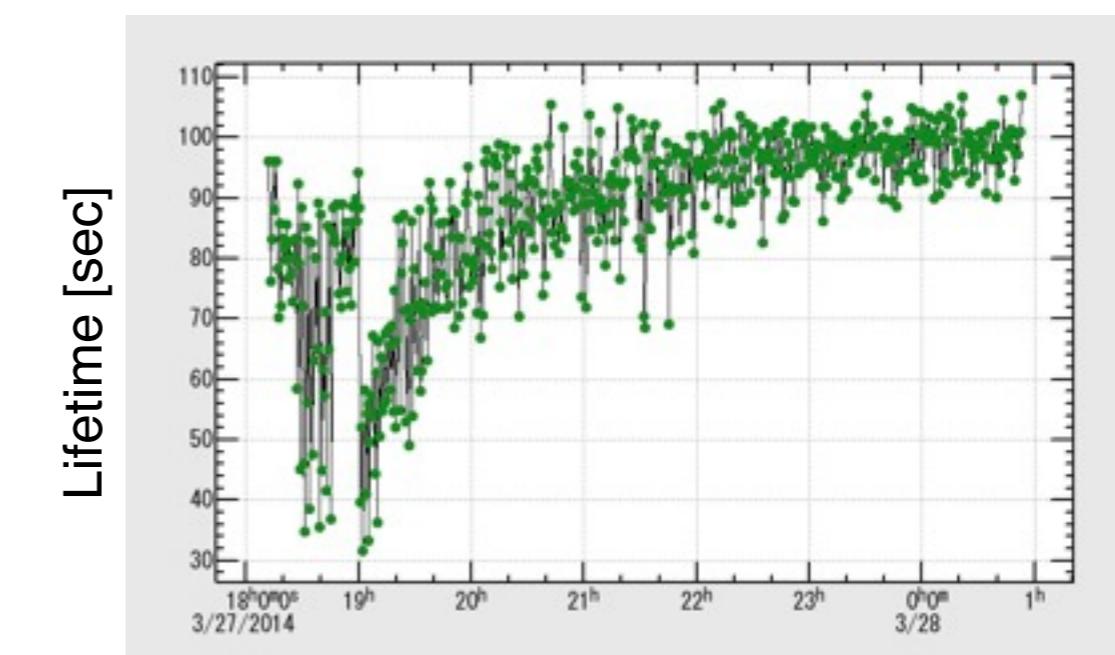
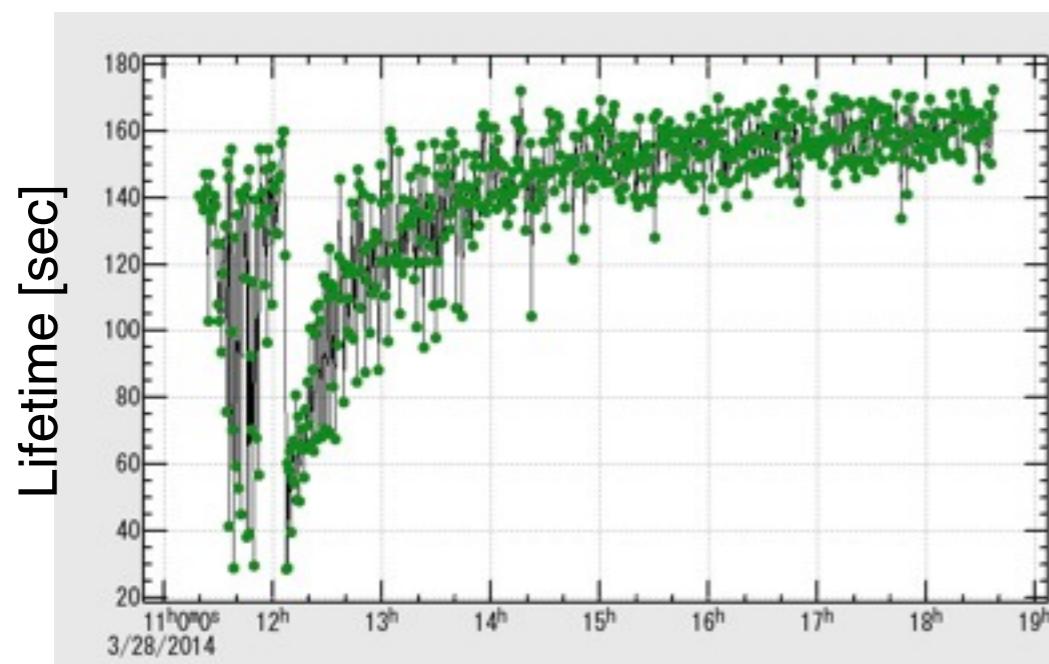
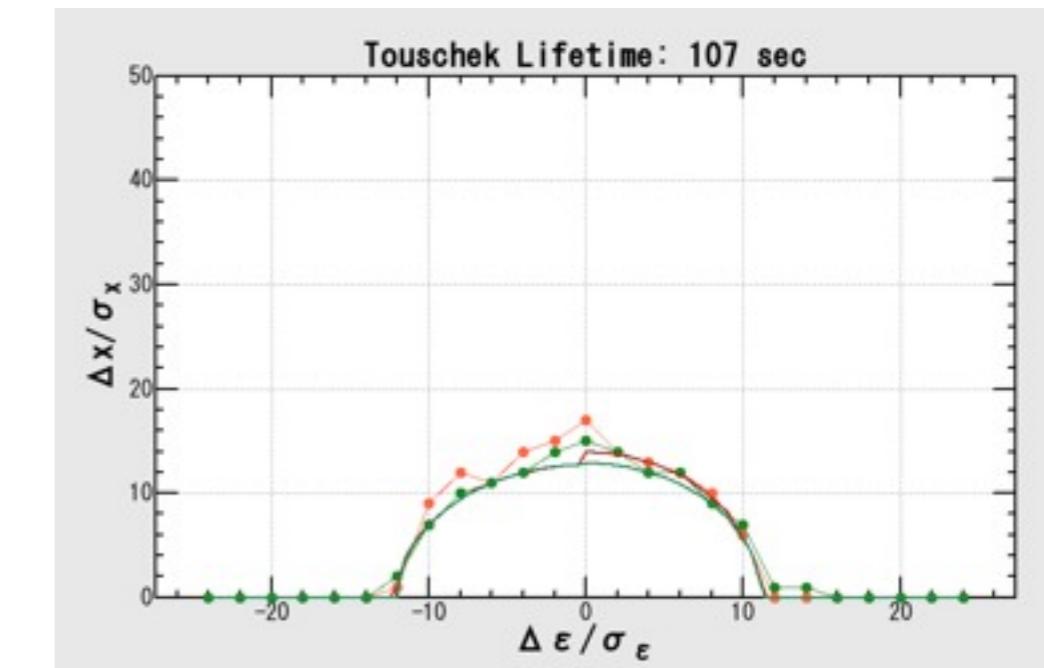
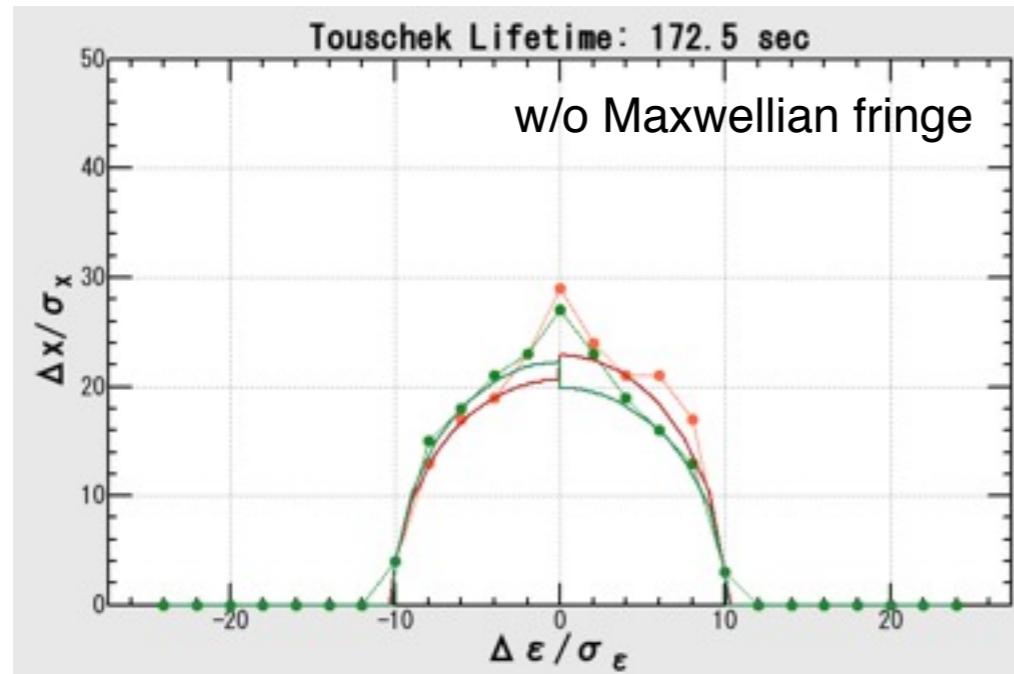


Simple IR
QC1/QC2: DISFRIN

w/o Beam-Beam
 $K_2 = -11(N)/+11(O) [1/m^2]$
80 % of nominal

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optimized

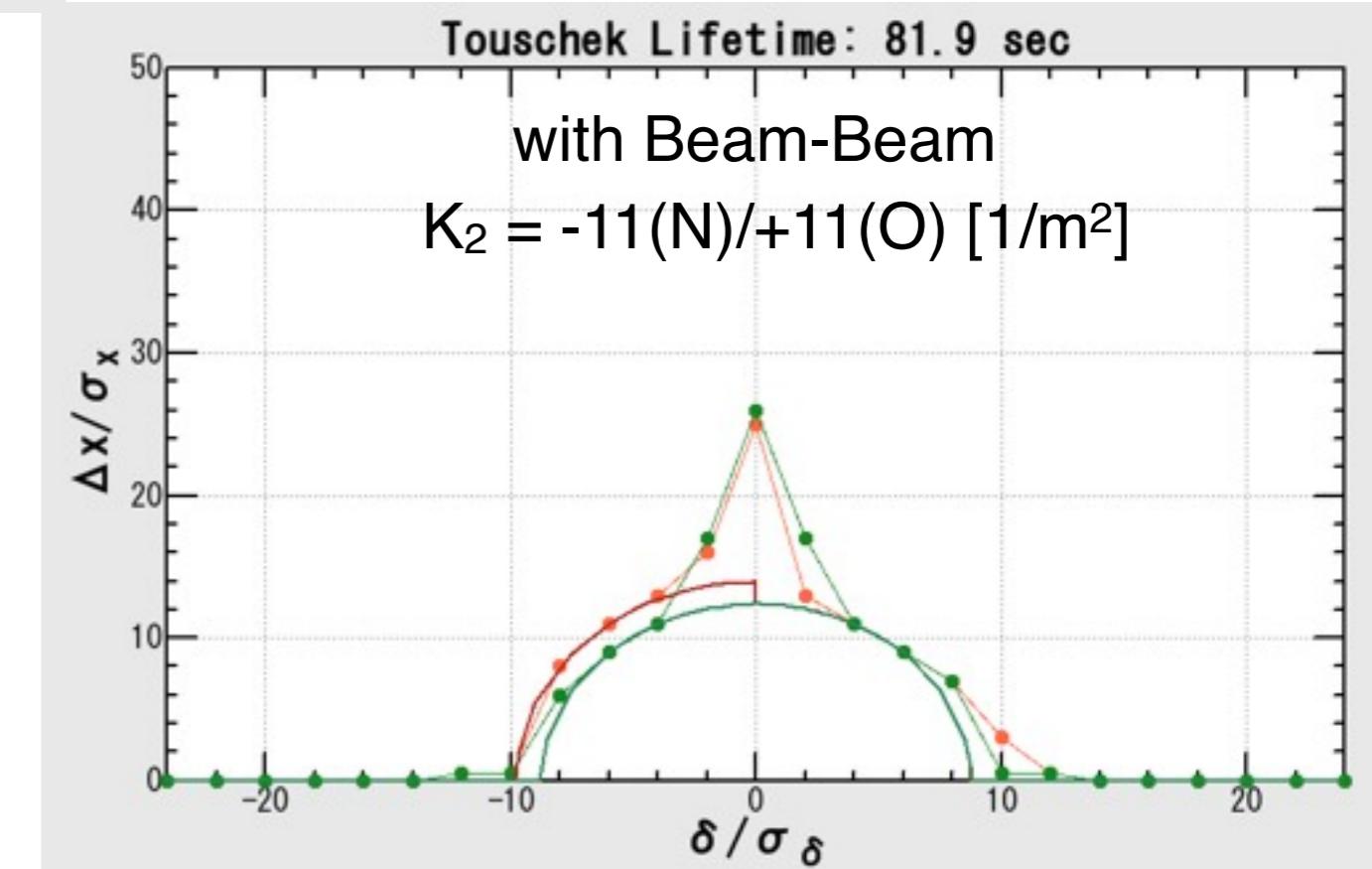
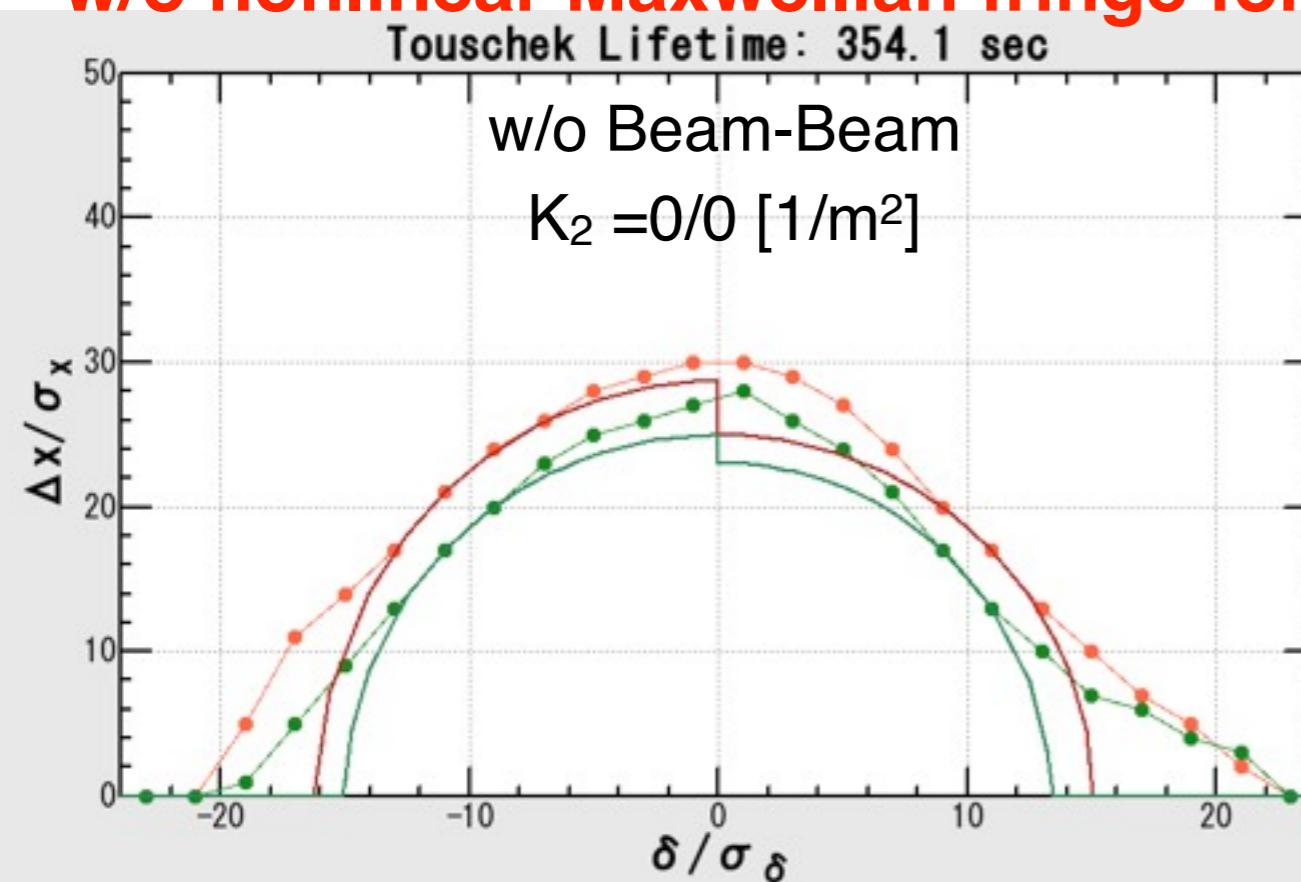
Simple IR

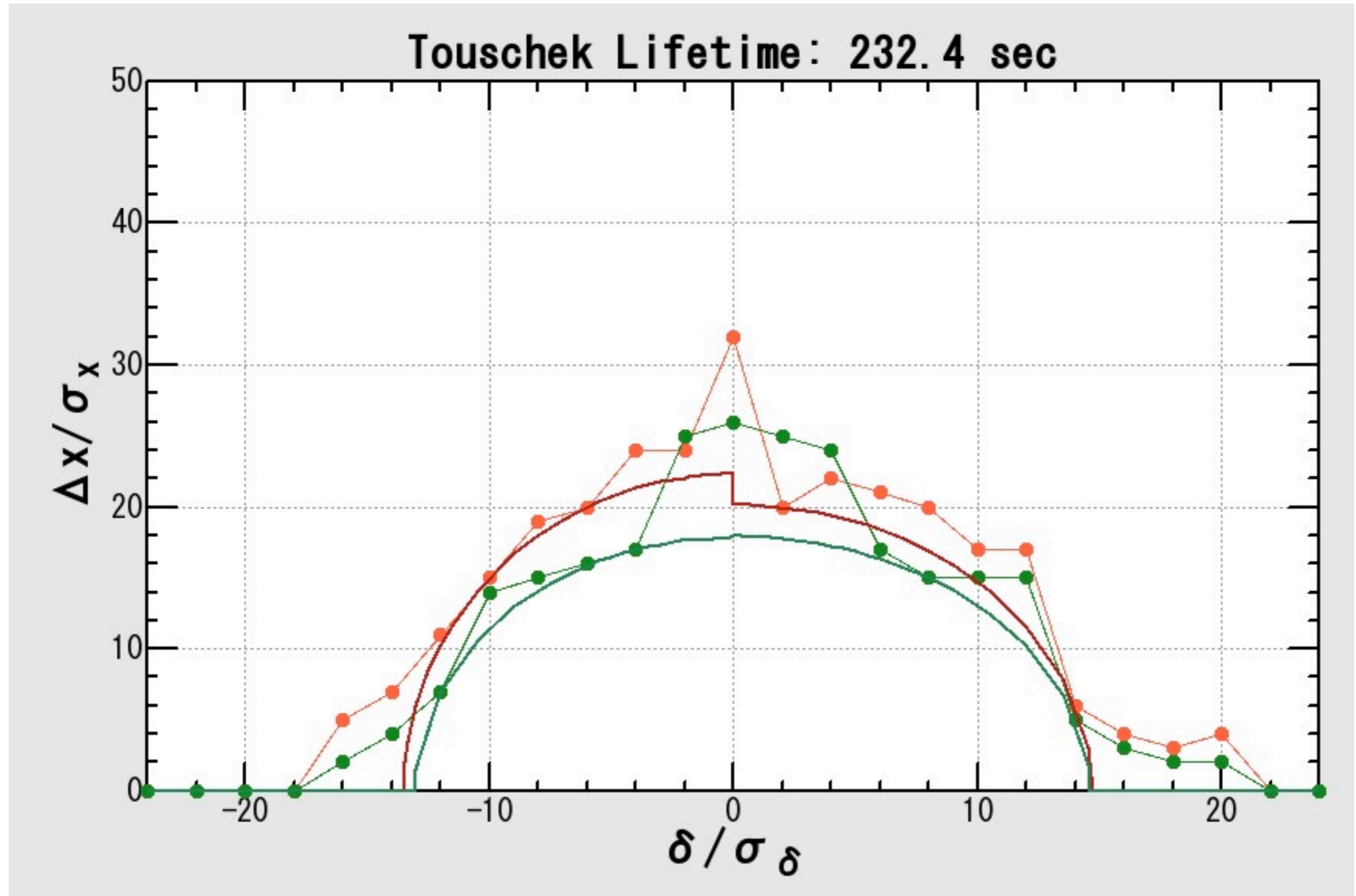


- Realistic lattice for Crab-Waist scheme in LER
- Dynamic aperture reduces as increasing K_2 of the crab sextupoles.
- The problem is a nonlinear kick($K_2 xy$ term) due to the crab sextupoles can not be cancelled for larger horizontal amplitudes without Beam-Beam effects. Linearity between the crab sextupoles is broken by IR nonlinear elements, especially Maxwellian fringe field.
- Optimization of sextupoles and octupoles can not recover the linearity of transfer matrix between the crab sextupoles with $K_2=11$ (nominal of 80 %), so far.

w/o nonlinear Maxwellian fringe for QC1/QC2

sler_1689_cw3_5b.sad





**Bad Polarity of
Crab-waist
sextupoles**

Simple IR optics with Beam-Beam

sler_1689_cw3_5b.sad

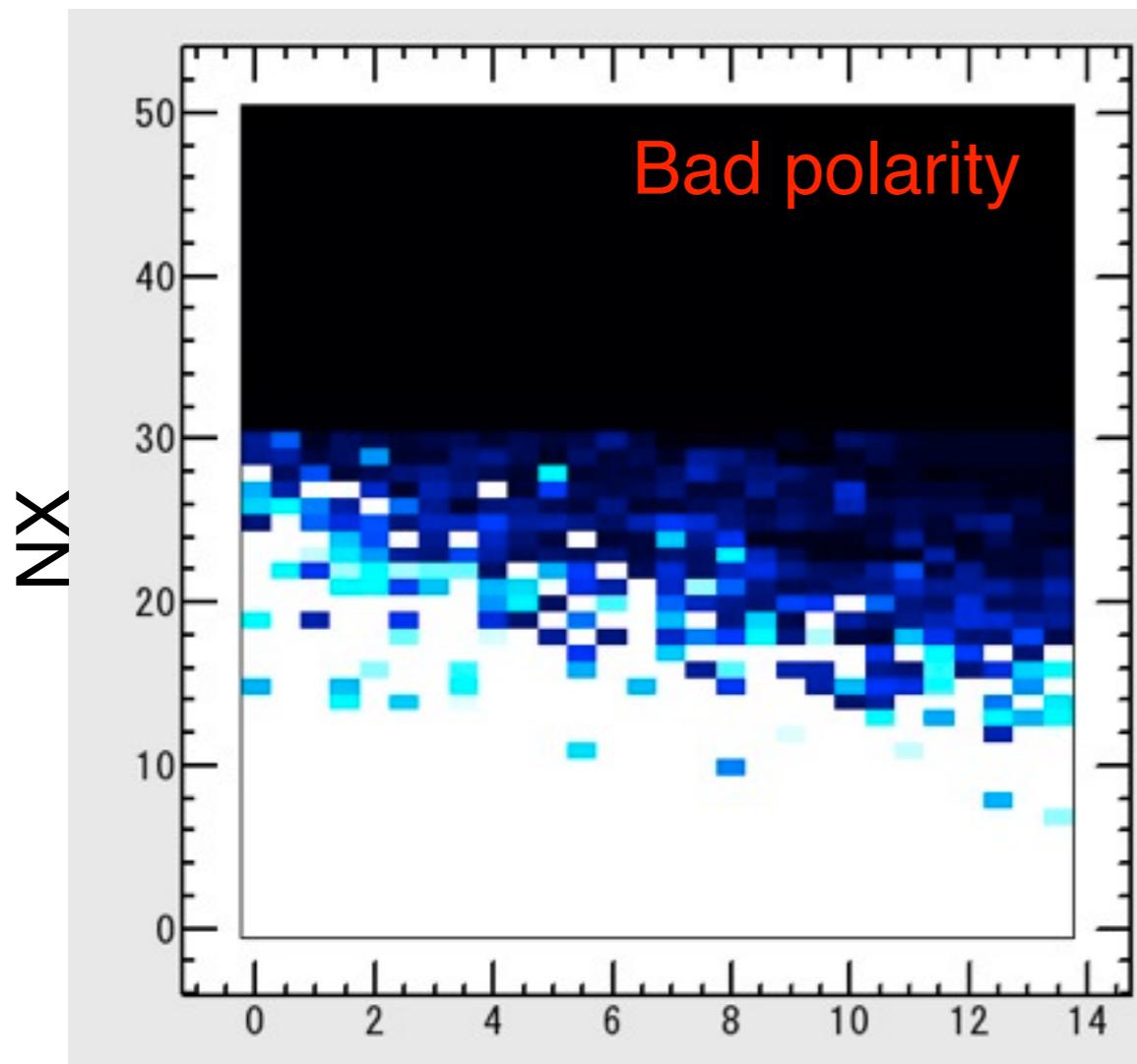
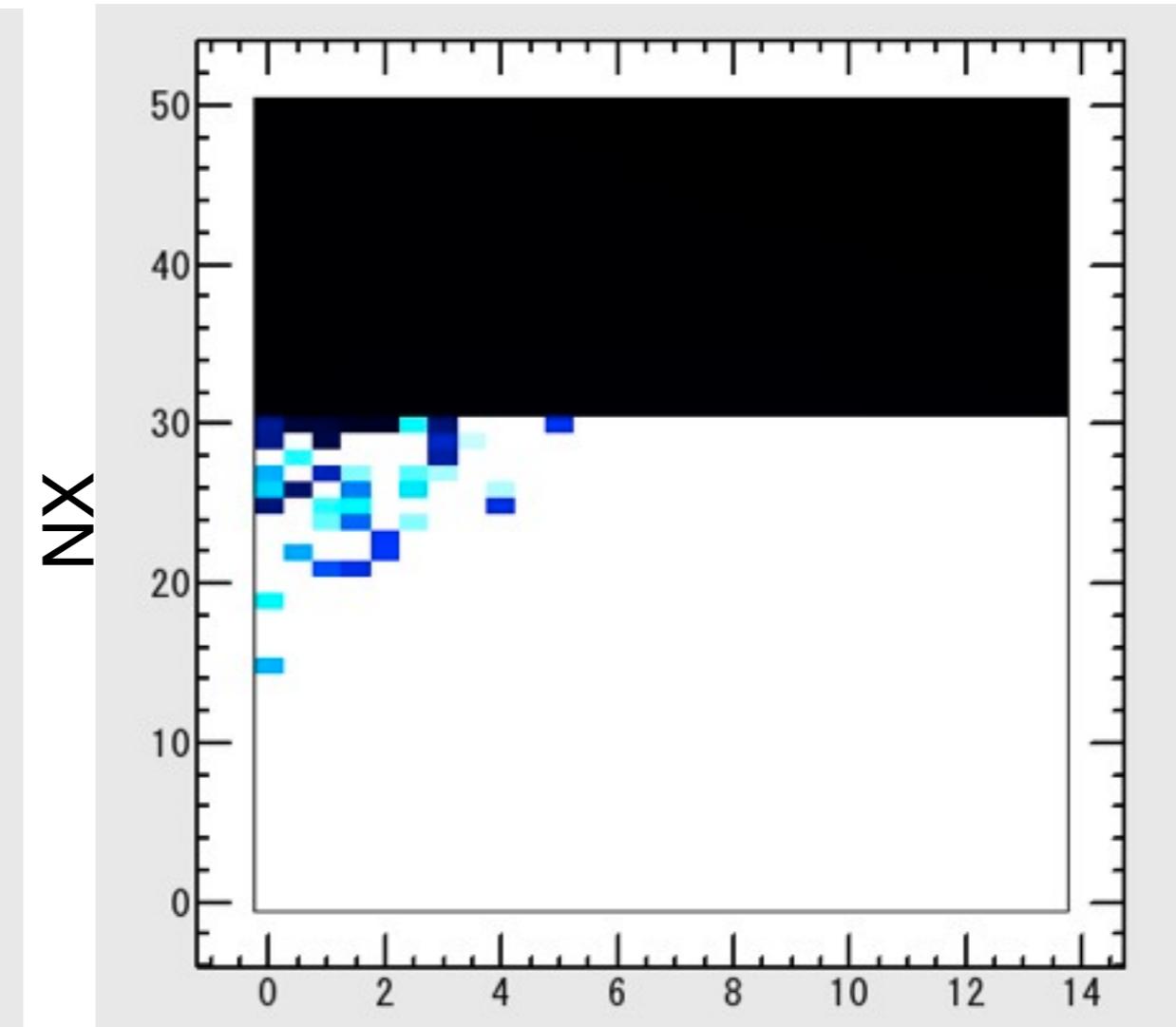
Initial momentum deviation

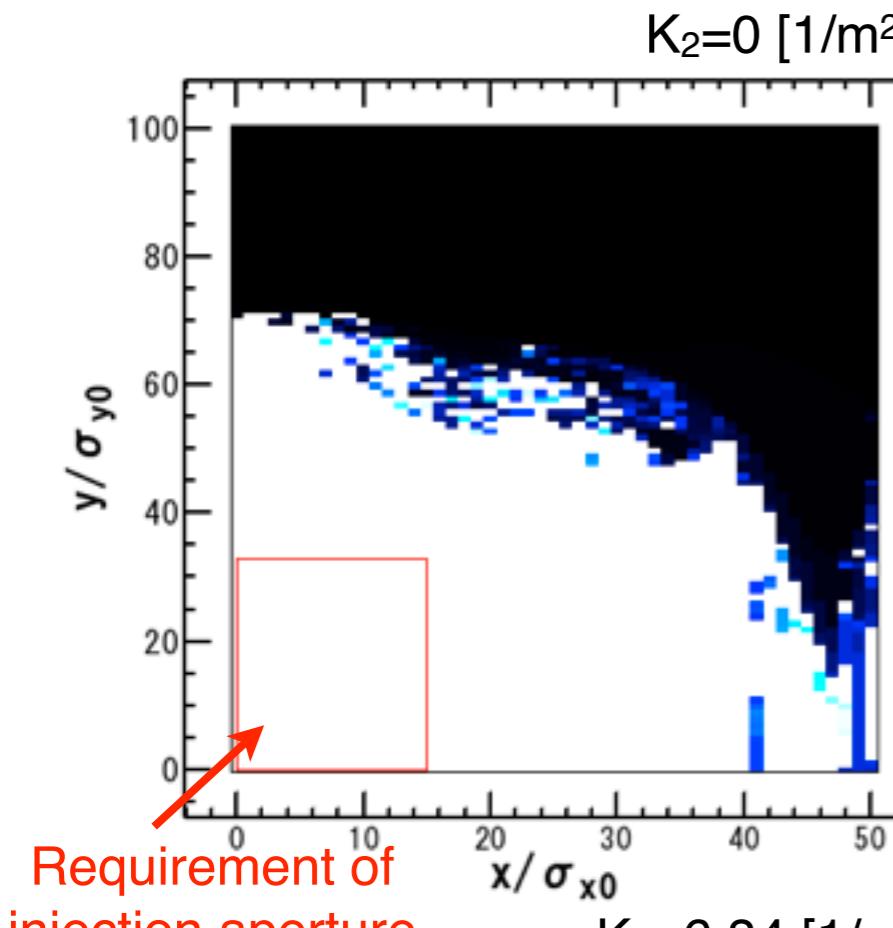
$$\delta_0 = \Delta p/p_0 = 0$$

 SXCWNP: $K_2 > 0$ [1/m²]

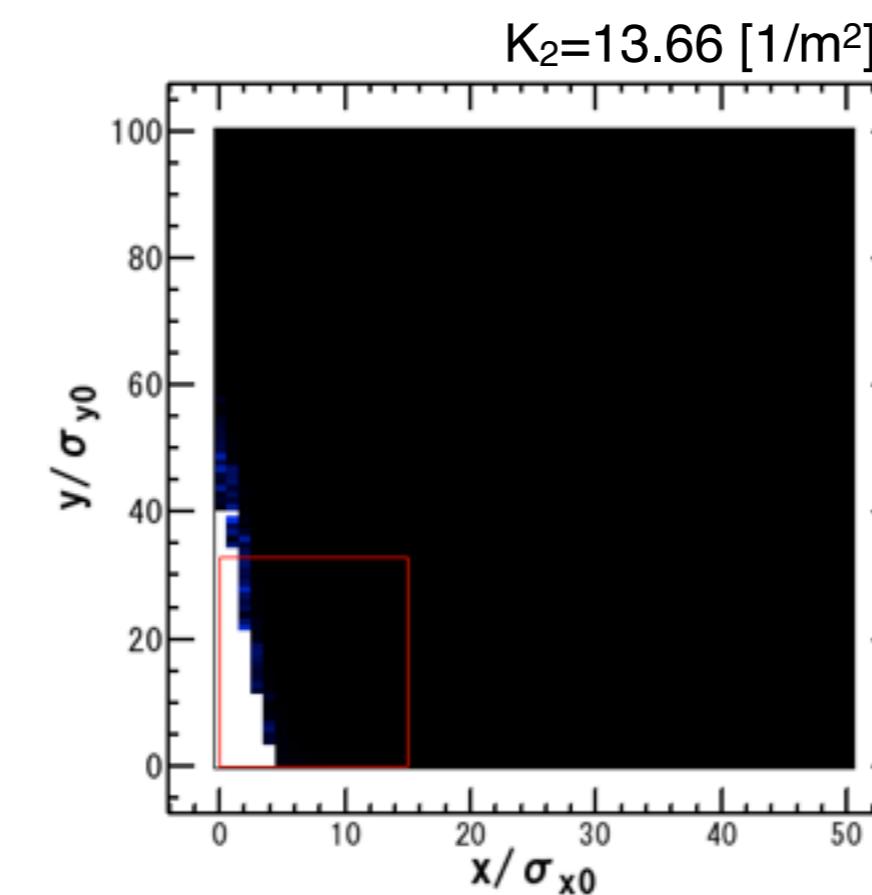
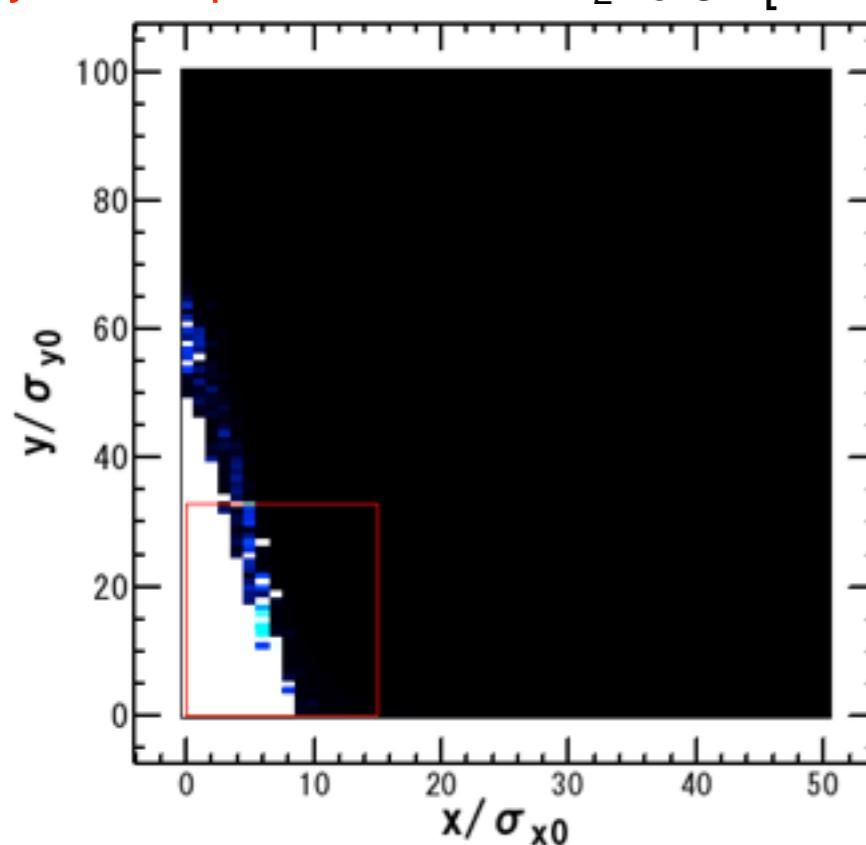
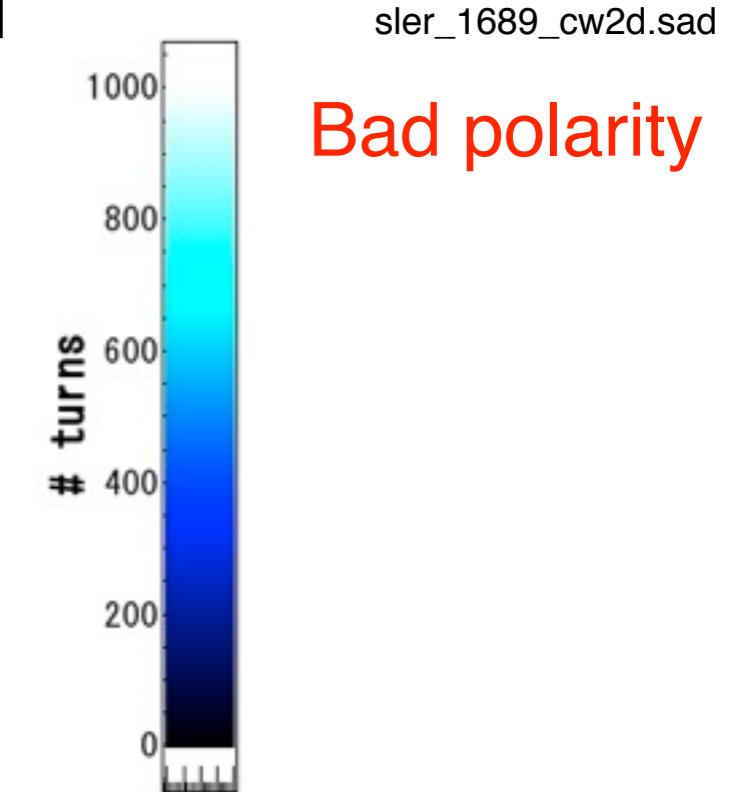
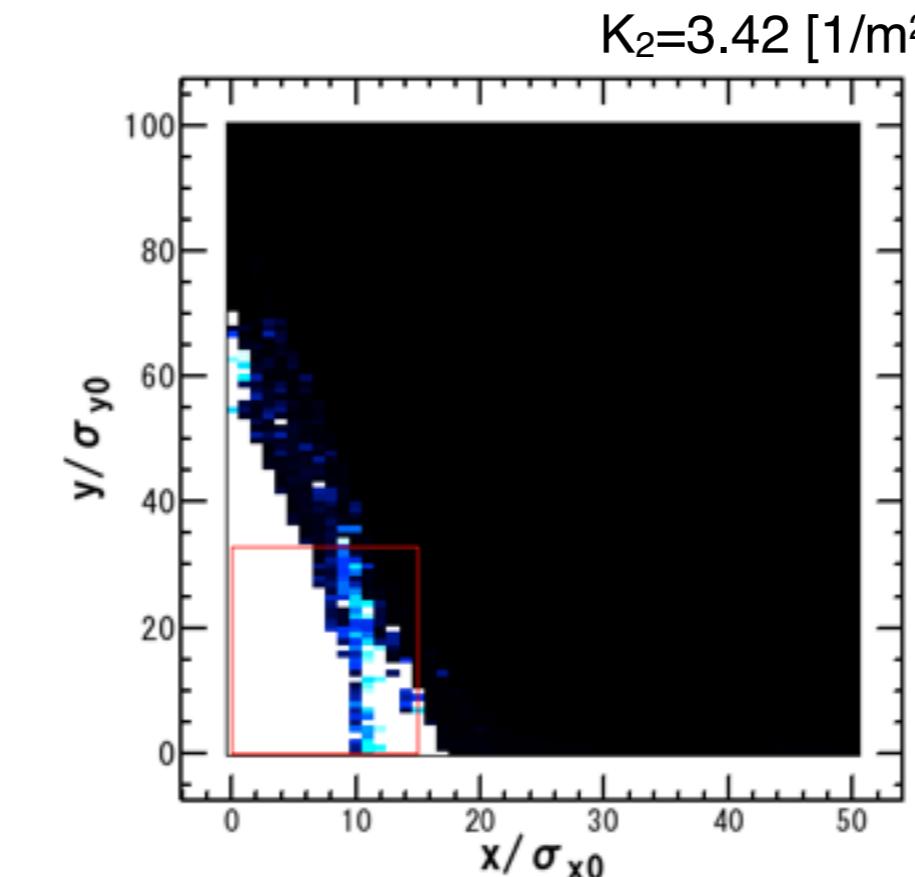
 SXCWOP: $K_2 < 0$ [1/m²]

 SXCWNP: $K_2 < 0$ [1/m²]

 SXCWOP: $K_2 > 0$ [1/m²]

 K_2 [1/m²] at SXCWNP

 K_2 [1/m²] at SXCWOP



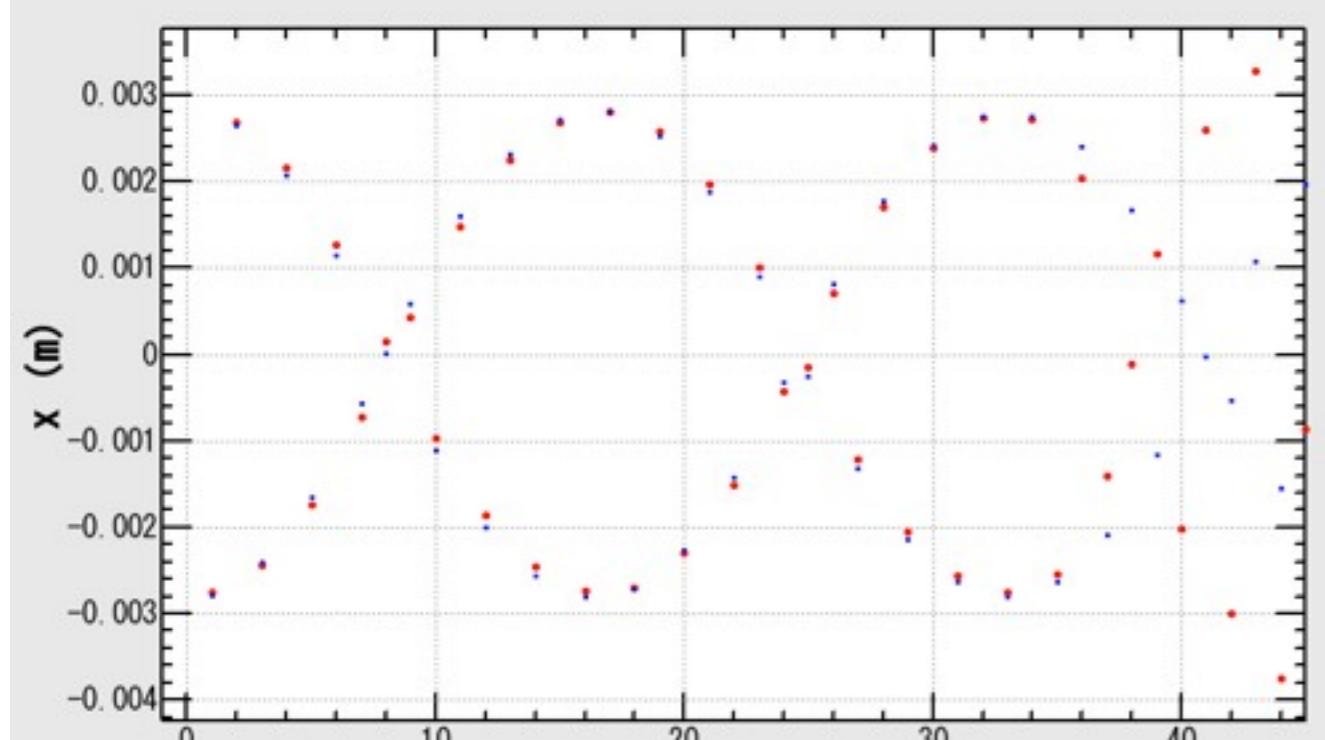
Requirement of
injection aperture



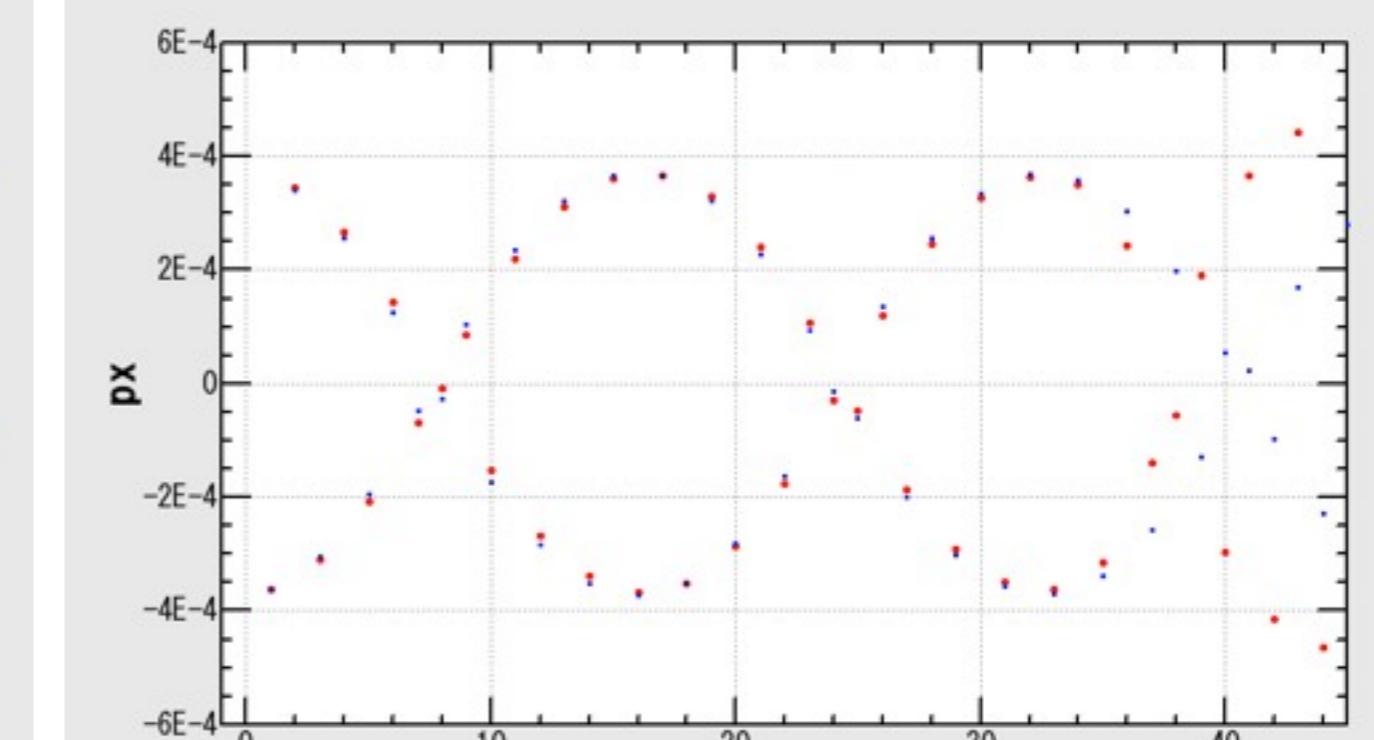
Initial momentum deviation

$$\delta_0 = \Delta p / p_0 = 0$$

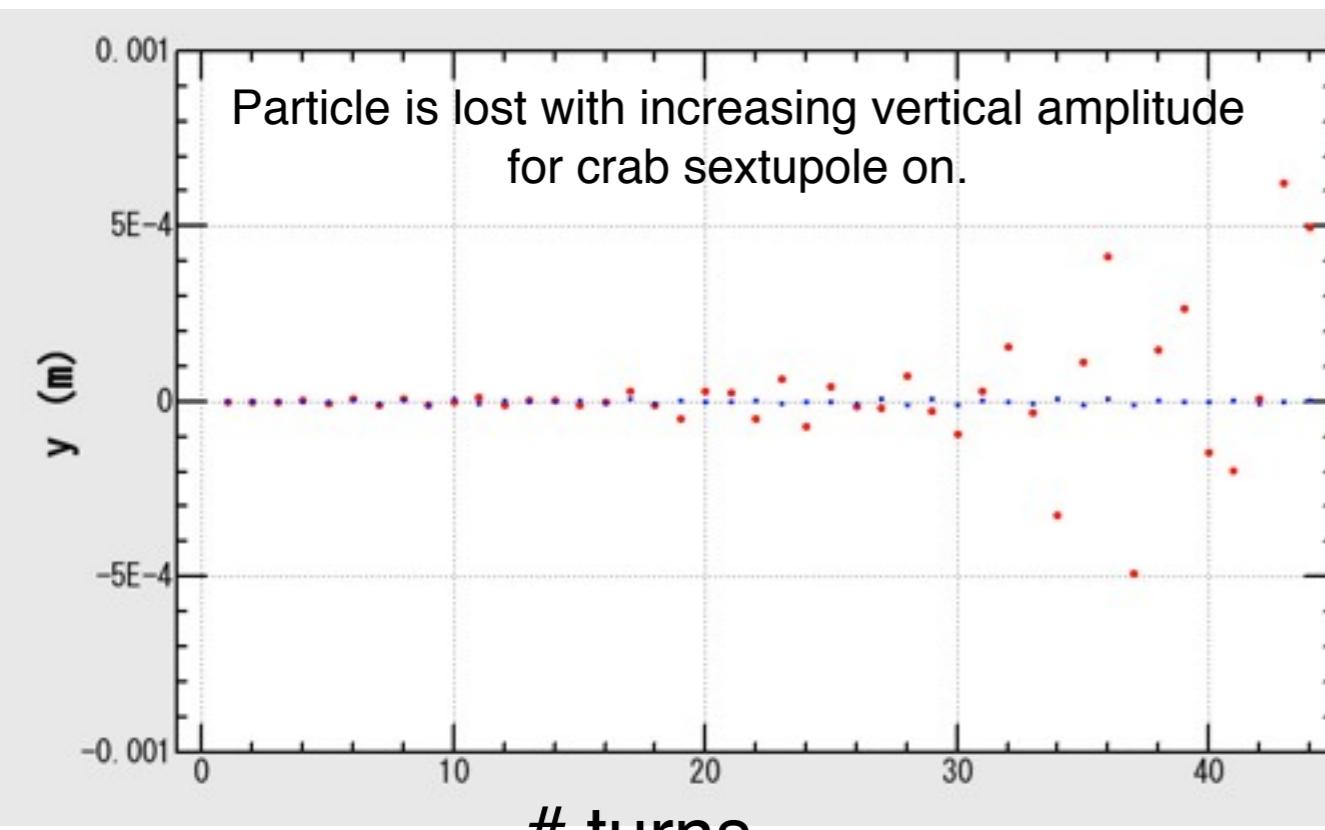
$$x_0 = 5 \sigma_x \quad y_0 = 0 \quad K_2 = 0 [1/m^2] \quad K_2 = 13.66 [1/m^2]$$



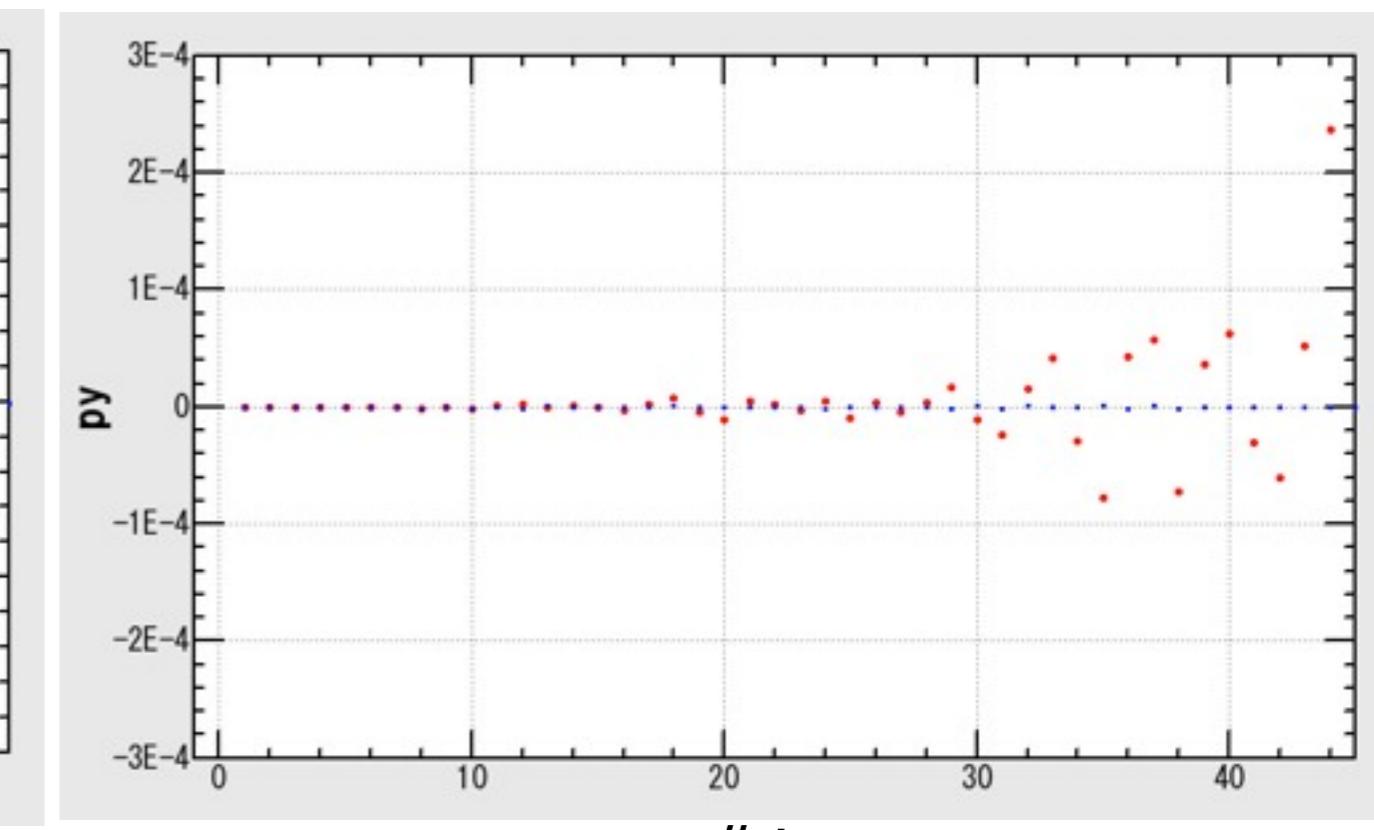
turns



turns

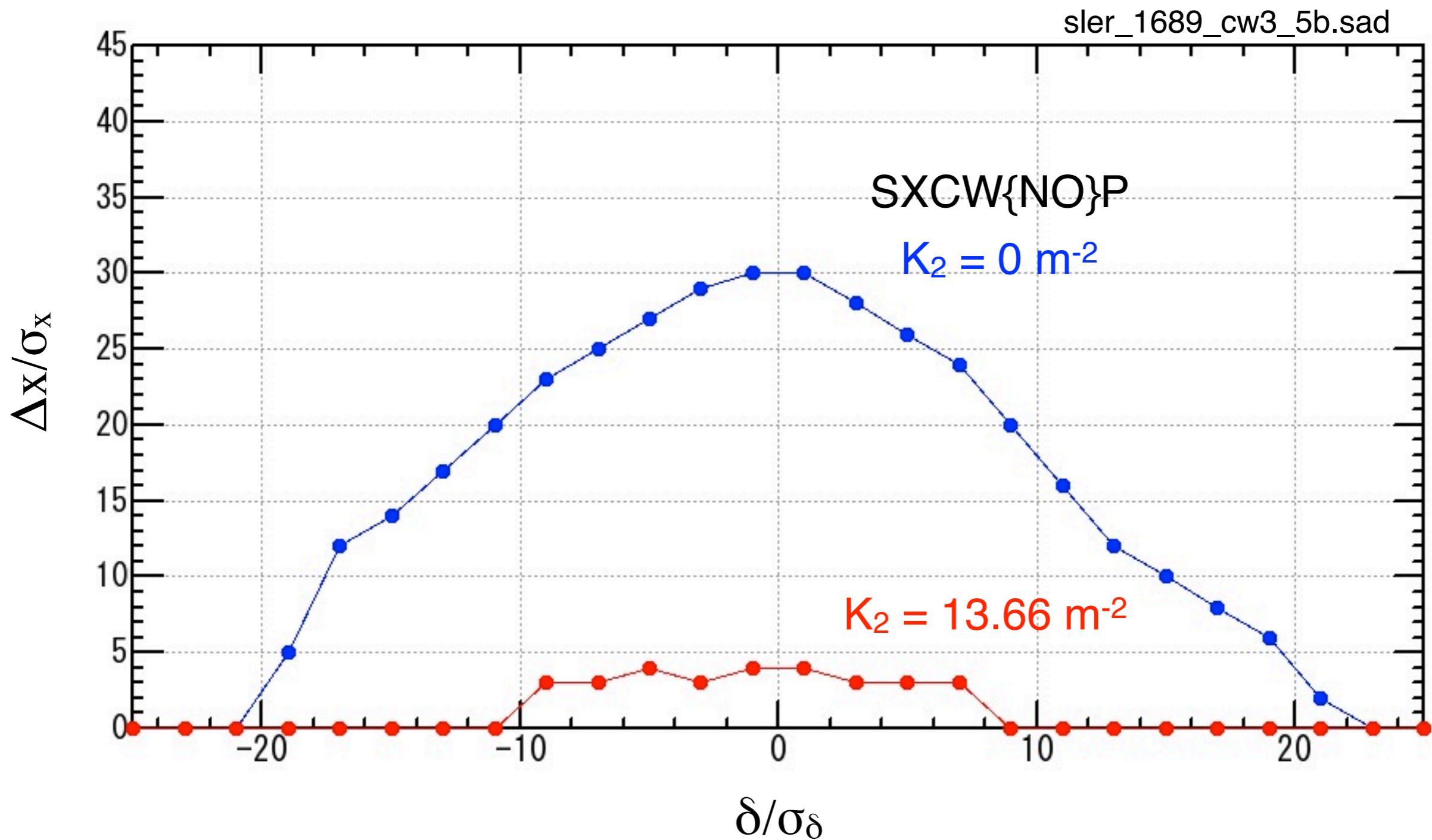


turns



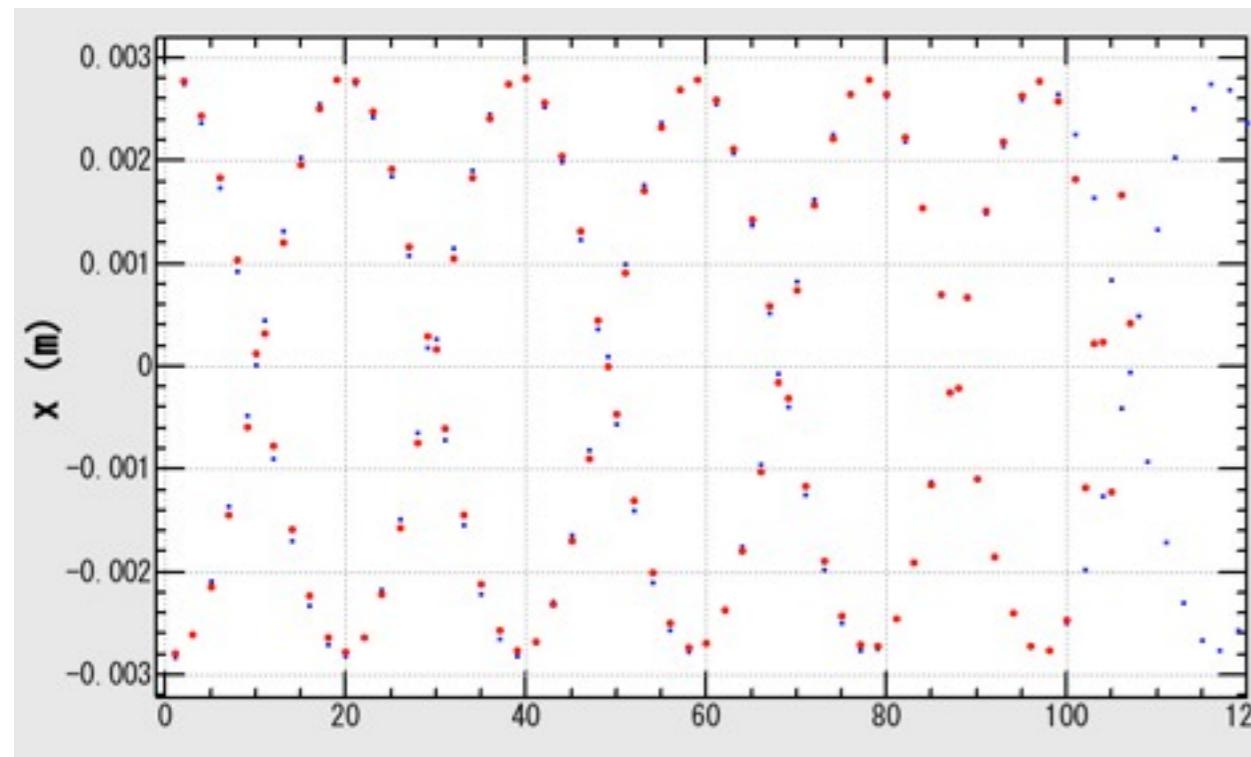
turns

Crab Waist Sextupole ON and OFF

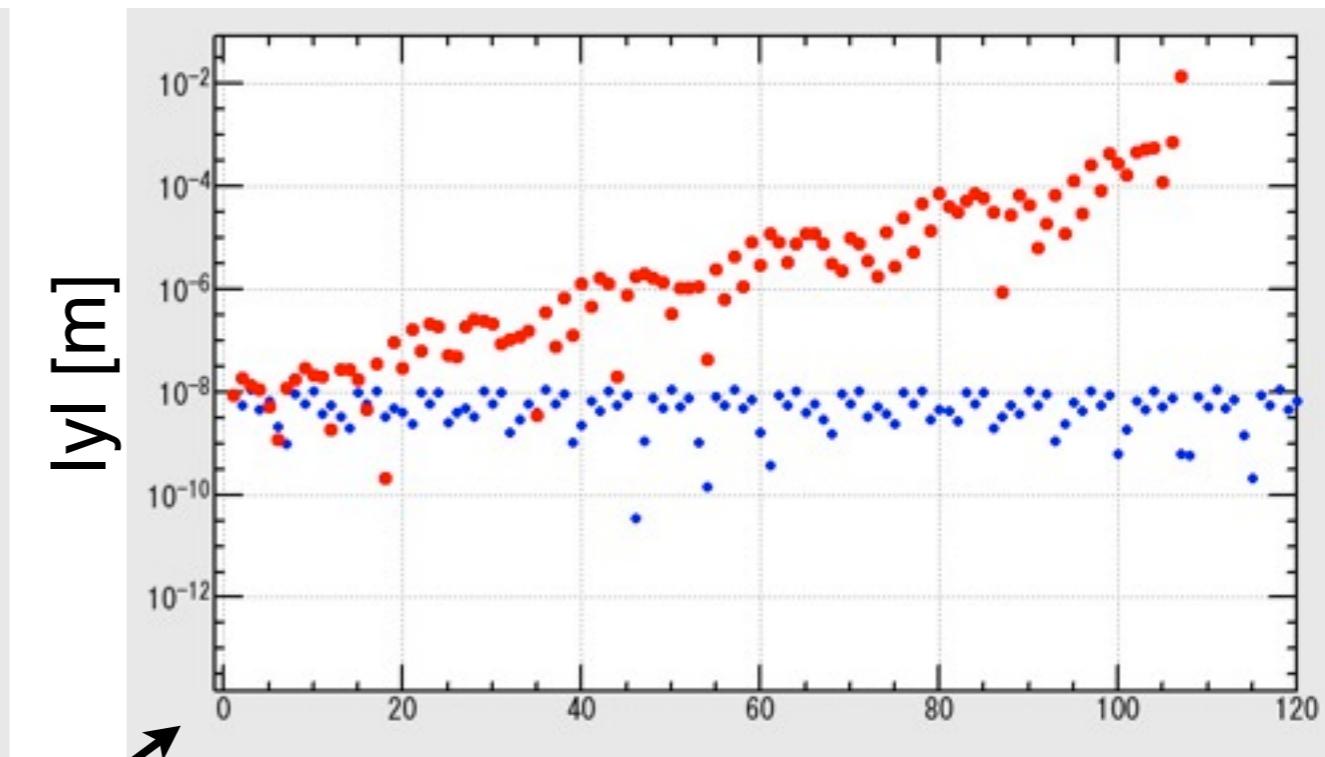


$x_0 = 5 \sigma_x$ $y_0 = 0$ $K_2 = 0 [1/m^2]$ $K_2 = 13.66 [1/m^2]$

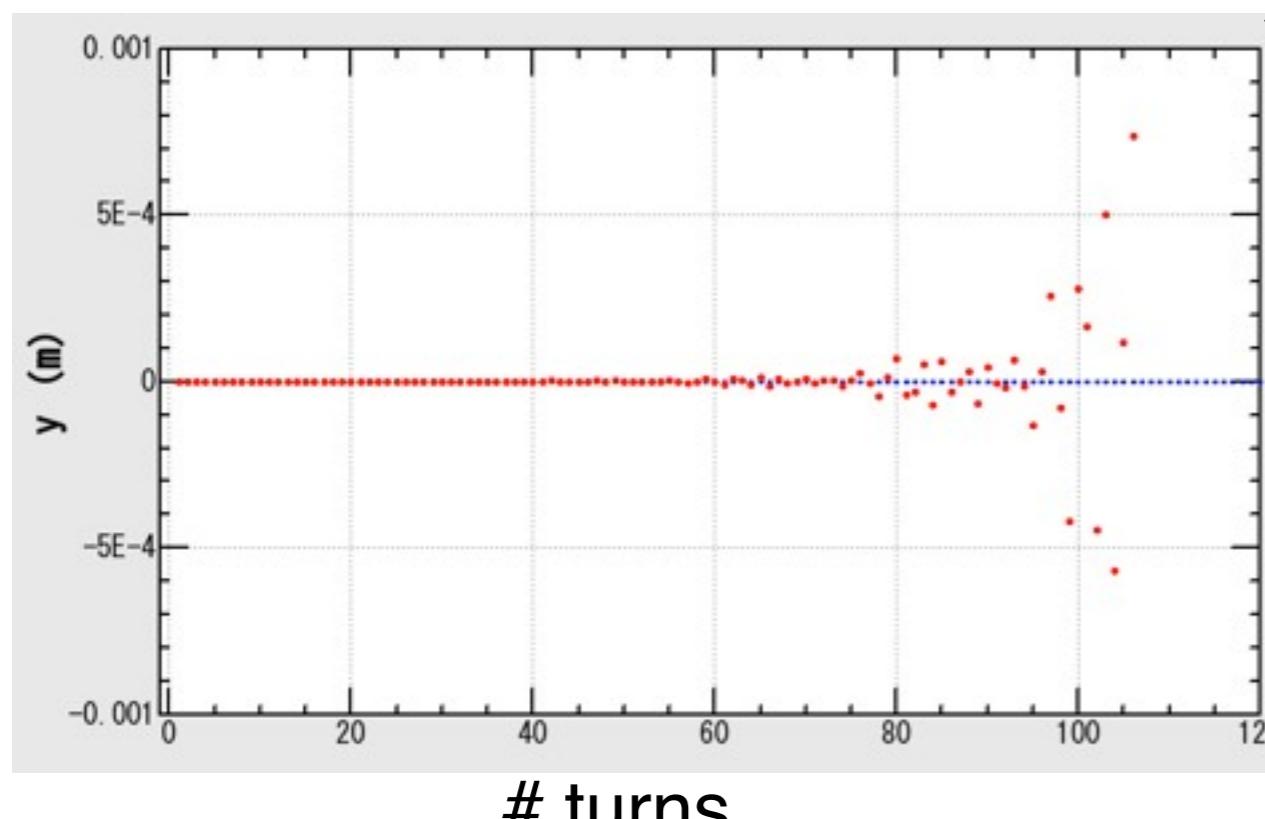
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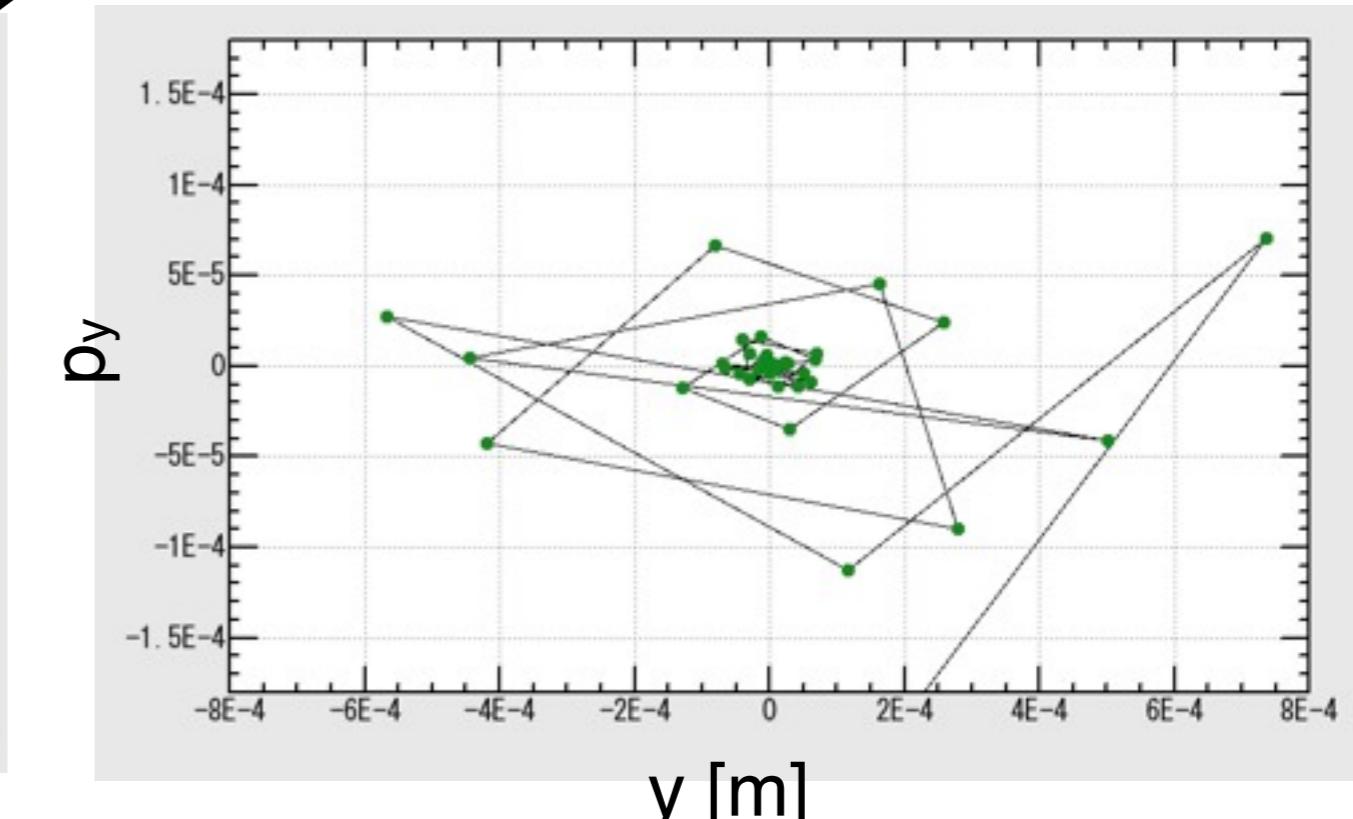
turns



turns



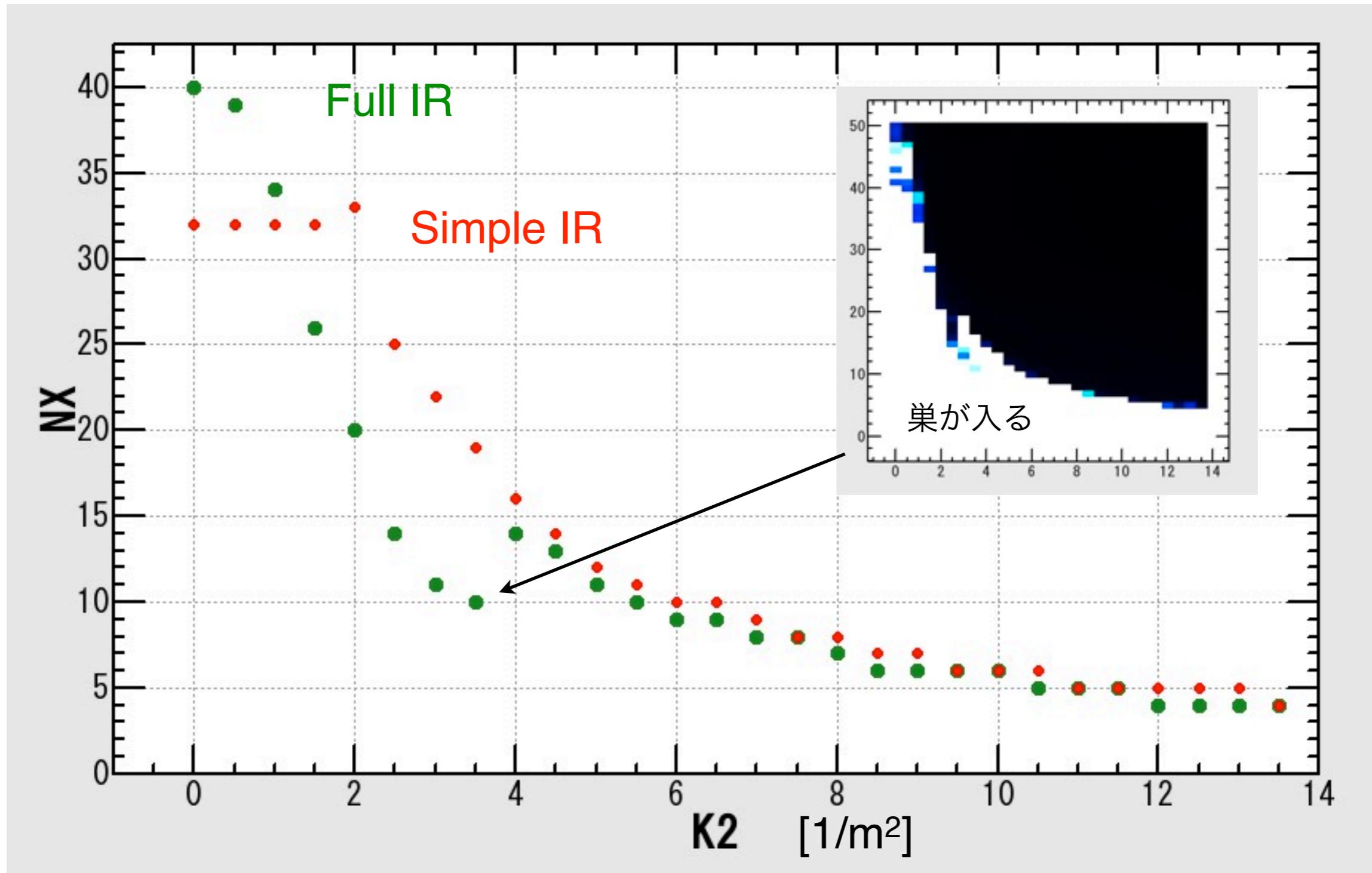
turns



y [m]

Comparison for On-momentum Aperture

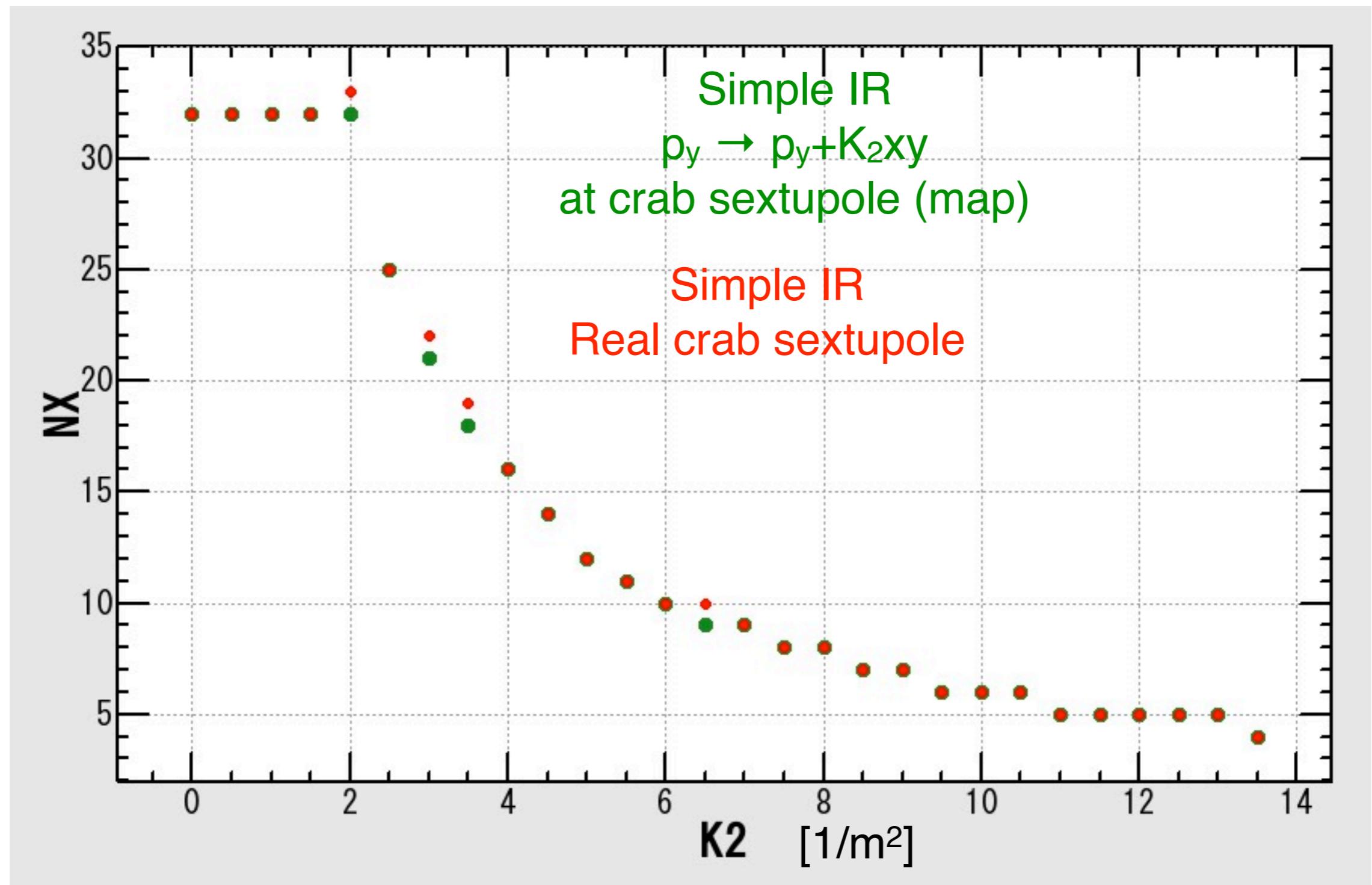
sler_1689_cw2d.sad sler_1689_cw3_5b.sad



No difference of aperture larger than K₂ = 4 [1/m²].

Comparison for On-momentum Aperture

sler_1689_cw3_5b.sad sler_1689_cw3_5b.sad



The $K_2 xy$ term restrict the transverse aperture.