DYNAMIC APERTURE AND MOMENTUM ACCEPTANCE IN THE ALTERNATIVE LATTICE DESIGN

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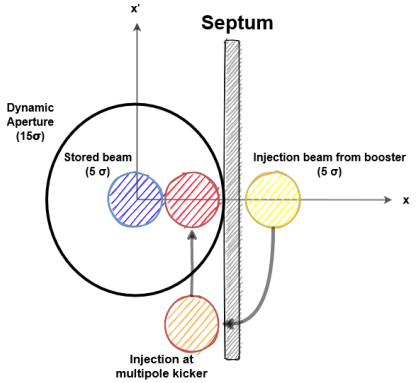
Thanks to G. Iadarola, R. de Maria, F. v. d. Veken, D. Shatilov, S. Liuzzo, R. Tomás, K. Oide, F. Zimmermann

Introduction

- Control of chromatic and anharmonic properties of FCC-ee strongly linked to its performance
  - Low β^* results strong sextupoles for chromaticity correction, beamstrahlung leading to particle with large $\Delta p/p$ requiring sufficient acceptance of machine, top-up injection with either large transverse or momentum offset, …
  - Similar issues encountered in SR light sources, though at a smaller scale
- New optics concepts explored by P. Raimondi to address some challenges, in particular relaxed alignment requirements and simpler powering scheme
  - New arc cell optics and IR lattice, providing either explicit or implicit correction of chromatic and anharmonic terms
- Alternative Lattice is under continuous (& rapid) development, with the results of full 6D tracking studies with SR serving as input for further improvement

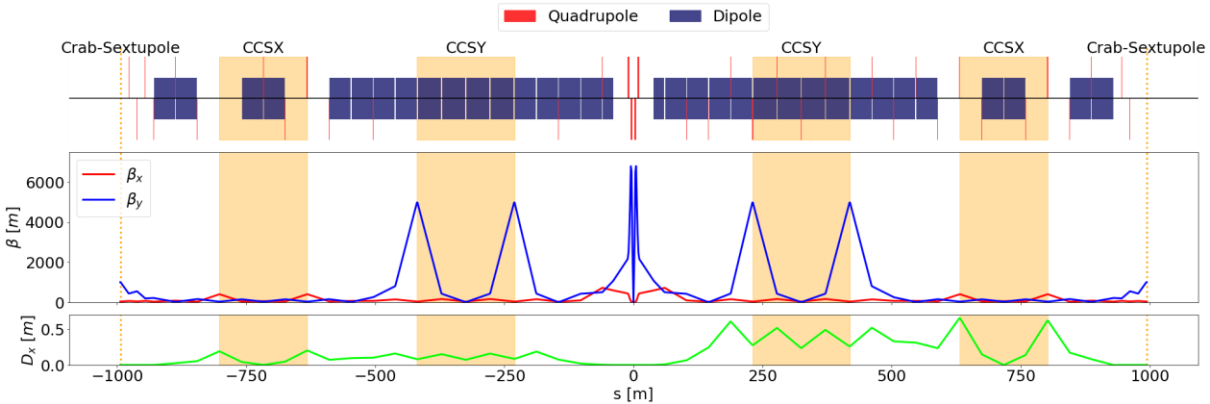
Requirements



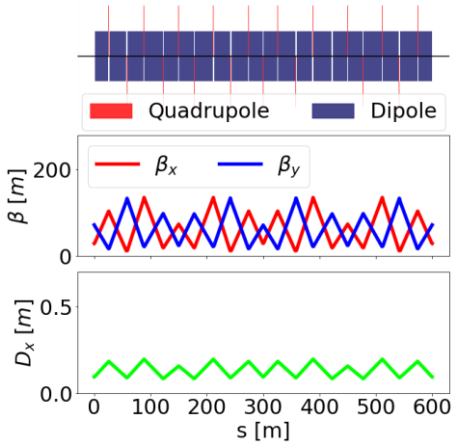
- Dynamic Aperture and Momentum acceptance strongly linked to the performance of the collider
  - Top-up injection is key ingredient in achieving target performance
    - Dynamic Aperture sufficiently large to keep stored beam and injected beam
    - In off-momentum injection scheme, requires sufficient DA for a given δ_p
  - To keep reasonable beam lifetime in the presence of beamstrahlung, a large momentum acceptance required
  - For $t\bar{t}$, requirement is $\delta_{acceptance} > 2.8\%$, while for Z, threshold $\delta_{acceptance} > 1.3\%$
  - Have to be achieved in the presence of errors
  - Additional constraints to keep small $\partial\beta^*_{x,y}/\partial\delta_p$ to increase luminosity (Reference)

Particle tracking in the alternative lattice

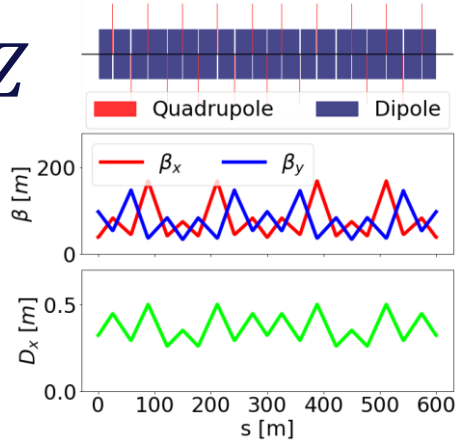
- Studies performed with recent lattice for both Z and $t\bar{t}$
  - Latest lattice available under branch V22_HFD in the FCC-ee optics repository



$t\bar{t}$



Z



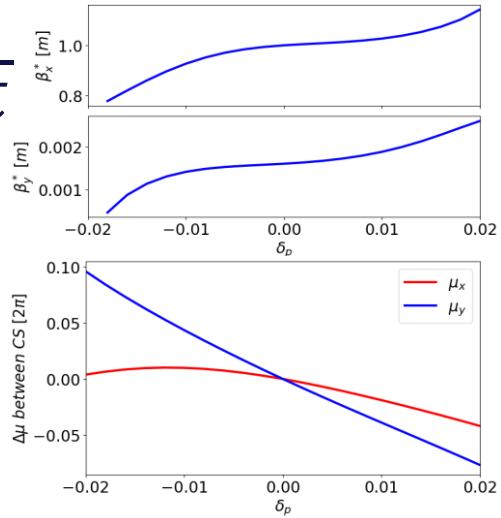
- For tracking, Xsuite tracking code used
  - Allows for 6D tracking with Synchrotron radiation and tapering
  - Also used for beam-beam and collimation studies in the FCC-ee

Chromatic optics around the low beta insertions

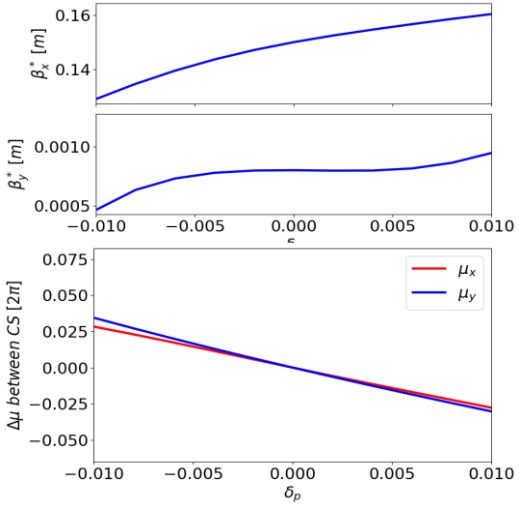
- Baseline IR design only features a vertical chromaticity correction section, whereas in the alternative layout, chromaticity correction in both planes
  - Moreover, dedicated crab-sextupoles and additional sextupole to correct chromatic optics

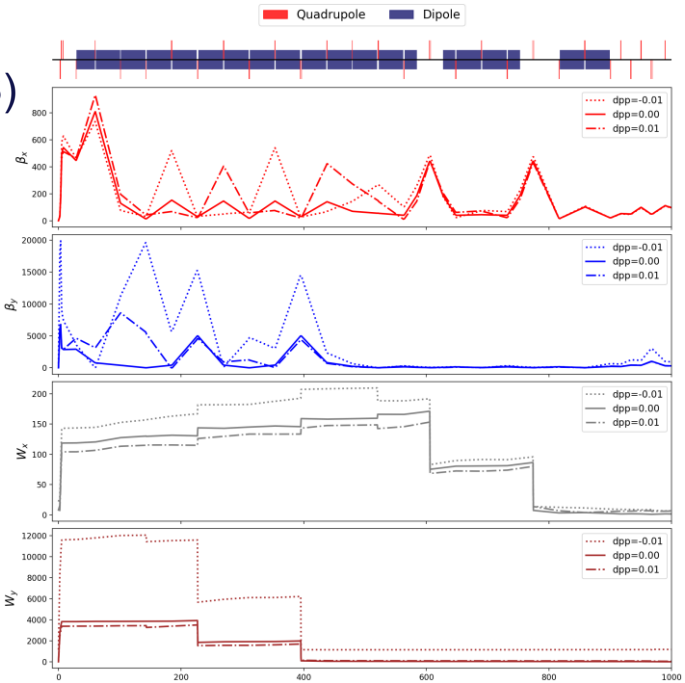
- Chromatic optics at the IP and between crab-sextupoles (CS) well controlled

$t\bar{t}$



Z

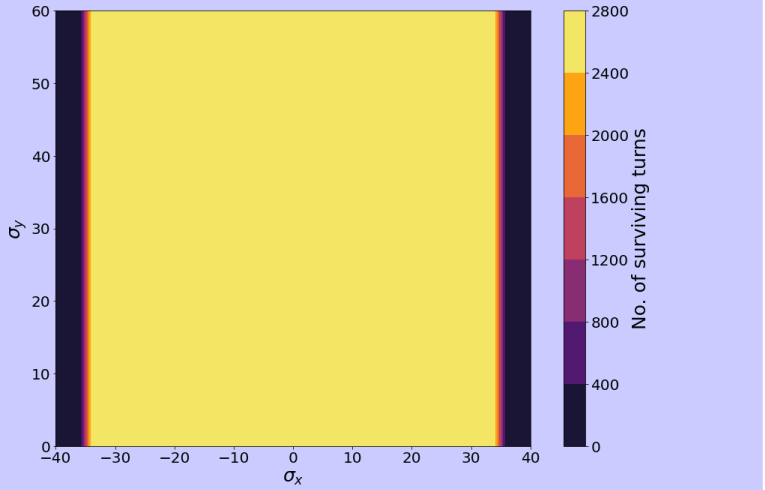
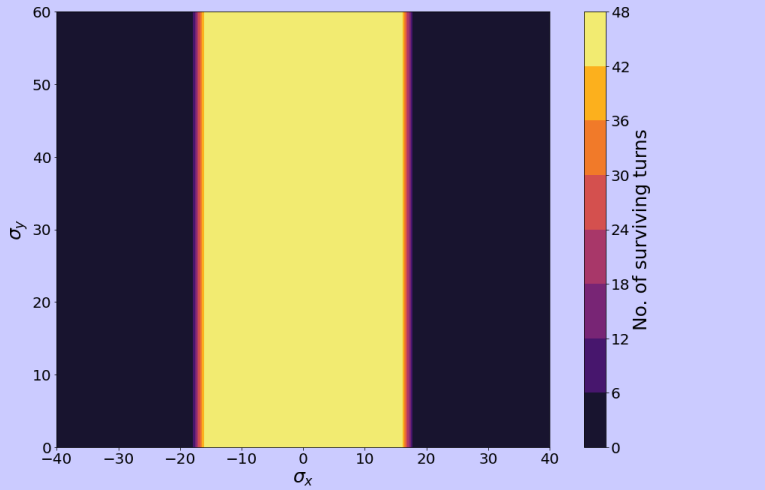




Dynamic aperture without radiation

- Tracking performed for one transverse damping time
  - Assuming emittance ratio of $\frac{\epsilon_y}{\epsilon_x} = 0.002$
- First check is 4D DA without synchrotron radiation and crab sextupoles turned off

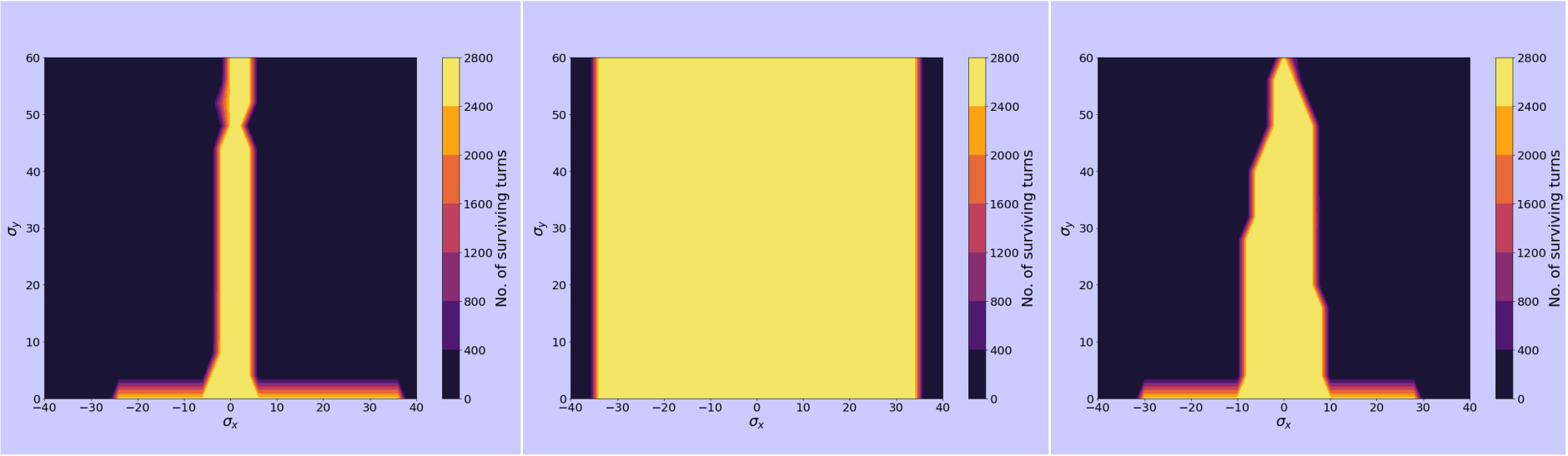
Operation mode	Turns
Z	2500
$t\bar{t}$	45

Z	$t\bar{t}$
	

Dynamic aperture without radiation

- Further tracking performed with initial momentum offset and no RF

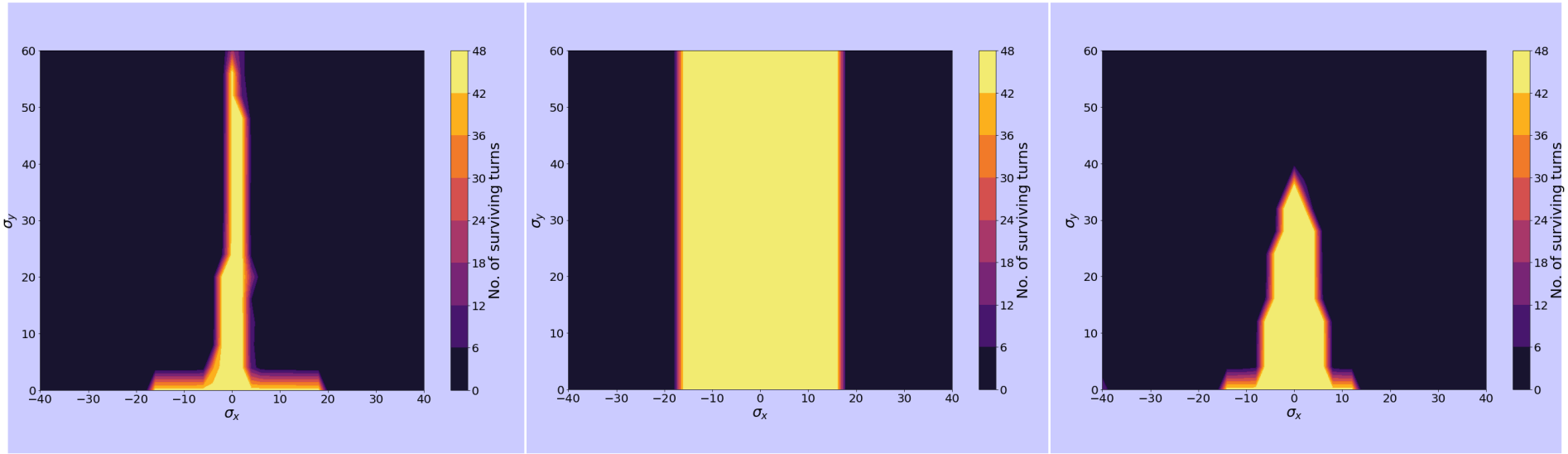
Z, $\delta_p = -1\%$	Z, $\delta_p = 0\%$	Z, $\delta_p = +1\%$



Dynamic aperture without radiation

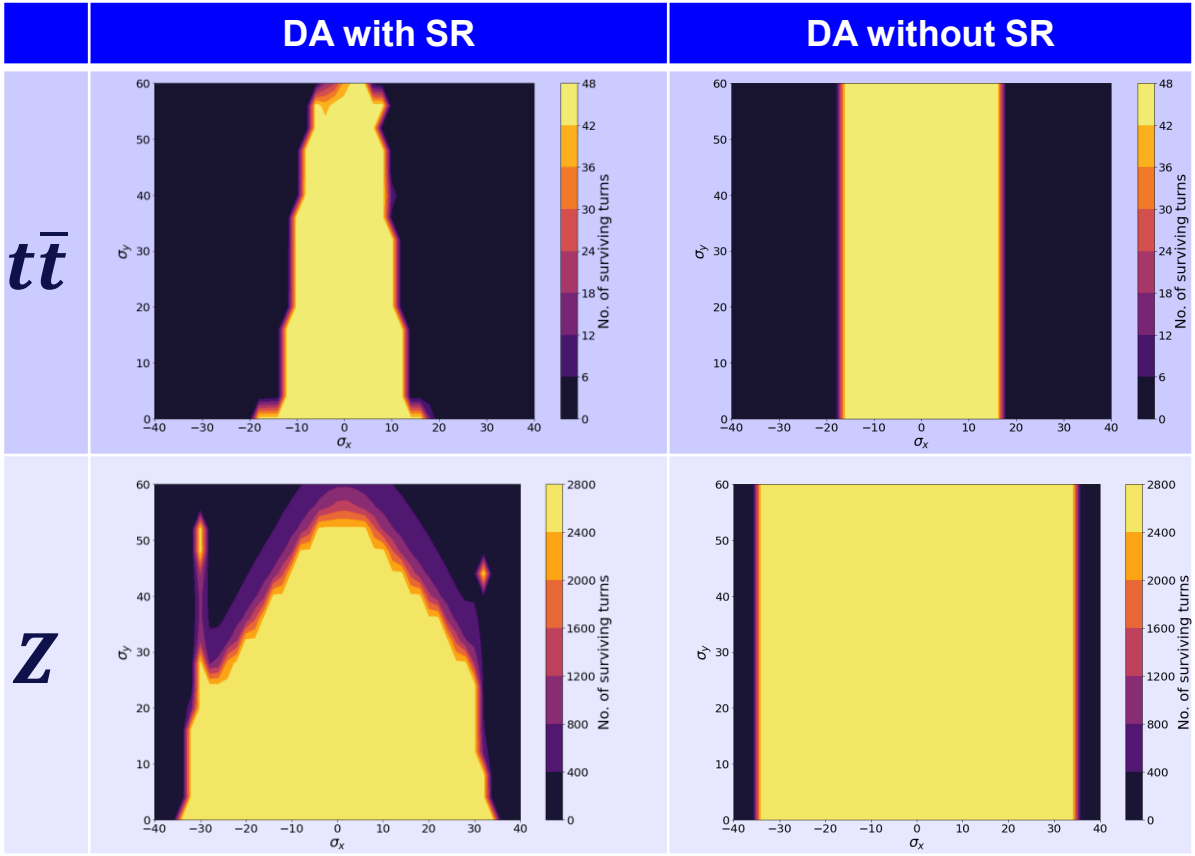
- Further tracking performed with initial momentum offset and no RF

$t\bar{t}$, $\delta_p = -1\%$	$t\bar{t}$, $\delta_p = 0\%$	$t\bar{t}$, $\delta_p = +1\%$



Dynamic aperture with radiation

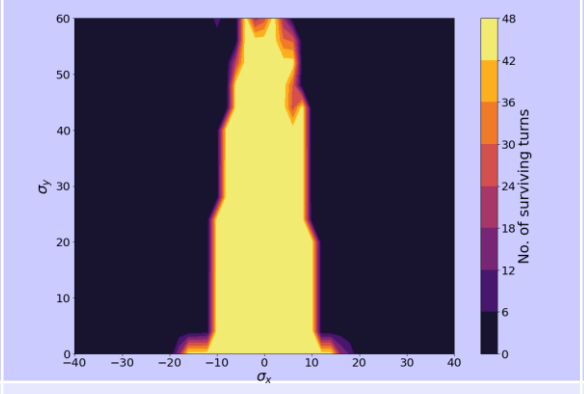
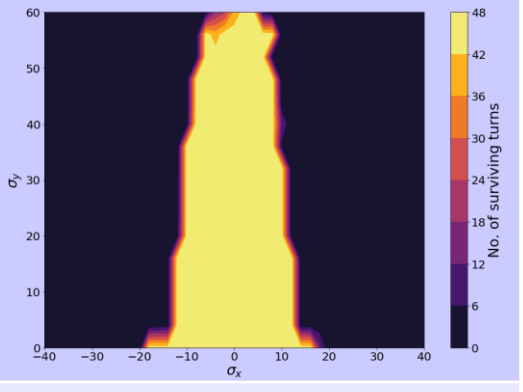
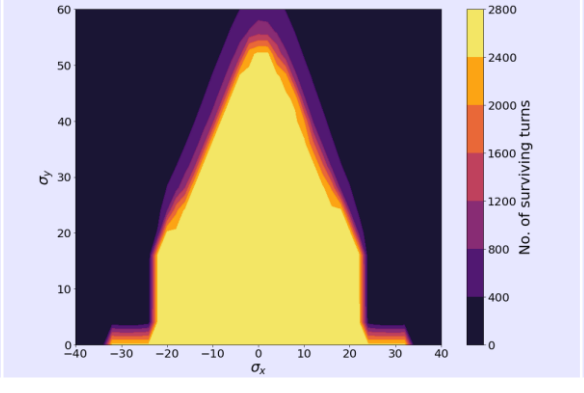
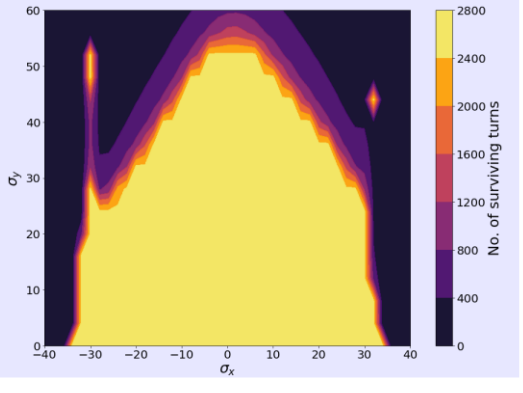
- Tracking studies repeated with SR emission in all elements and with tapered lattice
- Slightly more pronounced reduction of DA at $t\bar{t}$ operation mode, minor differences at Z



Dynamic aperture with radiation and crabwaist

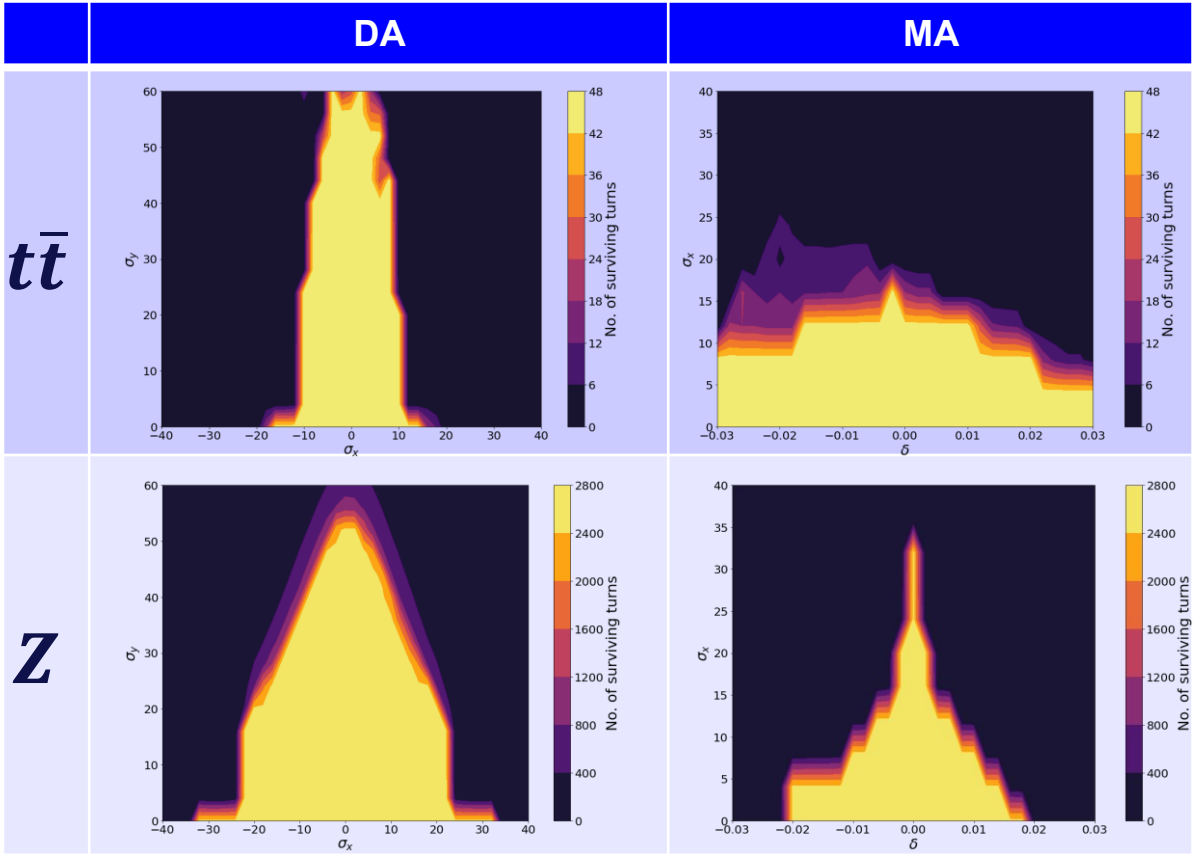
- Slight reduction of DA when tracking with both SR and crab-sextupoles turned on

Operation mode	Crabbing
$t\bar{t}$	40%
Z	80%

	DA with CS	DA without CS
$t\bar{t}$		
Z		

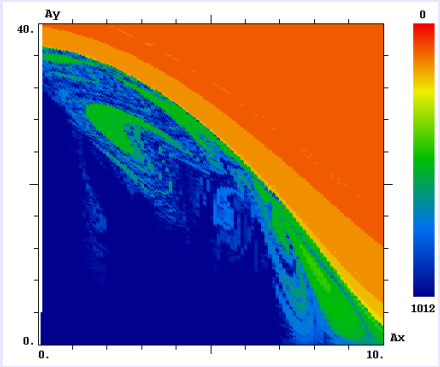
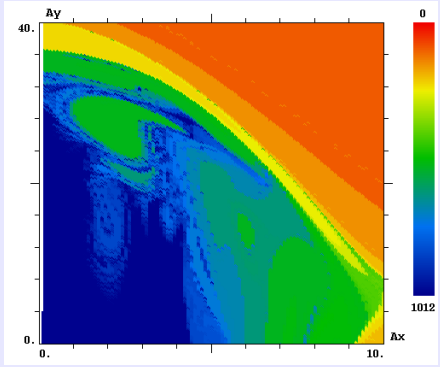
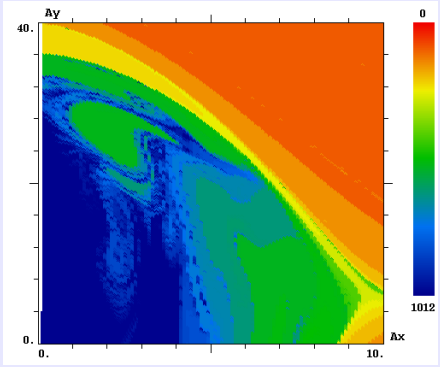
Dynamic aperture with radiation and crabwaist

- Pure horizontal motion stable over wide range in δ_p
  - Assess chromatic cross-terms and potential for correction to improve acceptance in both planes over δ_p range



Dynamic aperture in the presence of errors

- Tracking studies with errors performed by D. Shatilov using Lifetrack
  - Effective transverse misalignments in arc sextupoles to generate RMS$(\frac{\Delta\beta}{\beta}) \approx 1\%$ and $\frac{\epsilon_y}{\epsilon_x} \approx 0.002$

No errors	With misalignments in arc sextupoles	
Crabbing = 80%, $\delta_p = 0.5\%$	Crabbing = 80%, $\delta_p = 0.5\%$	Crabbing = 90%, $\delta_p = 0.5\%$
		

- Studies done by S. Liuzzo find arc quadrupoles and sextupoles are less sensitive to alignment errors than baseline optics (see IPAC23, WEPL023)

Outlook

- Alternative lattice design exploring ways to tackle some of the challenges in FCC-ee
- Arc cells and IR design provide either explicit or implicit correction of chromatic and anharmonic terms
- Tracking studies including synchrotron radiation and tapering show encouraging initial DA results
  - Different studies find the arc to be less sensitive to alignment errors than baseline design
- Next steps include systematic studies of alignment errors in different elements, tracking studies with beam-beam, further optimization of sextupole settings using MOGA, ..

Thanks for your attention!