Beam-beam + Dynamic Aperture

ICFA Mini-Workshop
on Commissioning of SuperKEKB and e+e- Colliders

2013.11.12

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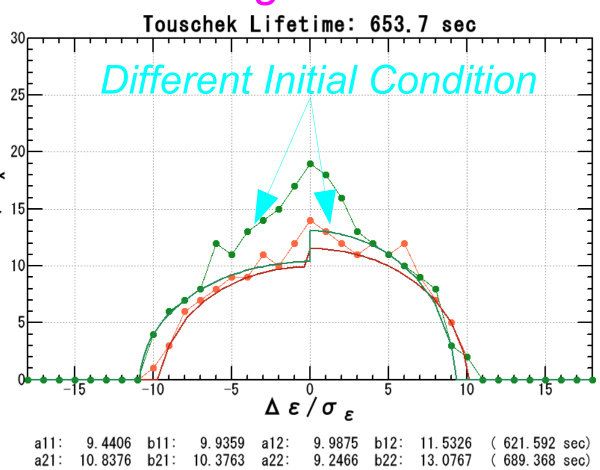
Dynamic Aperture & Lifetime

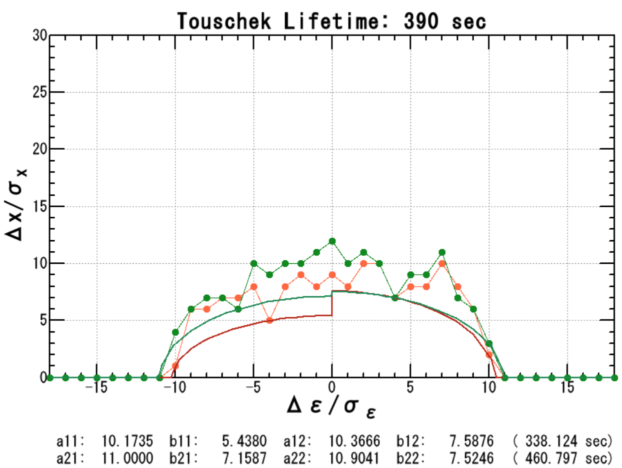
Design Target of Lifetime: 600sec

HER

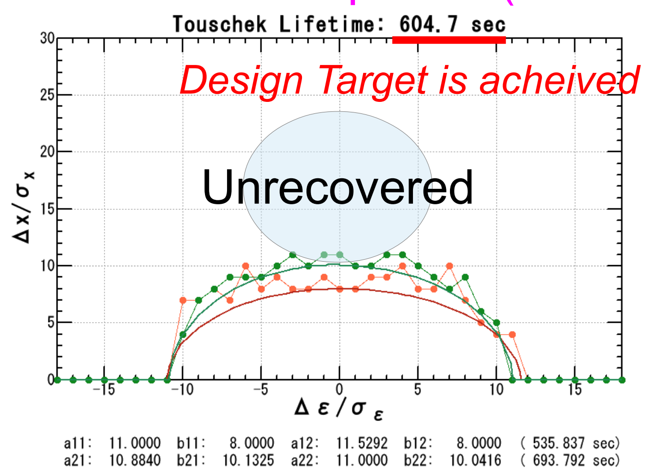
Design Lattice



With Beambeam

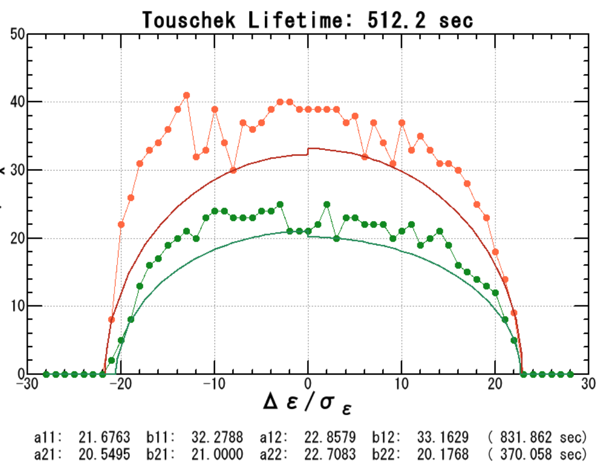


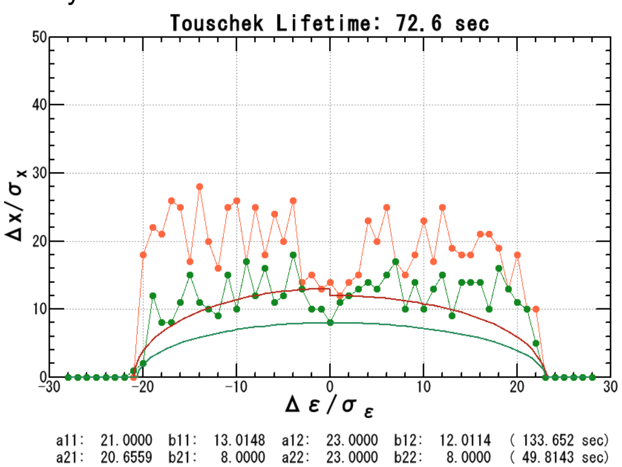
With BB + Re-Optimize(Sext/Oct)

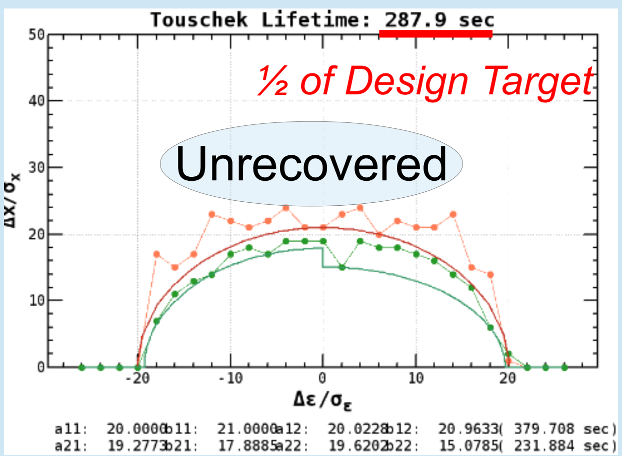


Working point (ν_x,ν_y)=(#.53, #.57)

LER





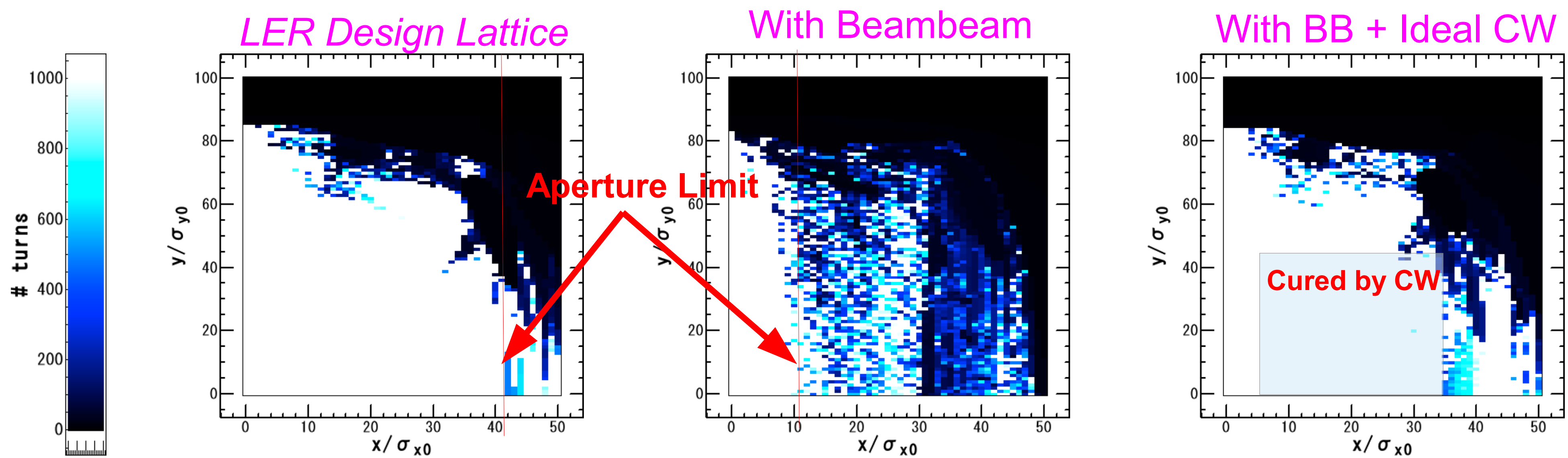


Different working point
(ν_x,ν_y)=(#.61, #.53)

We have to
- *understand origin of aperture degradation*
- *find method to cure transverse aperture*

DA cured by Ideal Crab Waist

Initial amplitude vs Number of turns



- Ideal CW replaces map f_{BB} with $f_{CW}(+\lambda)\cdot f_{BB}\cdot f_{CW}(-\lambda)$
- f_{CW} is constructed by thin sextupole between thin phase rotator pair.
- $f_{CW}(\lambda)$: $(x,x',y,y',z,\delta) \rightarrow (x,x'+\lambda/2\ y'^2, y-\lambda\ x\ y', y', z, \delta)$

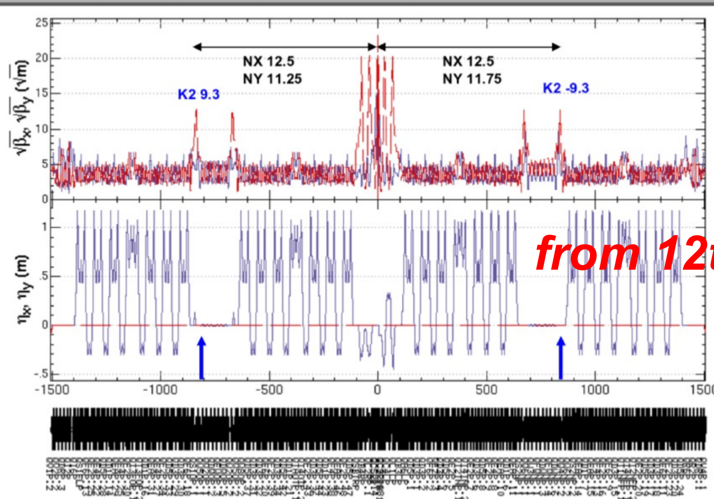
Past trial of CW on KEKB model

- Our past trial of CW on KEKB model lattice is failed because of degradation of aperture!

Questions

- *Who is preventing dynamic aperture?*
- *What is operating condition of CW?*

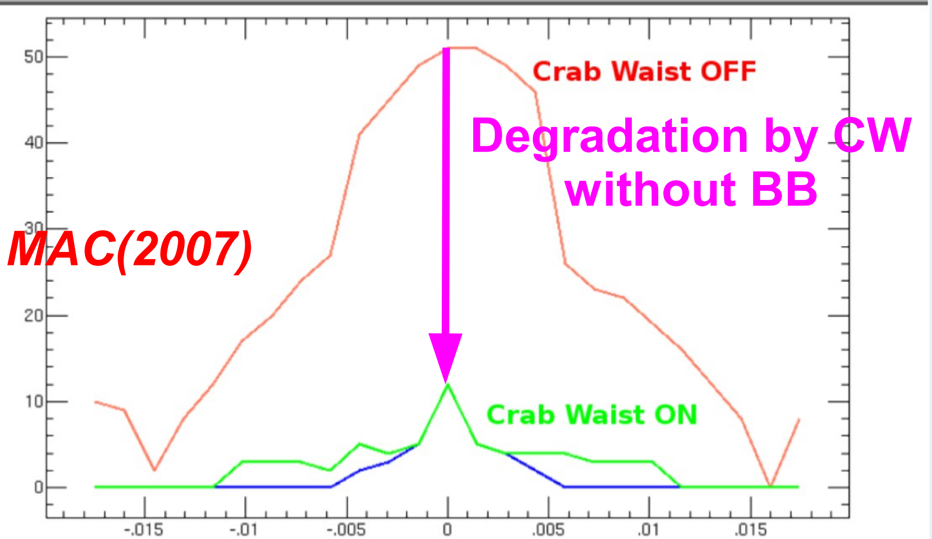
LER Model Optics for Crab Waist



- Insert thin sextupole pair into NIKKO and OHO section
- Transfer between crab waist sextupole pair is I'

from 12th KEKB MAC(2007)

Dynamic Aperture of LER Model Optics

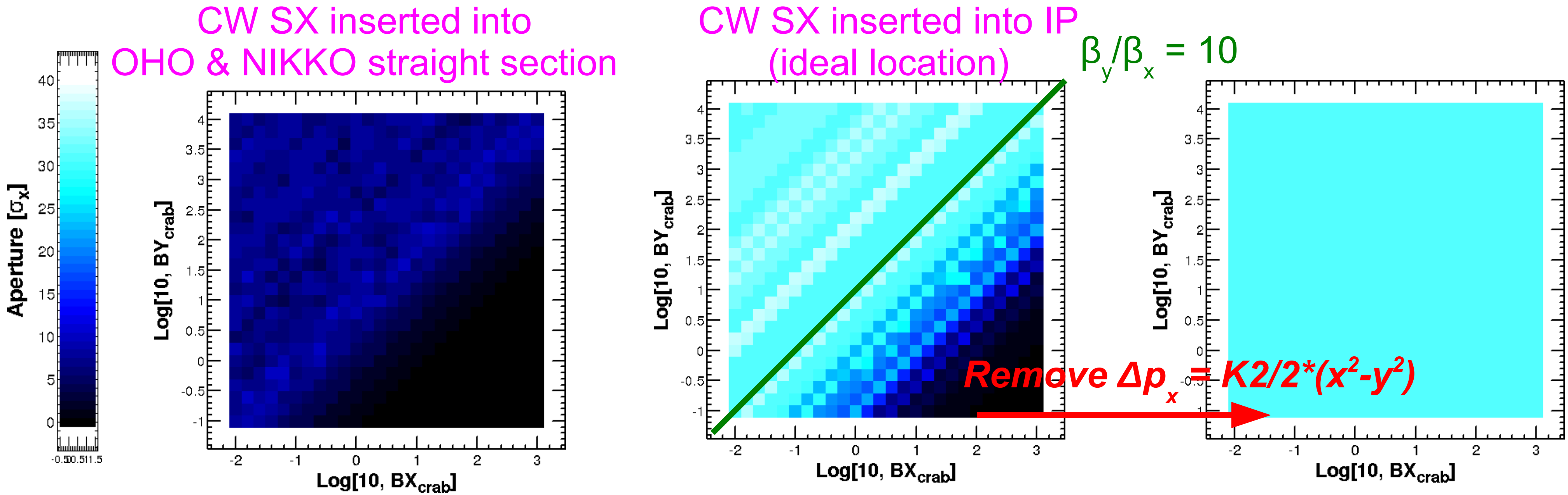


- Tracking Condition: XY-Coupling 10%, RFSW ON

CW operating condition study(1)

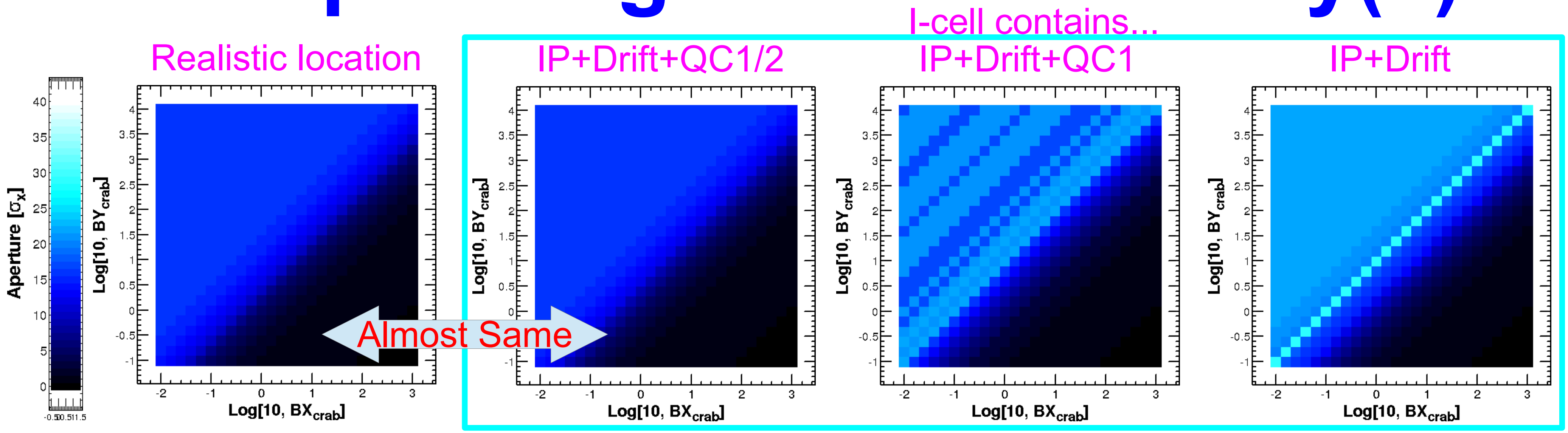
- Simplified IR lattice model for study
  - Remove solenoid, QC's offset & rotation, K0,SK0,SK1
  - Control QC's multipoles Kn,SKn($n \geqq 2$)
  - Insert CW sextupole pair by using both thin sextupole and thin phase rotator into dispersion free section
  - Fix betatron phase between CW sextupole and IP to ($\pi + 2n\pi$, $\pi/2 + 2m\pi$) ($^{\forall}n,m \in \mathbf{Z}$)
  - Fix α_x & α_y at CW sextupole to 0
  - Control β_x & β_y at CW sextupole

CW operating condition study(2)



- Scan β-functions at CW sextupole
- CW works with ideal location, however, does not work with realistic location
- Aperture depends on β_y/β_x ratio at CW sextpole
- This limit is caused by $K2/2*(x^2-y^2)$ term.

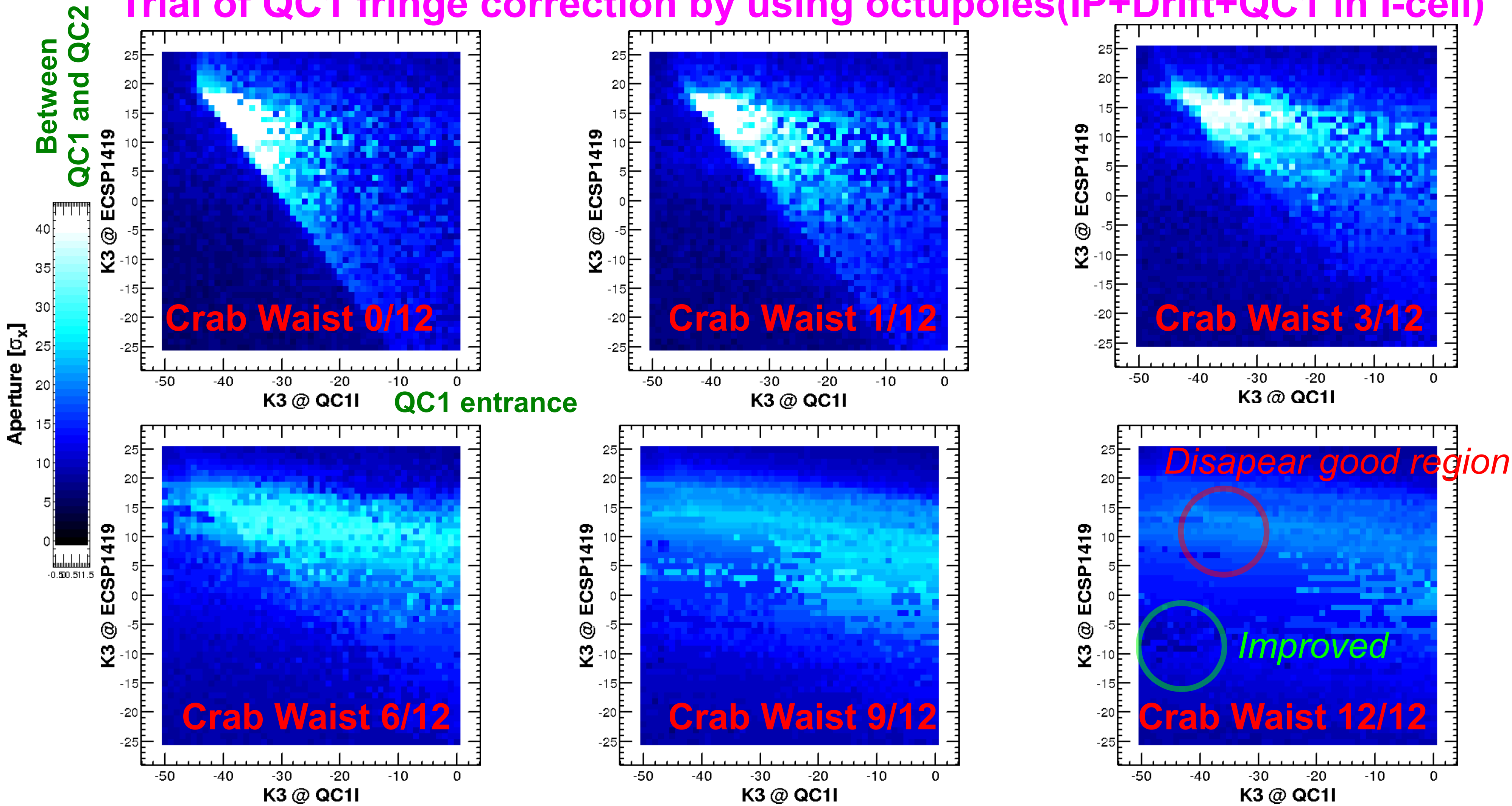
CW operating condition study(3)



- Location dependency test on simplified lattice without higher order multipoles
- Aperture depends with final focus quadrupoles between CW I-cell
- Aperture blocker WOULD be non-linear Maxwellian fringe of FF quadrupoles

CW operating condition study(4)

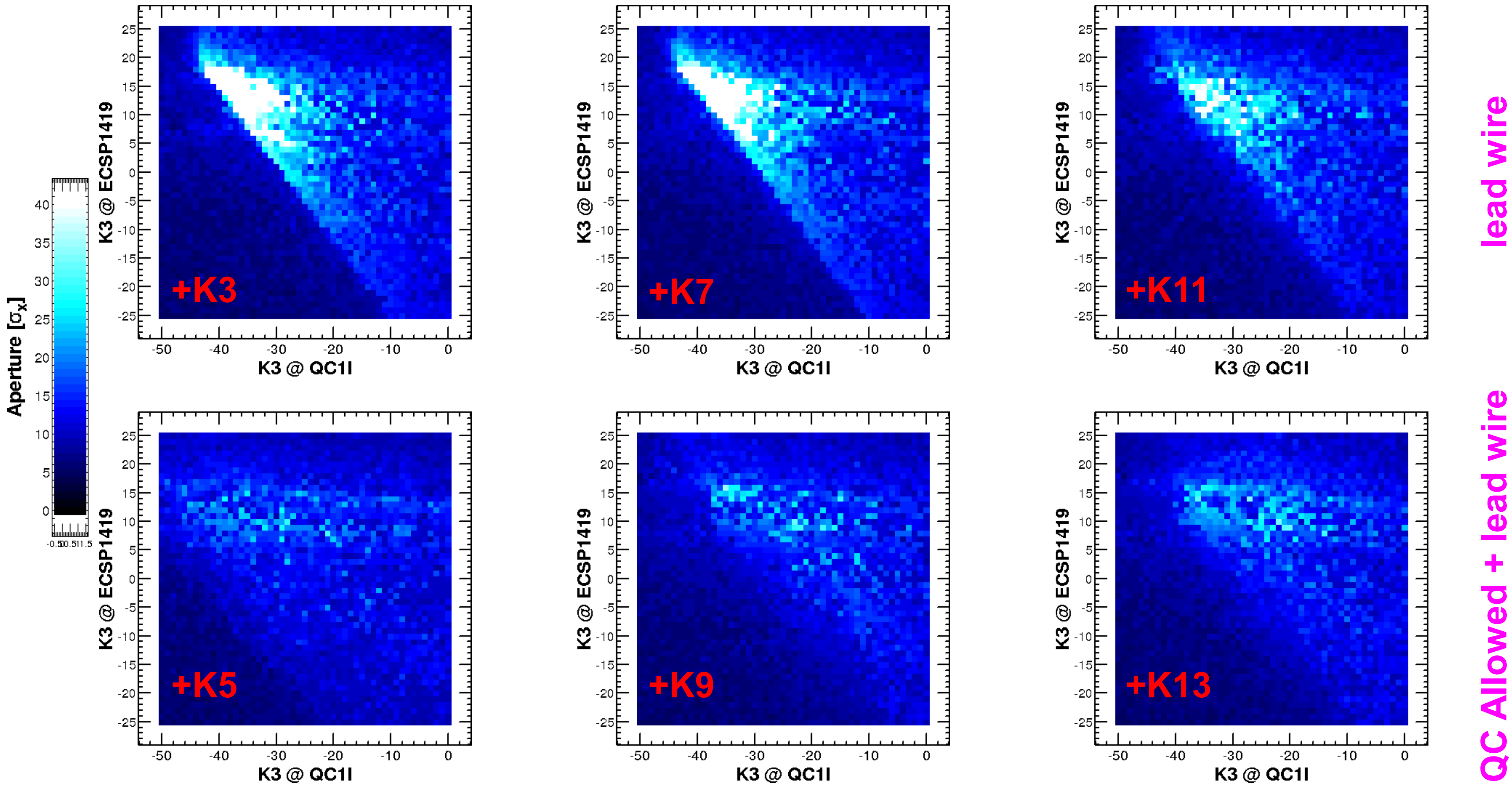
Trial of QC1 fringe correction by using octupoles(IP+Drift+QC1 in I-cell)



- CW improves aperture of worst cases
- CW limits aperture of best case

DA blocking multipole study(1)

Simplified IR + QC's Higher Order Multipole in Design(without CW)

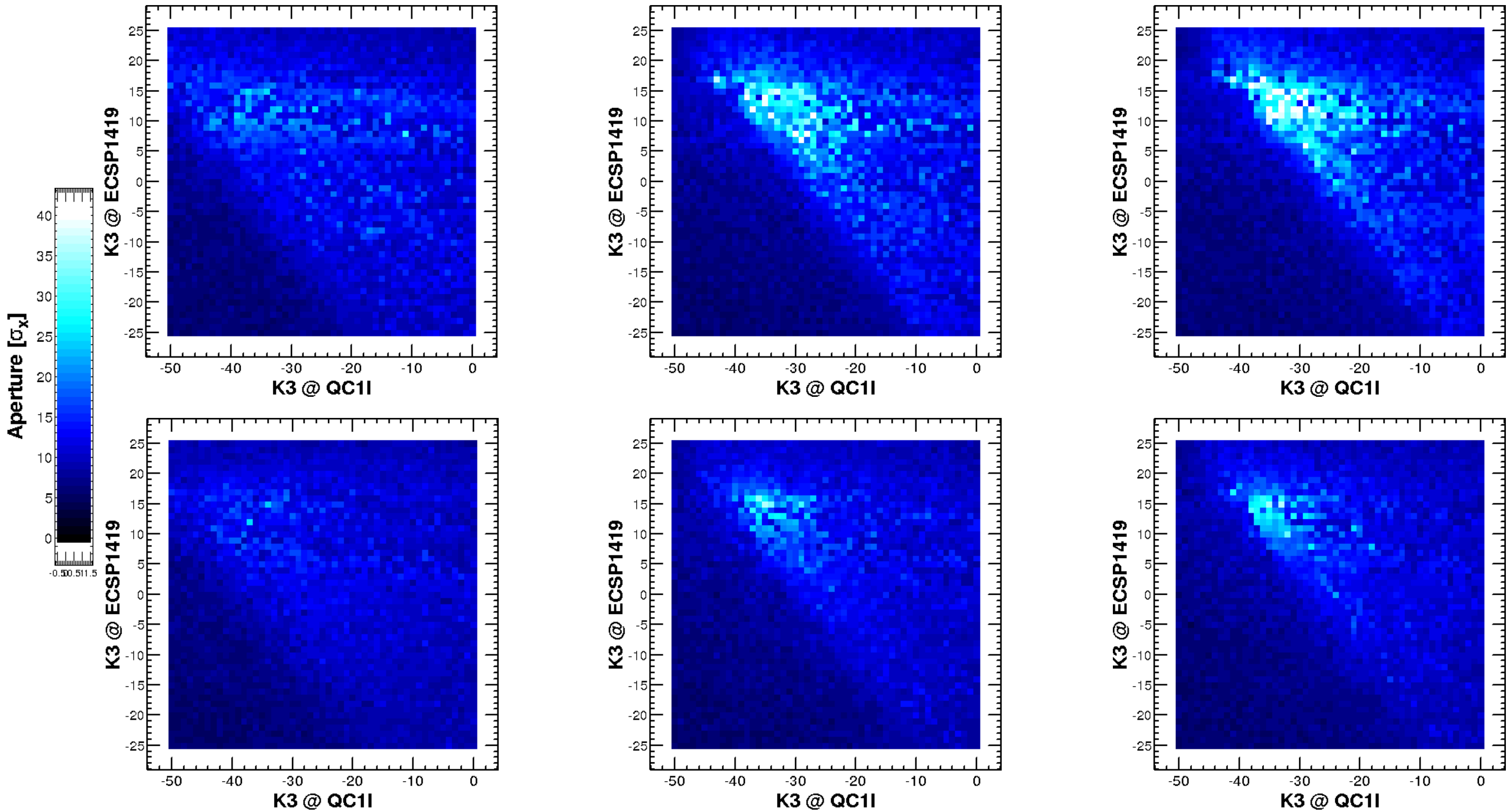


- **Good DA region disappears by adding QC's allowed multipoles in design**

DA blocking multipole study(2)

Simplifed IR + Non-allowed(K3,7,11,15,19) & Allowed(K5,K9,K13,17,K21) in Design without CW

Allowd 100% | *Allowd 10%* | *Allowd 1%*



Without off-axis solenoid

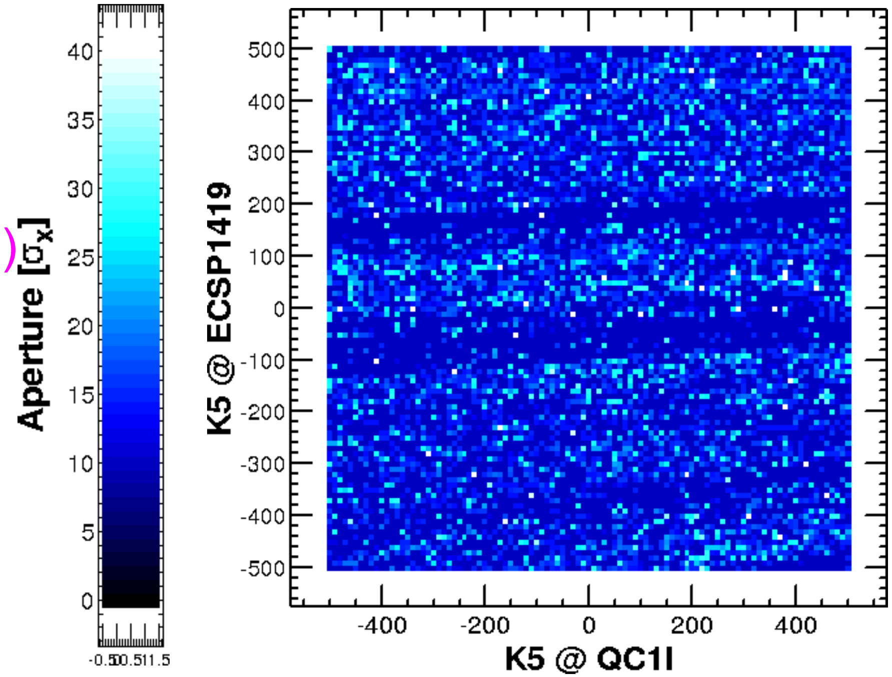
With off-axis solenoid (SK2-SK9)

- **Off-axis solenoid multipoles reduce aperture, but, is not critical**

DA blocking multipole study(3)

Trial to correct K5 allowed multipoles

- Smiplified IR + K5(QCs Allowed in Design)
- K3 correctors are optimized(QC1I, ECSP1419)
- K5 correctors are introduced into same place



- Aperture degraded by adding QC's K5 allowed multipole is improved by using K5 correctors
- Some correction parameter point exceeds 40σ
- Good parameter region looks like fragmented

Summary

- Beam-beam effect reduces dynamic aperture & Touschek lifetime
- DA degradation by BB effect COULD be cured by crab waist if I-cell of CW was linear
- Intrinsic non-linearity(Maxwellian fringe) blocks dynamic aperture of CW on our lattice
- Achieving 40σ aperture by using octupole correctors is difficult without QCs allowed multipole supression
- Tuning K5 corrector on real machine WOULD be difficult because of fragmentation of good parameter region

Backup

CW location dependency without higher order multipoles