# DA studies with Xsuite & bisection applied to DA analysis

With help from scripts made by M. Hofer and P. Kicsiny
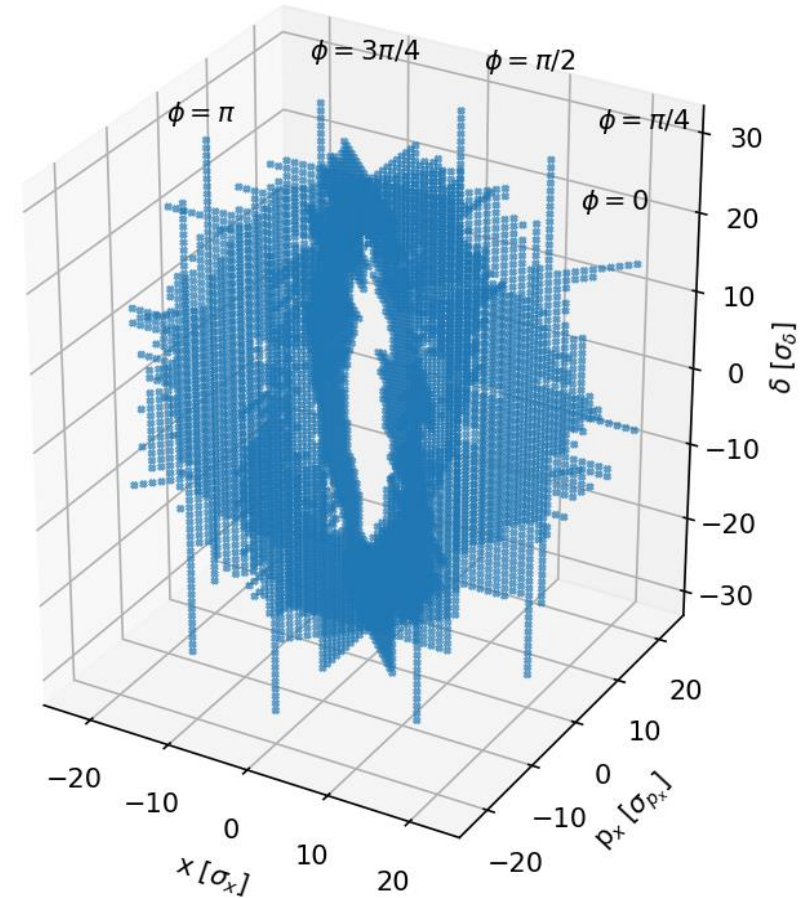
Oide's DA

- Tracking planes with varying action J, phase φ and energy offset δ
- J varies in ±40σ, δ varies in ±3% (or less depending on beam energy)
- Φ is [0, π/4, π/2, 3π/4, π, -3π/4, -π/2, -π/4]
- Average the particle survival over the various phases
- X = Y = J cos(Φ) , PX = PY = J sin(Φ) and $J_x/J_y = \varepsilon_x/\varepsilon_y$
- The 'brute force' DA tracks a lot of macroparticles
  - *e.g.* 10k to 40k macroparticles depending on grid size and refinement.
  - The particles surviving in the 'central region' of the DA take a lot of time for a not so relevant information, and the better the DA the more time it will take.
- Proposal: perform a bisection to find the DA limit to decrease the macroparticles tracked and the DA simulation duration.
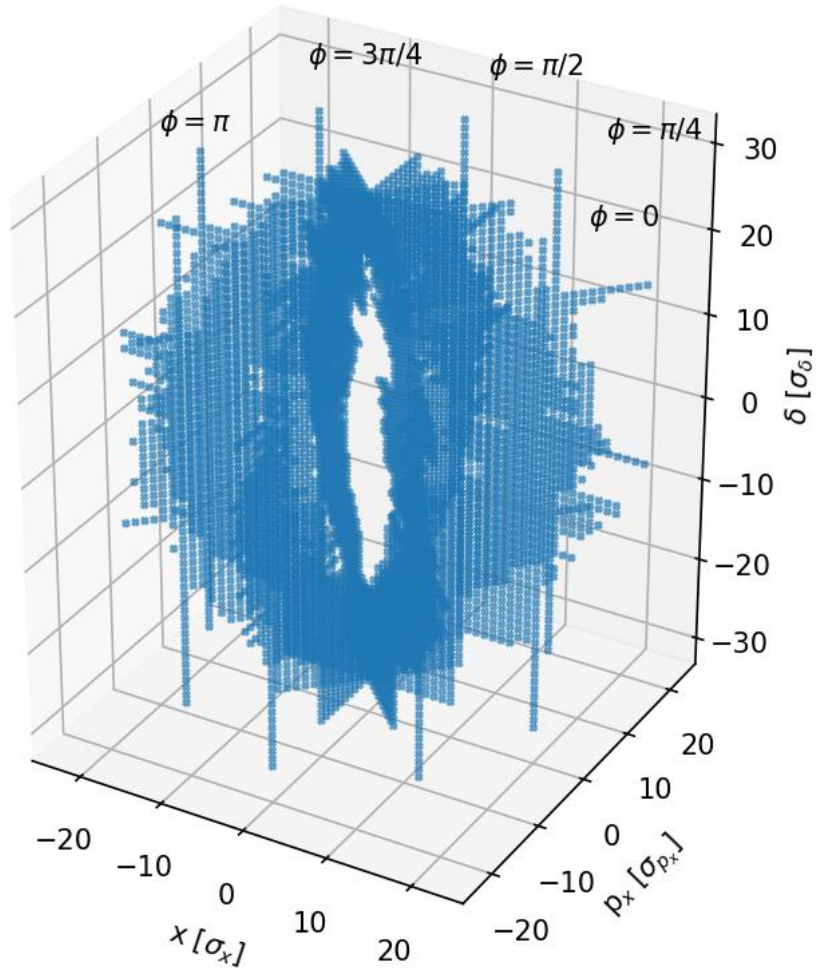
Oide's DA - Macroparticle grid
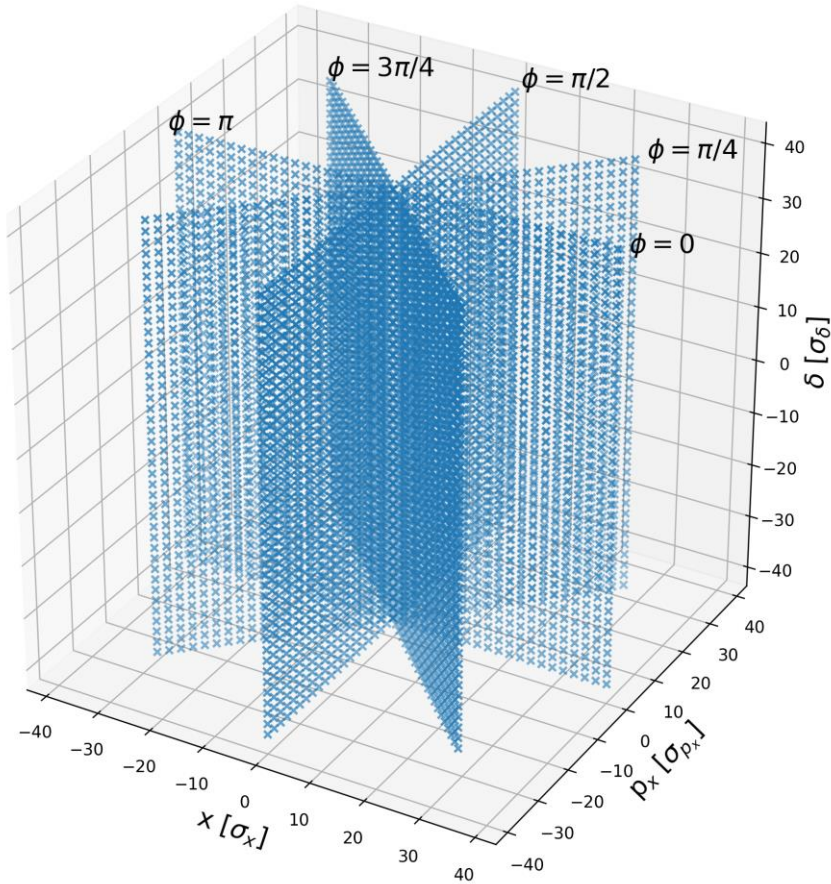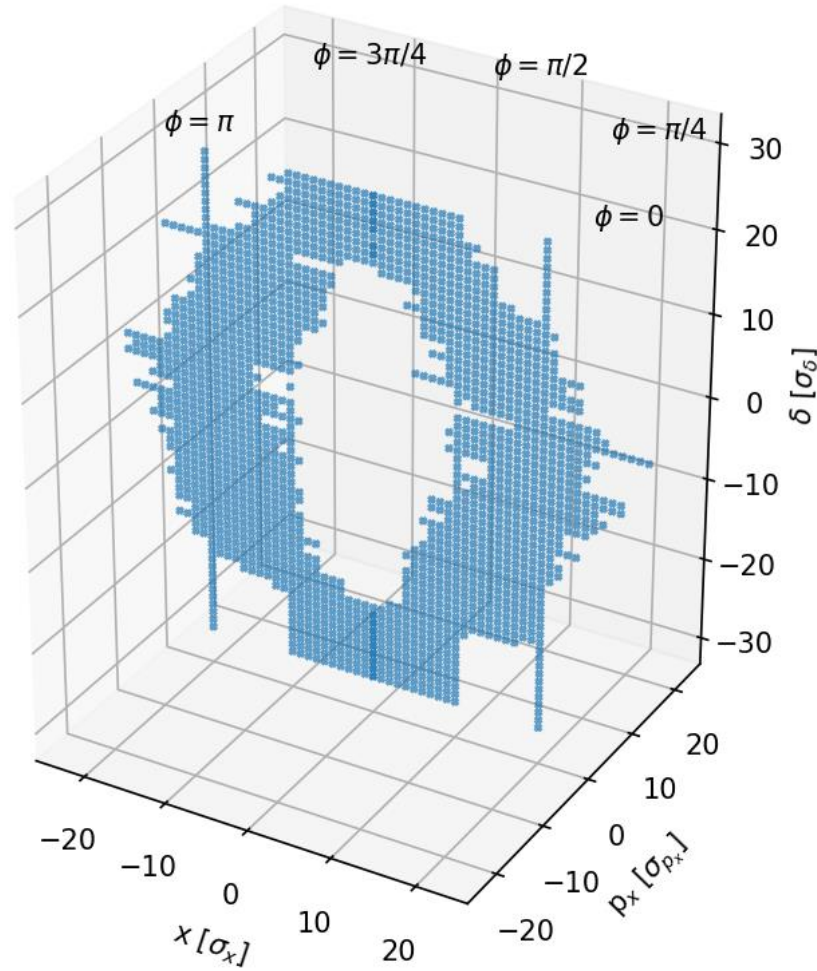

'Brute force' grid
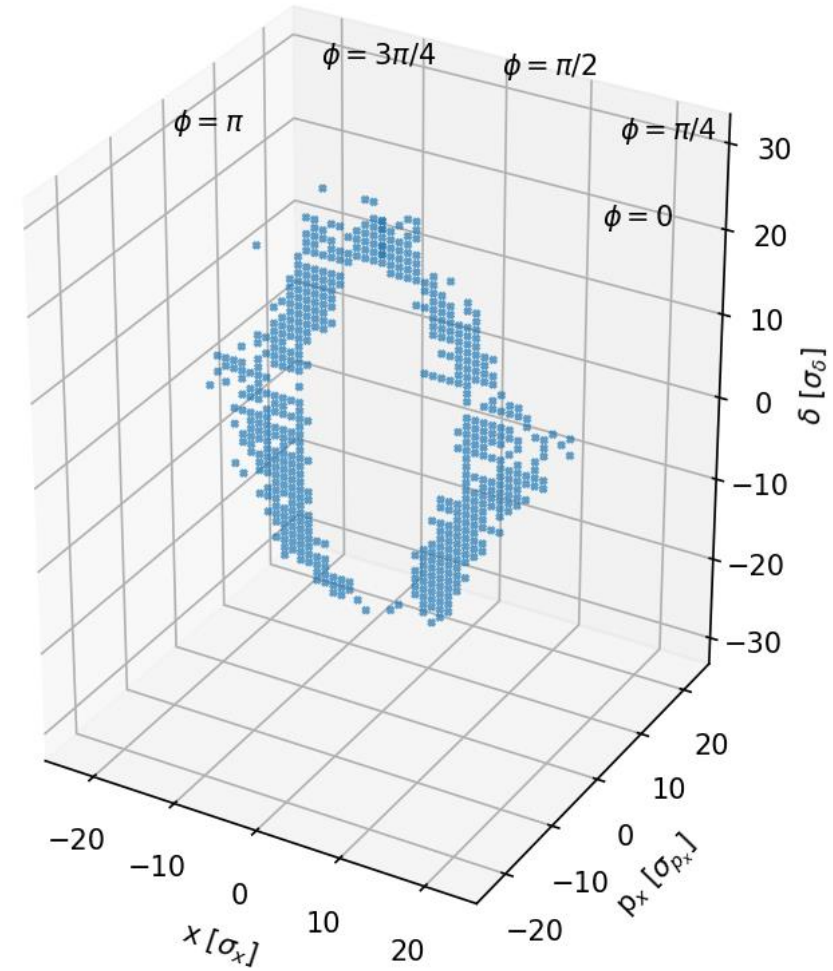

Grid resulting from bisection

Oide's DA - Macroparticle grid

All phases

Only φ=0

Only φ=0, and all survived

Resulting DA

As you increase the 'depth' of tracked macroparticle in action J, the central area becomes increasingly whiter, proving the particles survived.

Some parts of the central region appear less white because of the average between phase planes because some planes have no data at this (δ,J) position.
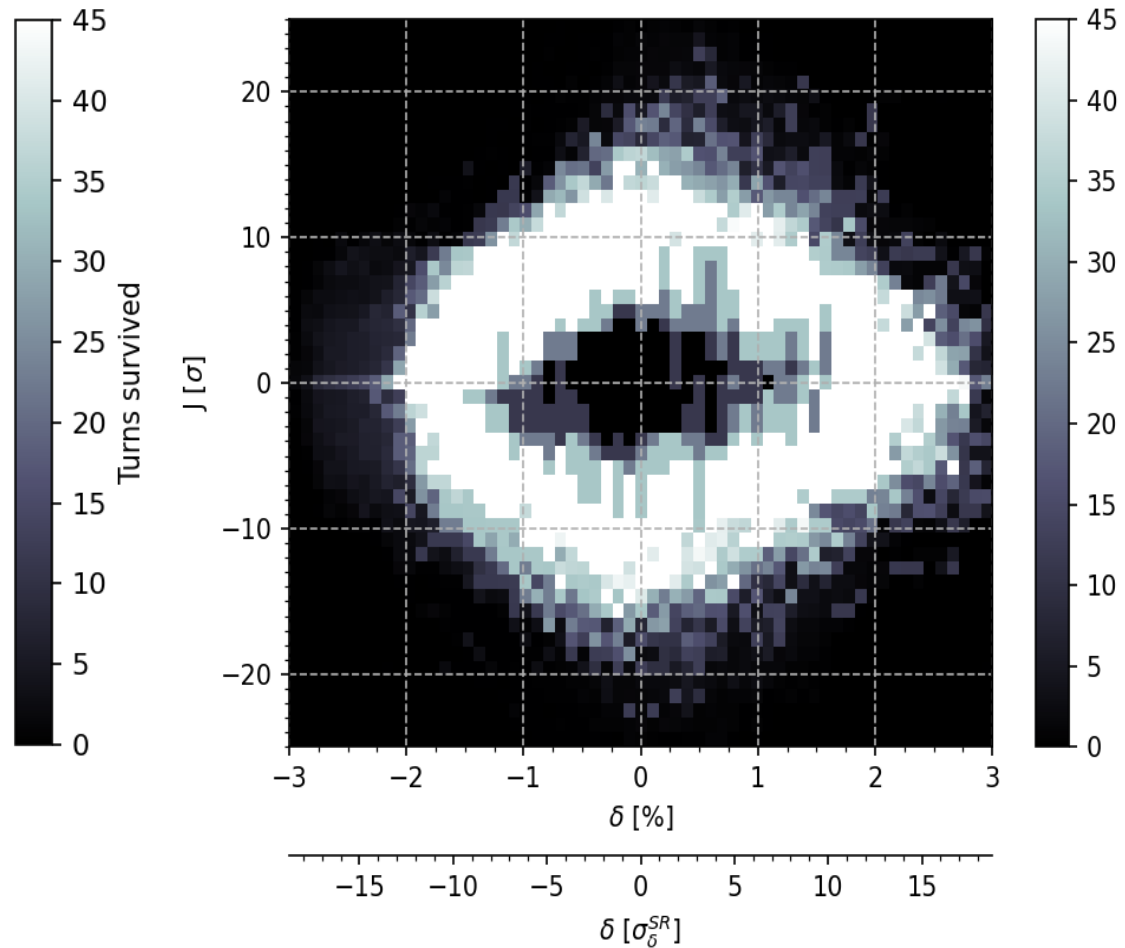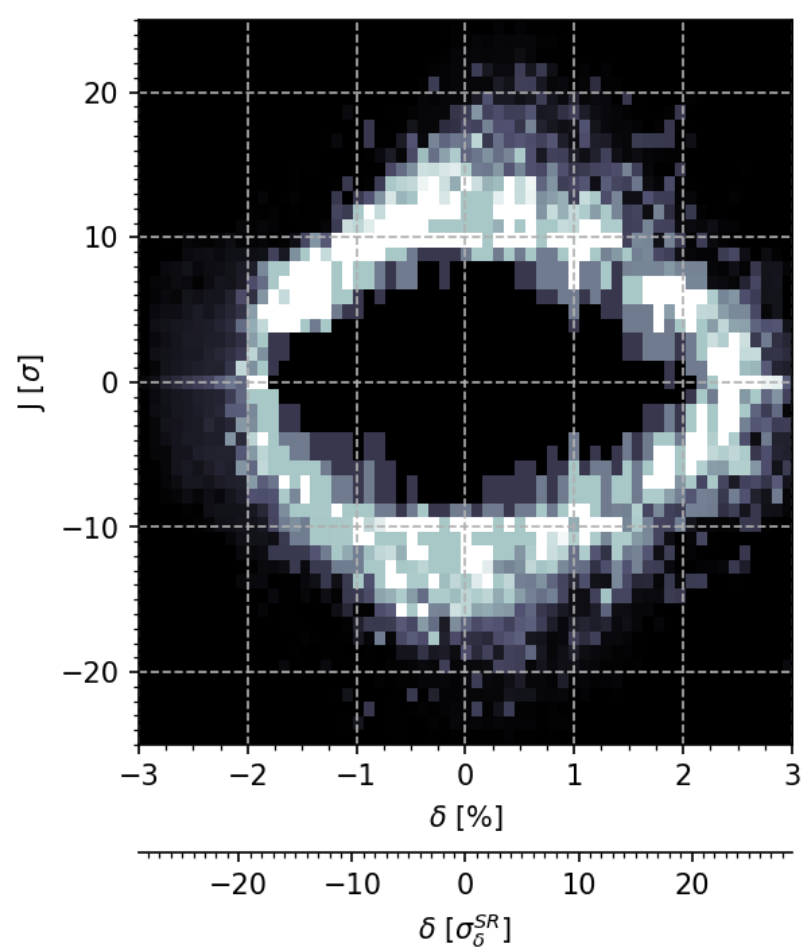
Potential interest of bisection for DA

- Assuming a fixed time to track in the FCC-ee lattice, let's say 6ms/macroparticle/turn, if one needs less macroparticles to find the DA than a 'brute force' method:
  - One can increase the number of turns to perform the DA (is it necessary ?)
  - One can refine the grid to perform a more precise DA (is it necessary ?)
  - One can compute the DA faster in view of DA optimization as presented by S. White.
- This method can be implemented as a test on the GitLab repository.

Some results

DA at Z with varying RF voltage (V24.3_LCC)
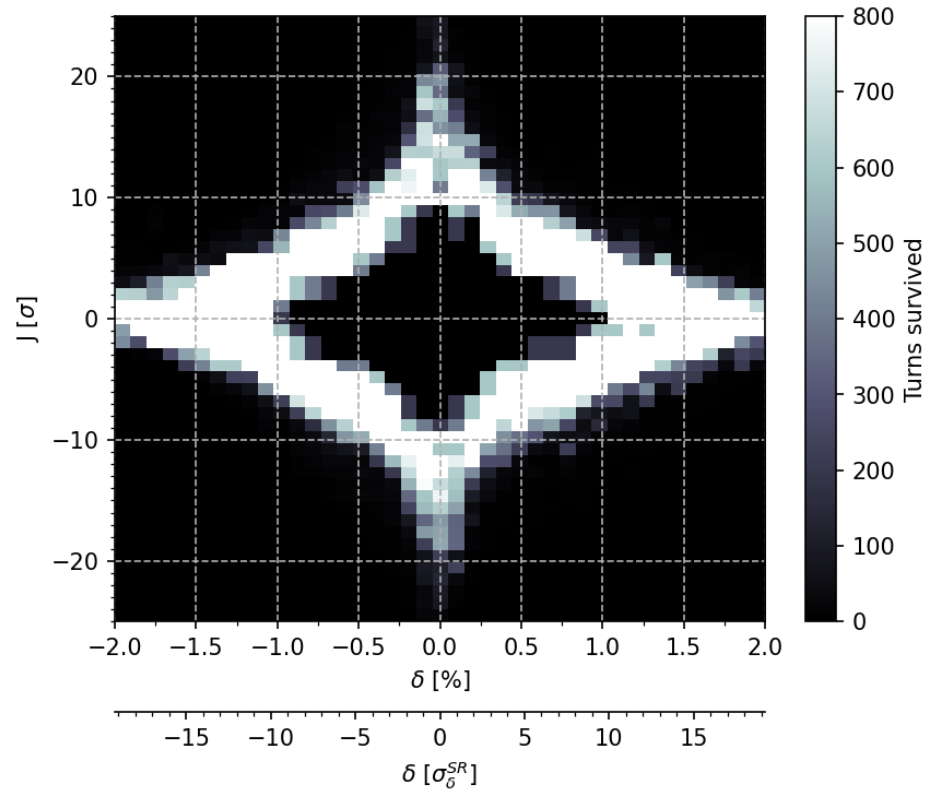
200 MV total RF voltage
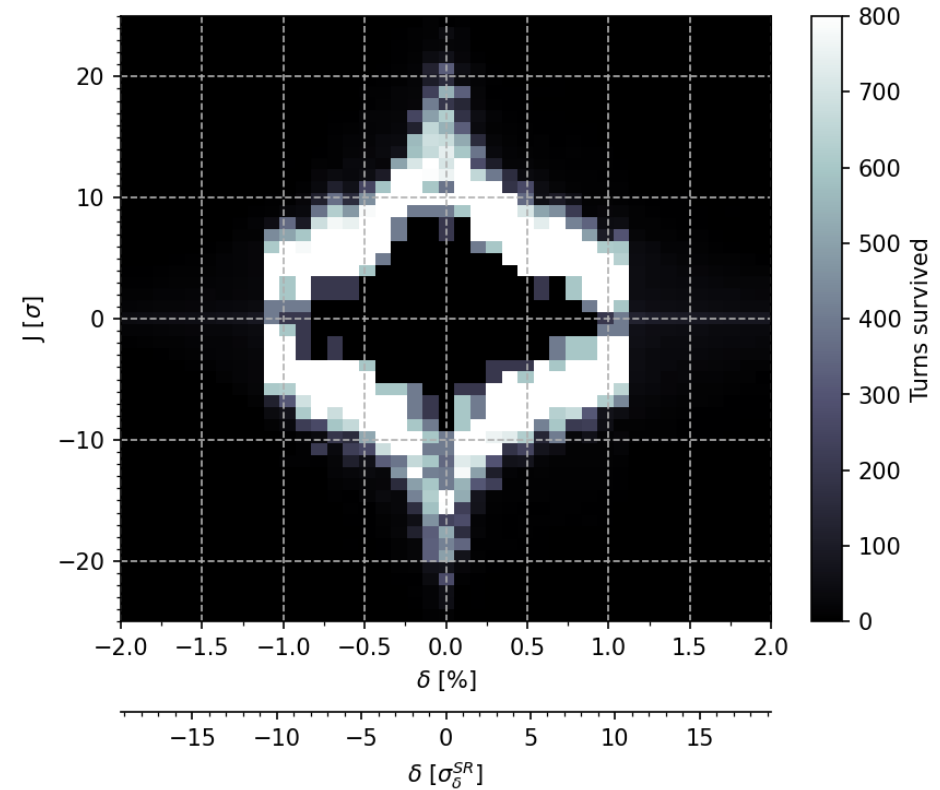
80 MV total RF voltage

Agrees with the RF acceptance formula.

V24.1 (LCC) @Z

LCC_V24.3 | E_{beam}=45.6 GeV, I_{beam}=1456mA (N=2.45E+11ppb)
ε_x=0.69nm.rad, $\varepsilon_y/\varepsilon_x$ = 2‰, $\beta^*_{x,y}$={0.10m, 0.7mm}
σ_δ=0.037%, σ_z=5.2mm, $Q_{x|y|s}$={198.200, 174.296, 0.030}
V_{rf} 400|800MHz=0.08GV|0.00GV, No crab waist   900 turns

CW=0%

Similar DA with crab waist off between Xsuite and SAD.
Still better DA off-energy

With crab waist on, seems to be different,
- which value for cs_comp is set in SAD ?
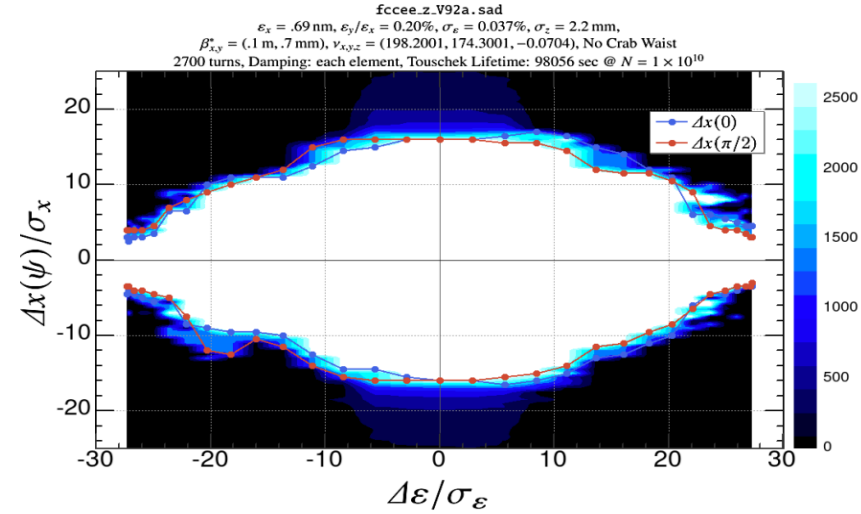- the number of turns differ 900 turns for Xsuite, 2700 turns for SAD.

The RF voltage is 80 MV.
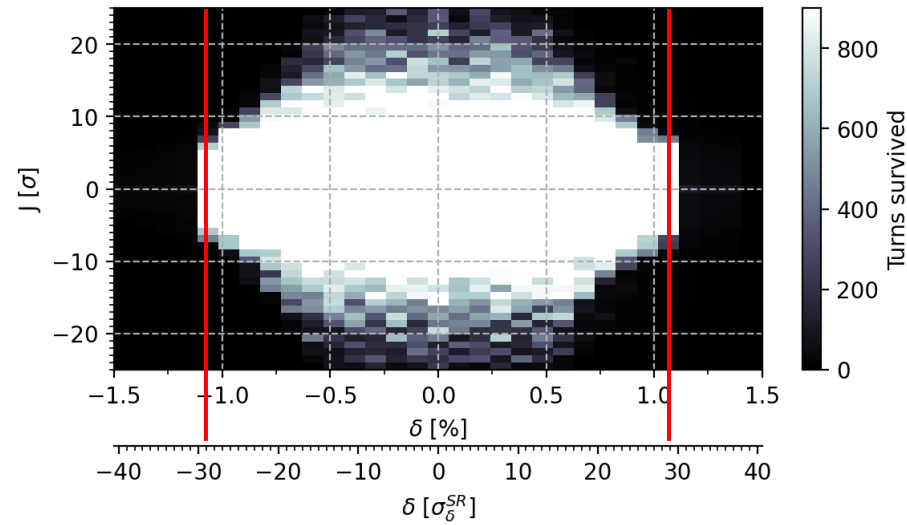
SAD results from K. Oide

LCC_V24.3 | E_{beam}=45.6 GeV, I_{beam}=1456mA (N=2.45E+11ppb)
ε_x=0.69nm.rad, $\varepsilon_y/\varepsilon_x$ = 2‰, $\beta^*_{x,y}$={0.10m, 0.7mm}
σ_δ=0.037%, σ_z=5.2mm, $Q_{x|y|s}$={198.200, 174.296, 0.030}
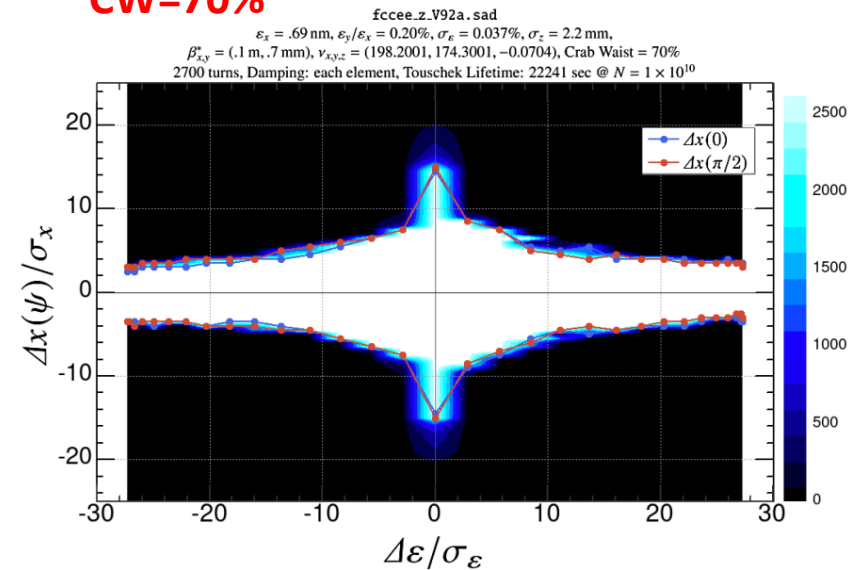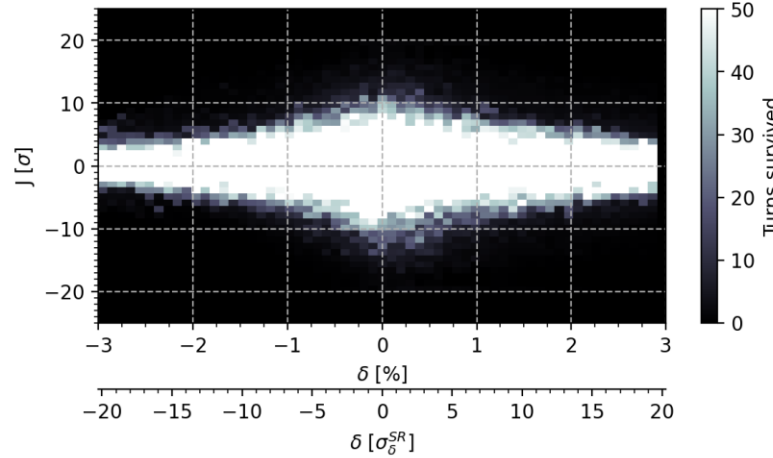V_{rf} 400|800MHz=0.08GV|0.00GV, Crab waist=70%, 900 turns
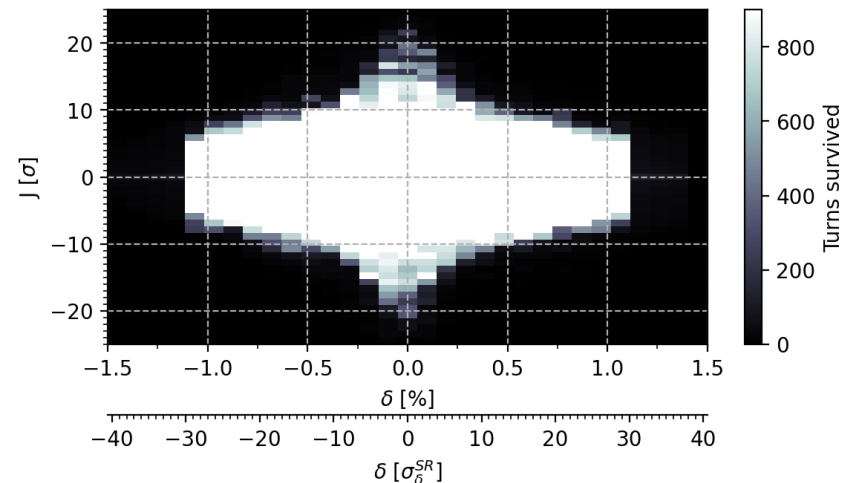
CW=70%

V24.1 (LCC) @tt

LCC_V24.3 | E_{beam}=182.5 GeV, I_{beam}=5mA (N=2.02E+11ppb)
ε_x=2.11nm.rad, $\varepsilon_y/\varepsilon_x$ = 2‰, $\beta^*_{x,y}$={1.00m, 1.5mm}
σ_δ=0.148%, σ_z=1.6mm, $Q_{x|y|s}$={350.206, 266.277, 0.124}
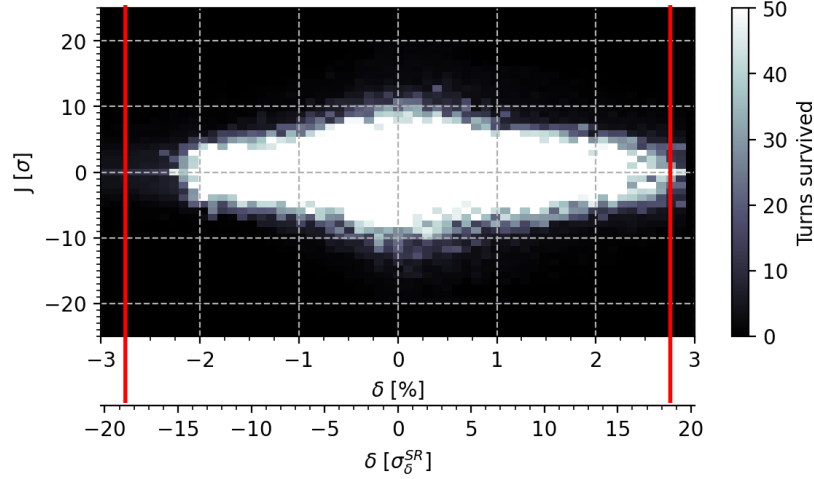Crab waist=40%, 50 turns

Vrf = 11.65GV and 800MHz

CW = 40%

fccee_t_V92_2.sad
ε_x = 2.1 nm, $\varepsilon_y/\varepsilon_x$ = 0.20%, σ_ε = 0.143%, σ_z = 2.0 mm,
$\beta^*_{x,y}$ = (.97 m, 1.6 mm), $\nu_{x,y,z}$ = (350.2018, 266.2883, −0.1068), Crab Waist = 40%
42 turns, Damping: each element, Touschek Lifetime: 4.06×10^7 sec @ $N = 1 \times 10^{10}$
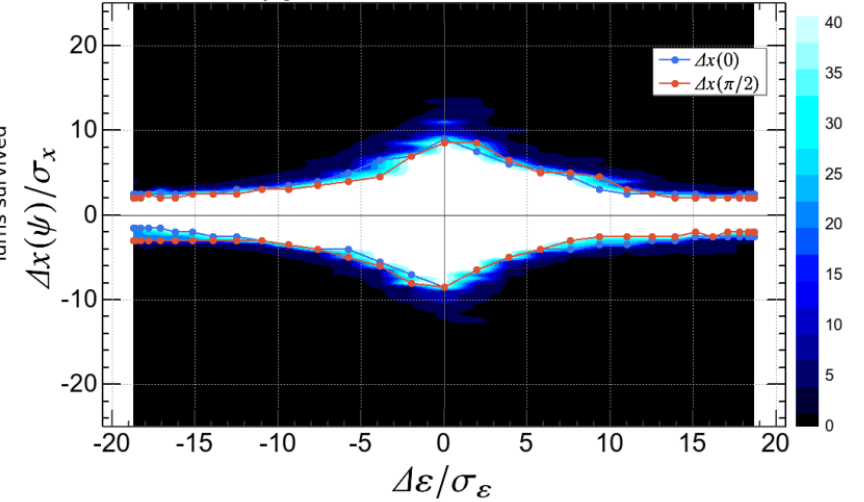
LCC_V24.3 | E_{beam}=182.5 GeV, I_{beam}=5mA (N=2.02E+11ppb)
ε_x=2.11nm.rad, $\varepsilon_y/\varepsilon_x$ = 2‰, $\beta^*_{x,y}$={1.00m, 1.5mm}
σ_δ=0.148%, σ_z=2.1mm, $Q_{x|y|s}$={350.206, 266.277, 0.097}
', Crab waist=40%, 50 turns

Vrf = 10GV and 800MHz

Crab waist at 0 or 40%
cs_frac = cs_comp = 0.4

800MHz RF frequency with
harmonic = 242400 and not 135000
and same RF voltage as GHC lattice

LCC_V24.3 | E_{beam}=182.5 GeV, I_{beam}=5mA (N=2.02E+11ppb)
ε_x=2.11nm.rad, $\varepsilon_y/\varepsilon_x$ = 2‰, $\beta^*_{x,y}$={1.00m, 1.5mm}
σ_δ=0.148%, σ_z=2.1mm, $Q_{x|y|s}$={350.206, 266.277, 0.097}
Vrf = 10GV and 800MHz   ,   No crab waist   , 50 turns
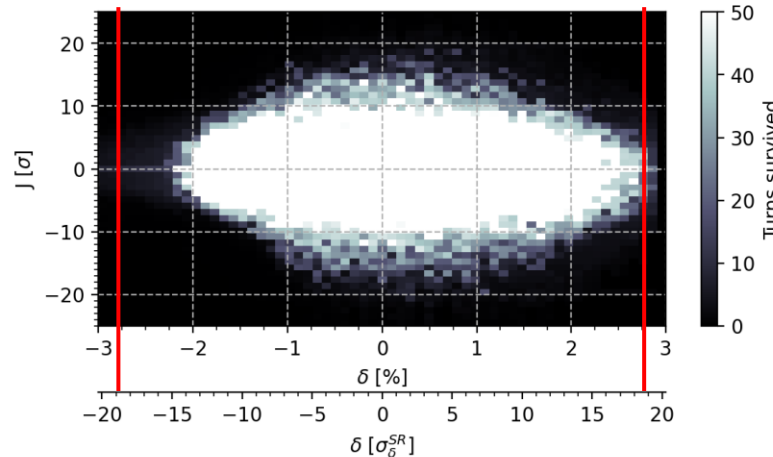
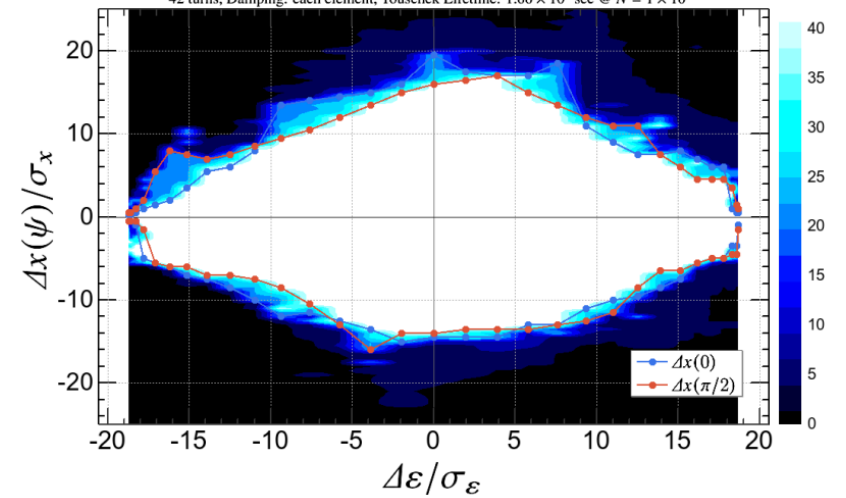

CW = 0

fccee_t_V92_2.sad
ε_x = 2.1 nm, $\varepsilon_y/\varepsilon_x$ = 0.20%, σ_ε = 0.143%, σ_z = 2.0 mm,
$\beta^*_{x,y}$ = (.97 m, 1.6 mm), $\nu_{x,y,z}$ = (350.2018, 266.2883, −0.1068), No Crab Waist
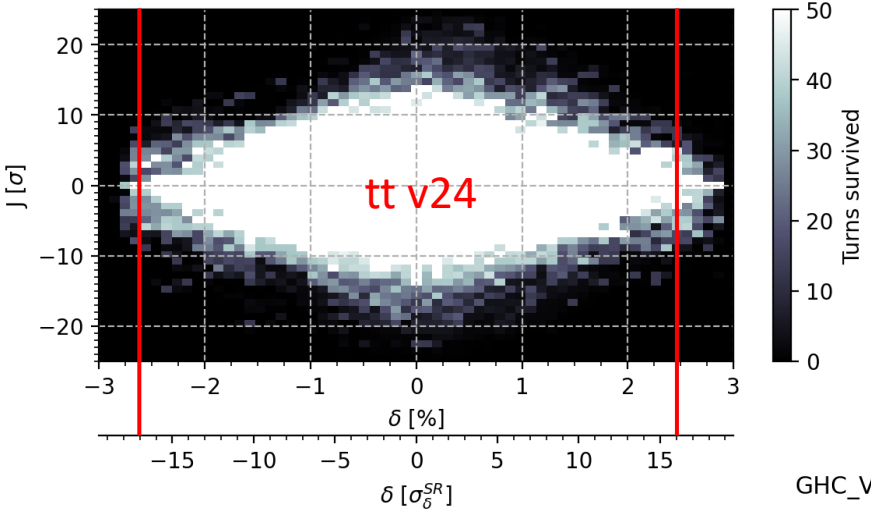42 turns, Damping: each element, Touschek Lifetime: 1.66×10^8 sec @ $N = 1 \times 10^{10}$

V23 vs V24.1 (GHC lattice) @tt

GHC_V24.1 | E_{beam}=182.5 GeV, I_{beam}=5mA (N=1.69E+11ppb)
ε_x=1.49nm.rad, $\varepsilon_y/\varepsilon_x$ = 2‰, $\beta_{x,y}^*$={0.80m, 1.5mm}
σ_δ =0.154%, σ_z = 1.6mm, $Q_{x|y|s}$={398.138, 398.209, 0.100}
V_{rf} 400|800MHz=2.10GV|9.55GV, Crab waist=40%, 50 turns

tt v24

tt v24

GHC_V23 | E_{beam}=182.5 GeV, I_{beam}=4mA (N=1.69E+11ppb)
ε_x=1.61nm.rad, $\varepsilon_y/\varepsilon_x$ = 2‰, $\beta_{x,y}^*$={0.80m, 1.5mm}
σ_δ=0.162%, σ_z=2.0mm, $Q_{x|y|s}$={398.138, 398.209, 0.083}
V_{rf} 400|800MHz=2.10GV|9.55GV, Crab waist=40%, 45 turns

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Peter's result

tt v23
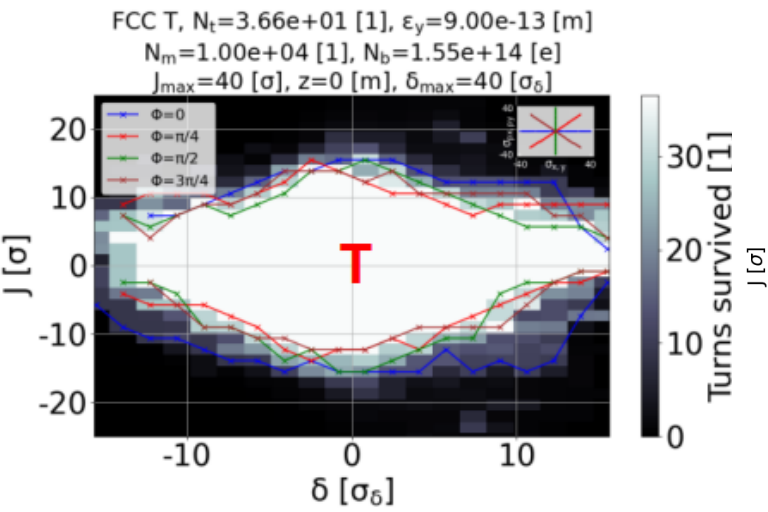
$t\bar{t}$
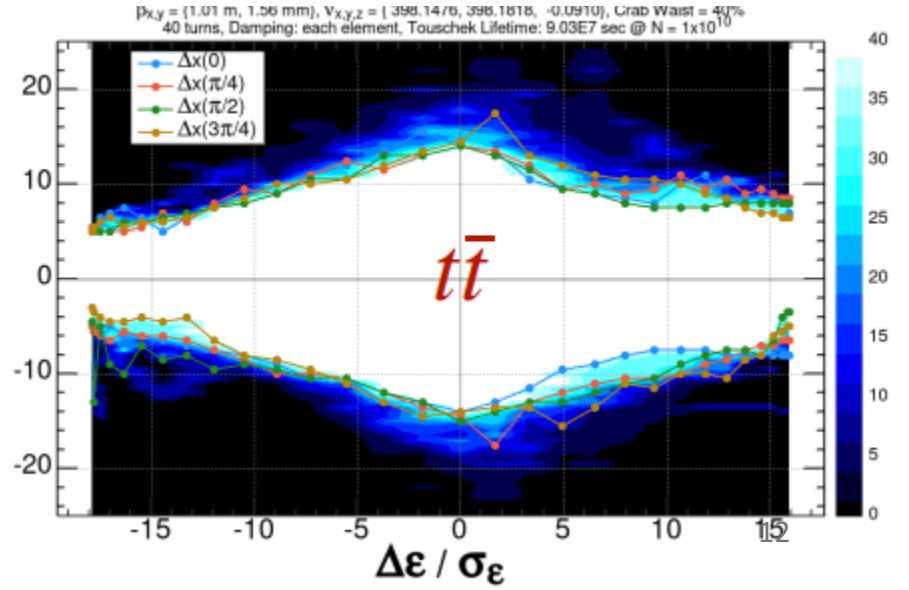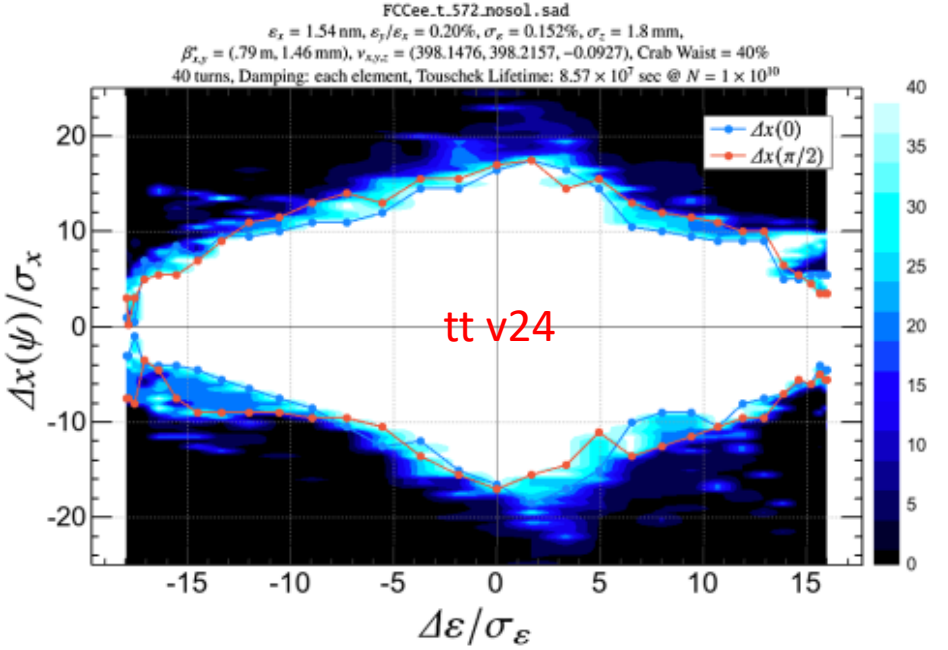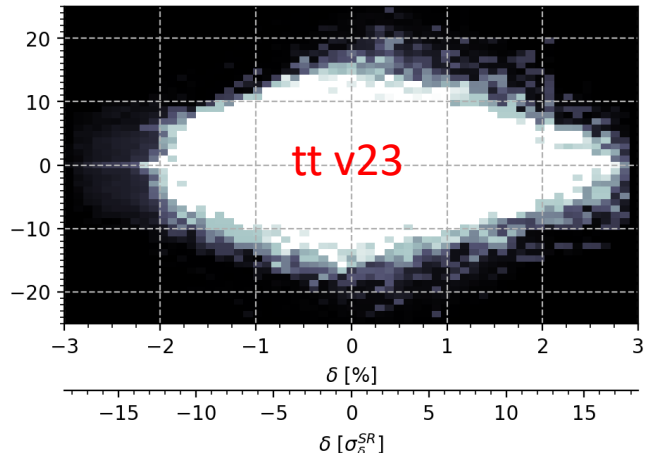
V24.1 (GHC lattice) @Z

GHC_V24.1 | E_{beam}=45.6 GeV, I_{beam}=1278mA (N=2.16E+11ppb)
ε_x=0.70nm.rad, $\varepsilon_y/\varepsilon_x$ = 2‰, $\beta_{x,y}^*$={0.10m, 0.7mm}
σ_δ =0.039%, σ_z = 5.5mm, $Q_{x|y|s}$={218.156, 222.199, 0.029}
V_{rf} 400|800MHz=0.08GV|0.00GV, Crab waist=70%, 800 turns
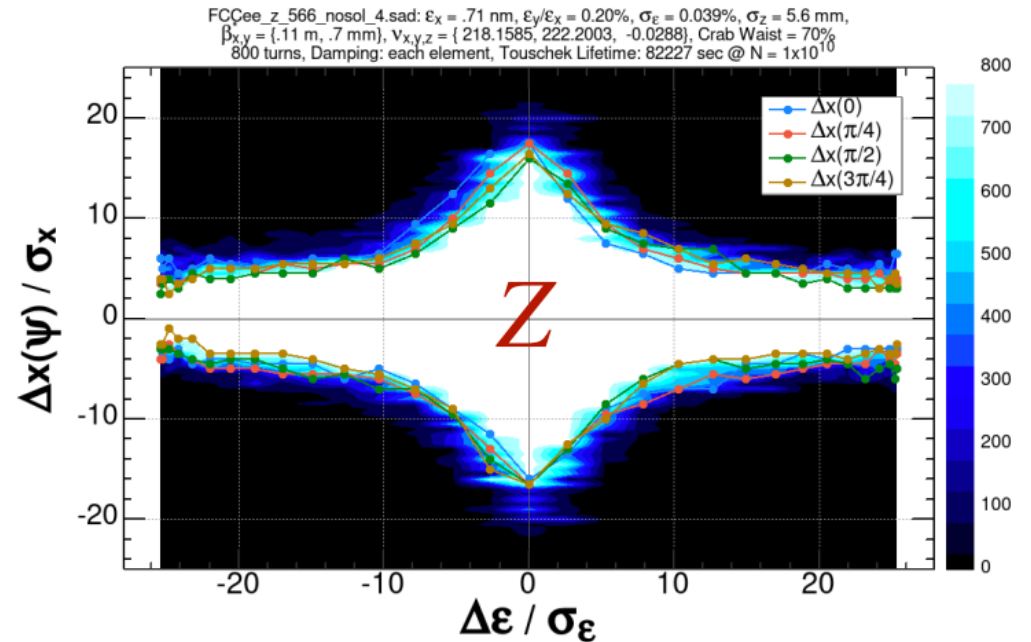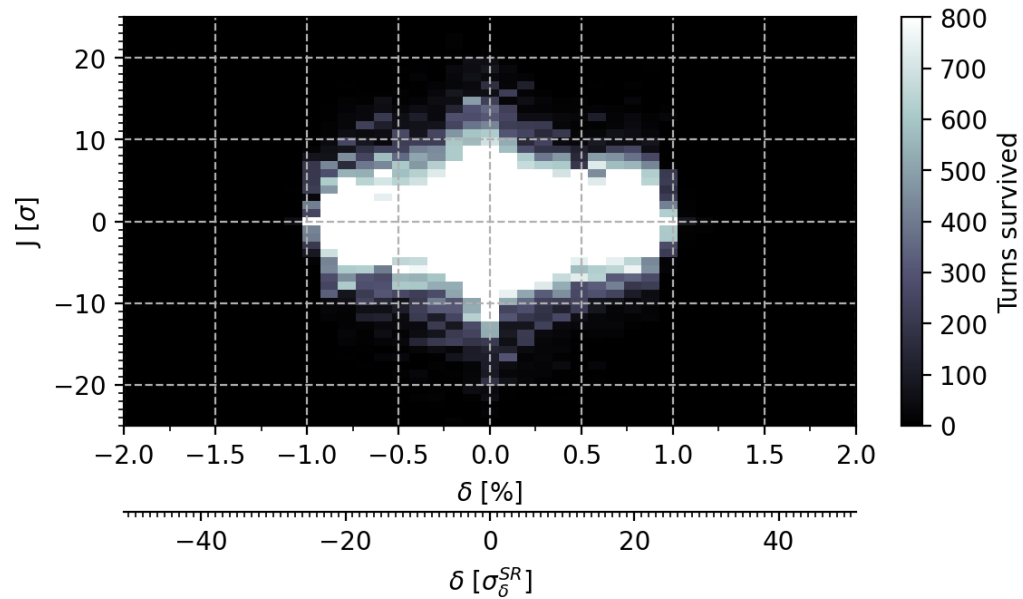
Summary & outlook

- Used Xsuite to perform DA study similar to what P. Kisciny had presented in previous optics meeting(s) with the addition of bisection to find the DA limit or chaotic region with less macroparticles (*i.e.* faster).

- It can be implemented as a **test on Gitlab**, and it can be used to **perform DA-based optimization with Xsuite**.

- Preliminary DA comparison between Xsuite and SAD yields comparable results **without crab waist** (K. Oide results of 180th optics meeting). **Adding crab waist** the results differ more. May be explained by the use of different settings of some variables (*e.g.* cs_comp), different magnet slicing, different number of tracked turn, etc..

- Comparison with pyAT to come next, currently in discussion with S. White

Parameters

- SR with quantum fluctuation
- Slicing as in the GitLab repository for the GHC lattice ([ref](ref))
- Similar slicing for the LCC lattice (see next slide)

LCC lattice slicing

// Slicing with special attention ot IR quads and sextupoles
SELECT, FLAG=makethin, CLASS=RFCAVITY, SLICE = 1;
SELECT, FLAG=makethin, CLASS=sbend, SLICE = 4;
SELECT, FLAG=makethin, CLASS=rbend, SLICE = 4;
SELECT, FLAG=makethin, CLASS=quadrupole, SLICE = 4;
SELECT, FLAG=makethin, CLASS=sextupole, SLICE = 4;
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SELECT, FLAG=makethin, PATTERN=q[fd][123456], SLICE = 10;
SELECT, FLAG=makethin, PATTERN=q[fd][m], SLICE = 10;
SELECT, FLAG=makethin, PATTERN=qd0, SLICE = 125;
SELECT, FLAG=makethin, PATTERN=s[fd][xy], SLICE = 20;
SELECT, FLAG=makethin, PATTERN=s[fd][m], SLICE = 20;
SELECT, FLAG=makethin, PATTERN=scrab[lr], SLICE = 20;