Waist Lumi Studies and Plans

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Status and Plans

- Over the past year tools (Xsuite) have reached a maturity that allows for multiple effects at the same time
  - Beam-beam (and radiation)
  - Full lattice description with radiation and errors
  - Solenoid – Kicks and thick solenoid
- Emittance and dynamic aperture methods well tested and documented
- Tuning tools available:
  - Lattices with errors and corrections
  - IP tuning knobs
  - Relaxed optics
- Large potential for realistic and complete studies
  - Some ideas collected with Tatiana, Oide-San and Ohmi-San

Beam-Beam	Lattice Errors	Solenoid	Scan:	Observe:
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None	"Realistic" (Yi Wu)	None	- Beta* and waist	- DA - Emittance - Luminosity
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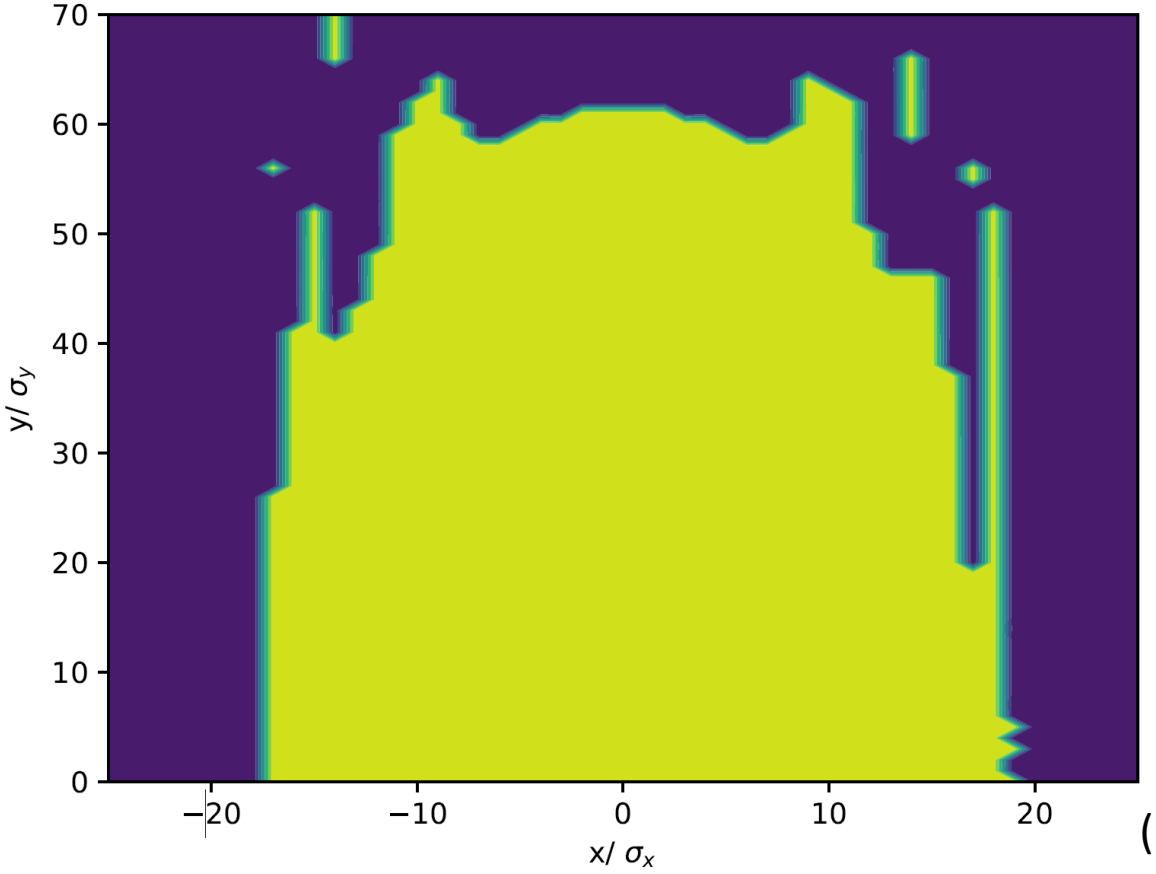
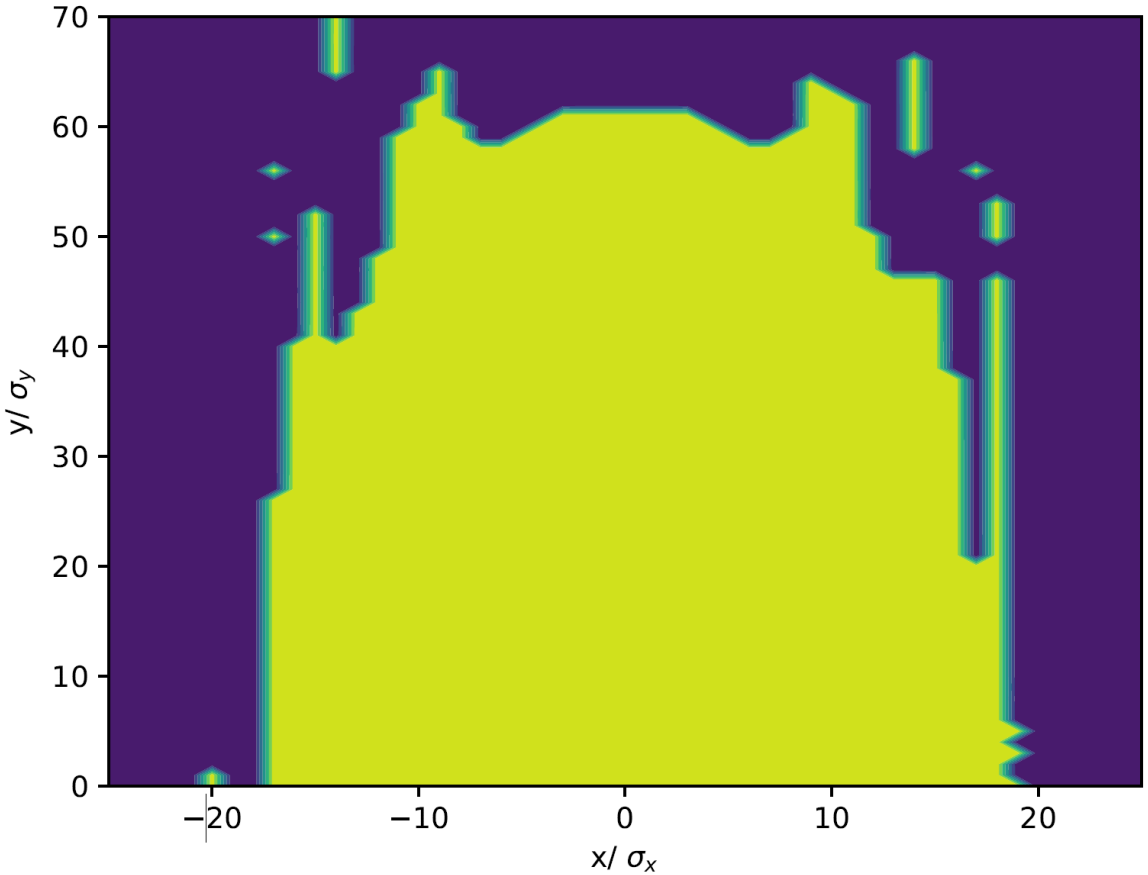
Dynamic Aperture with Beam-Beam

- Beam-beam has very little impact on DA without errors



(200 turns)



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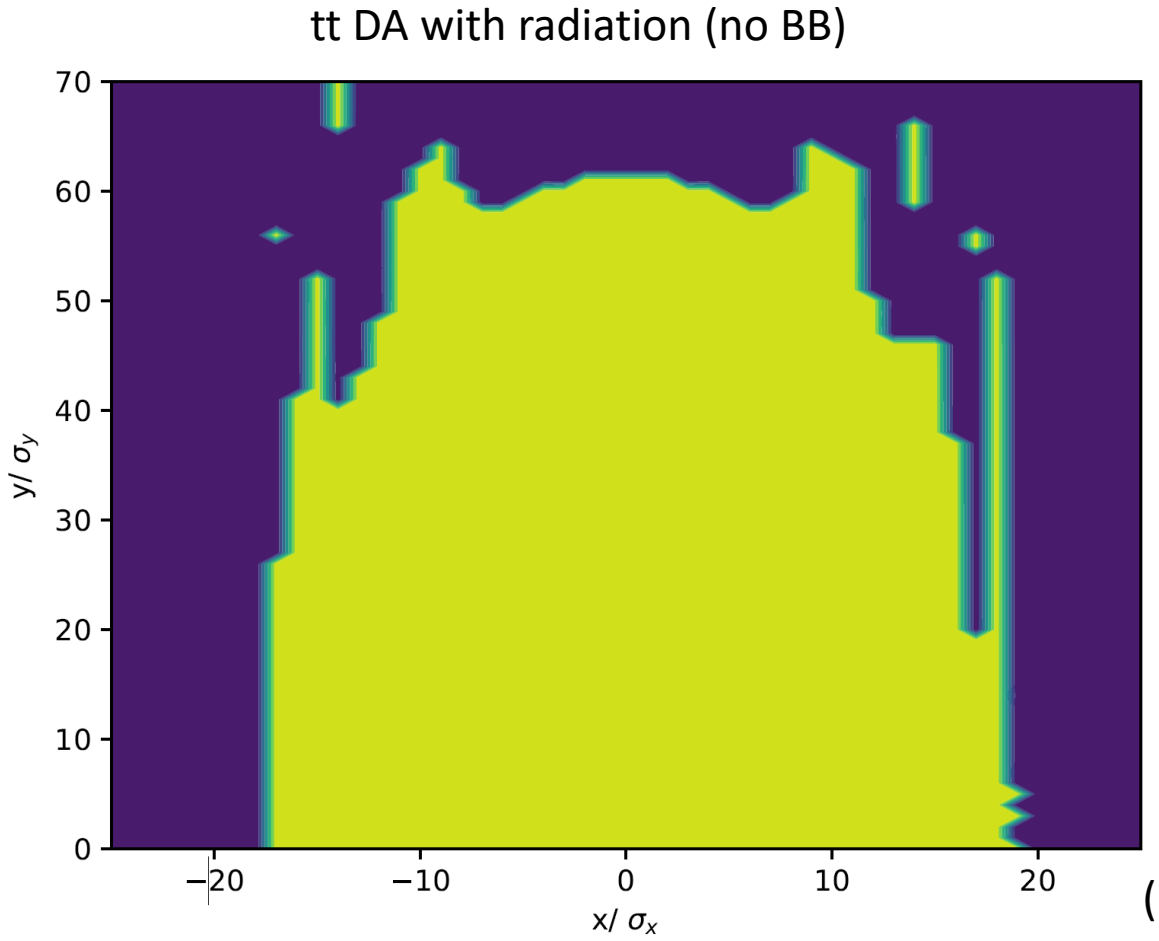

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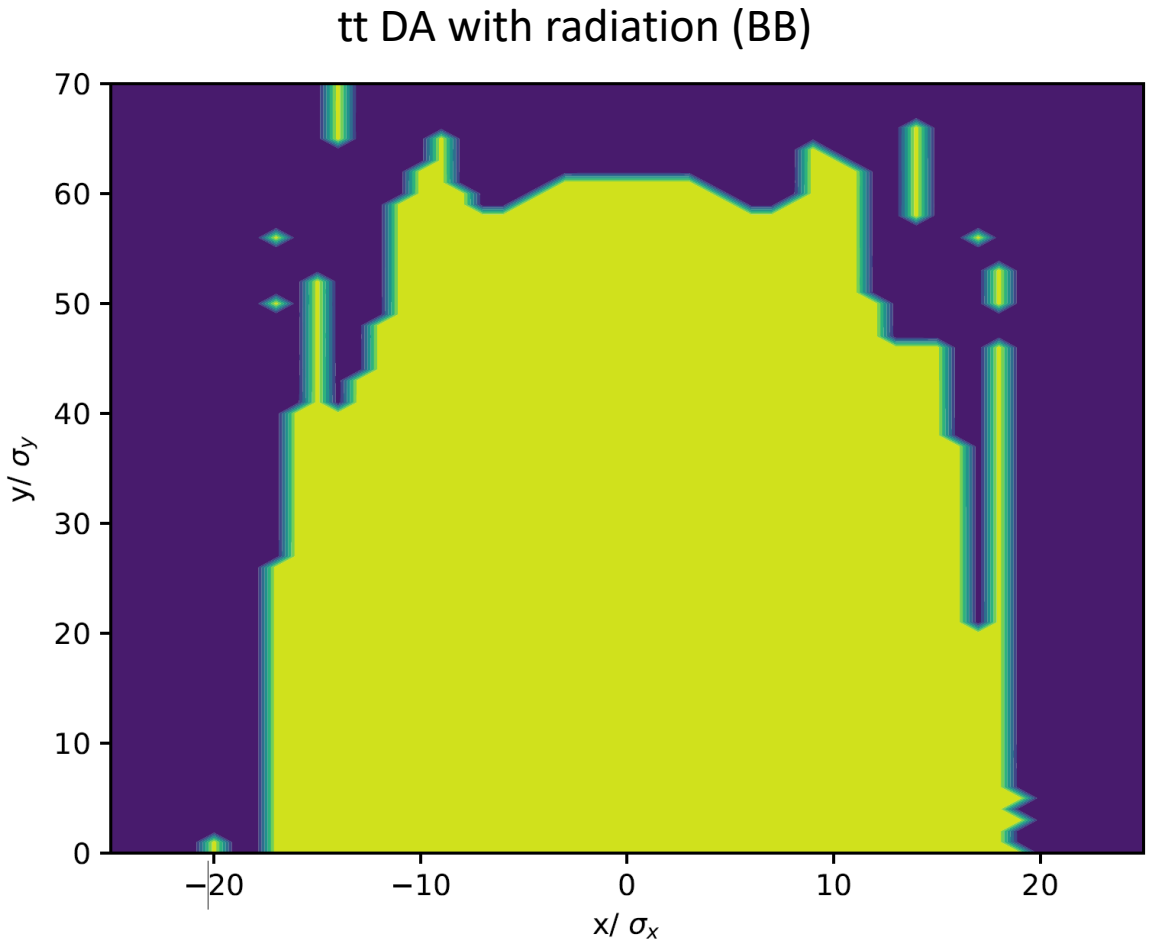


Dynamic Aperture with Beam-Beam

- Beam-beam has very little impact on DA without errors
- Dynamic aperture with effective errors and beam-beam problematic
  - Very small effective alignment errors $\sim 10^{-9}\mathrm{m}$
  - No closed solution found – not even for twiss
  - Need correction of
    - Orbit correction
    - Beta imbalances between the two IPs
      - Perhaps with beta knobs

Waist Scans Method

- Waist knobs created using cpymad
  - Modulate quadrupole strengths and record change in waist and beta at waist to create response matrix $\boldsymbol{M}$
  - Construct knobs using SVD $\boldsymbol{M = USV^T, M^{-1} \approx VS^{-1}U^T, k = M^{-1}o_{target}}$
  - Construct circuits for magnets and redefine:

```
BX_KNOB_1 = 0;
BY_KNOB_1 = 0;
WX_KNOB_1 = 0;
WY_KNOB_1 = 0;
qb6.4, K1 := 0.009024238684424 56*(1 + BX_KNOB_1*(0.3453429536209784 4) + BY_KNOB_1*(0.0013657495753194 45) + WX_KNOB_1*(0.0005419790606854425) +
WY_KNOB_1*(0.006355389543450406));
….
```

- Create lattices for scan:
  - Load lattice in MADX
  - Load redefinitions of quadrupole magnets
  - Set knob values
  - Slice and convert to X-Suite

Luminosity Studies

- Create lattices with different waist knob settings
  - Changing parameters in IP1 only
- Install beam-beam element in one IP
  - Luminosity table averages over all four IP's
  - Constructed with baseline parameters and 100 slices, flag_luminosity=1

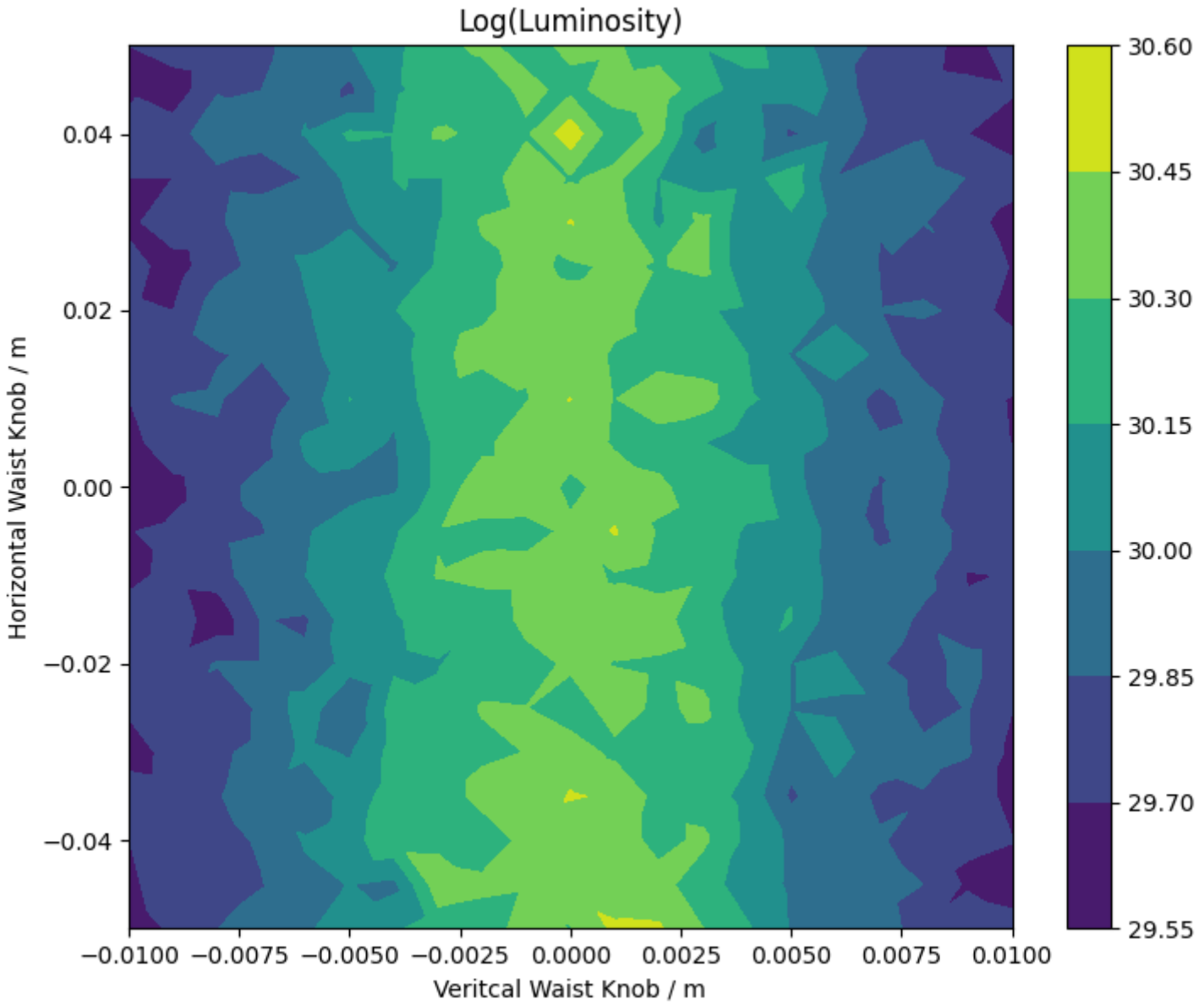
```
line.discard_tracker()
line.insert_element('bb.1', el_beambeam_b1.copy(), at_s=tab['s', 'ip.1'])
tab = line.get_table()
line.build_tracker(_context=context, use_prebuilt_kernels=False)
```

- Compute luminosity over 300 turns with 100,000 macro particles

```
el_beambeam_b1 = xf.BeamBeamBiGaussian3D(
    _context=context,
    config_for_update = None,
    other_beam_q0=1,
    phi=15e-3,
    alpha=0,
    min_sigma_diff     = 1e-28,
    slices_other_beam_num_particles      = slicer.bin_weights *
int(beam_params['BUNCH_POPULATION']),
    slices_other_beam_zeta_center = slicer.bin_centers,
    slices_other_beam_Sigma_11    = n_slices*[sigma_x**2],
    slices_other_beam_Sigma_22    = n_slices*[sigma_px**2],
    slices_other_beam_Sigma_33    = n_slices*[sigma_y**2],
    slices_other_beam_Sigma_44    = n_slices*[sigma_py**2],
    slices_other_beam_Sigma_12    = n_slices*[0],
    slices_other_beam_Sigma_34    = n_slices*[0],
    flag_luminosity=1,
)
```

Results

- Statistical noise
  - More particles might help
  - Need to check which turns are averaged
- Clear trend visible
  - Much more sensitive in y than in x
  - As expected since smaller beta in y



Realistic Errors and Corrections

- Obtained corrected Z lattice by Yi Wu
  - 30 µm alignment errors in arcs
  - Orbit corrections
- Creation of Xsuite lattice:
  - Load lattice into cpymad
  - Apply kicker strengths and load errors
  - Convert to Xsuite, allowing thick elements and alignment errors

line = xt.Line.from_madx_sequence(madx.sequence['FCCEE_P_RING'], allow_thick=True, enable_align_errors=True)

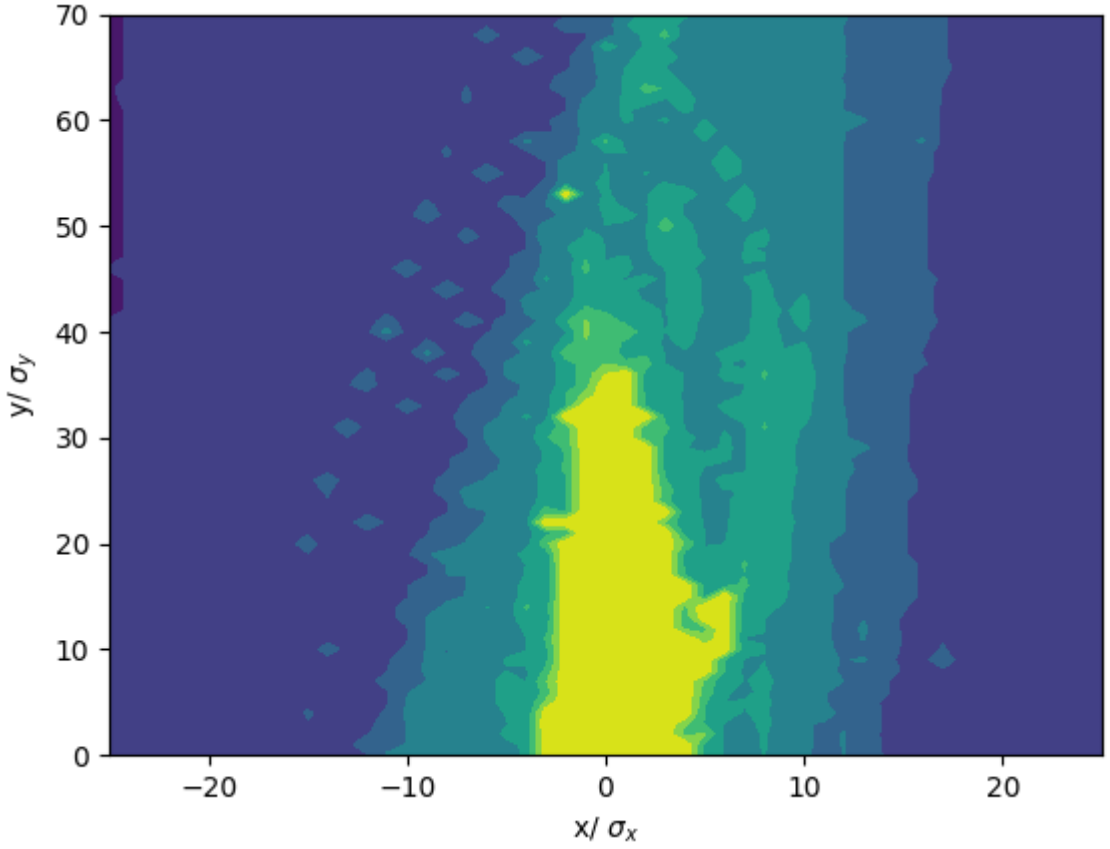
- Slice in Xsuite

```
line.slice_thick_elements(
   slicing_strategies=[
      # Slicing with thin elements
      xt.Strategy(slicing=xt.Teapot(1)), # (1) Default applied to all elements
      xt.Strategy(slicing=xt.Teapot(4), element_type=xt.Bend), # (4) Selection by element type
      xt.Strategy(slicing=xt.Teapot(4), element_type=xt.Quadrupole),  # (4) Selection by element type
      xt.Strategy(slicing=xt.Teapot(4), element_type=xt.Sextupole),  # (4) Selection by element type
      xt.Strategy(slicing=xt.Teapot(5), name='^qf.*'), # (5) Selection by name pattern
      xt.Strategy(slicing=xt.Teapot(5), name='^qd.*'), # (5) Selection by name pattern
      xt.Strategy(slicing=xt.Teapot(5), name='^qfg.*'), # (5) Selection by name pattern
      xt.Strategy(slicing=xt.Teapot(5), name='^qdg.*'), # (5) Selection by name pattern
      xt.Strategy(slicing=xt.Teapot(5), name='^ql.*'), # (5) Selection by name pattern
      xt.Strategy(slicing=xt.Teapot(5), name='^qs.*'), # (5) Selection by name pattern
      xt.Strategy(slicing=xt.Teapot(10), name='^qb.*'), # (10) Selection by name pattern
      xt.Strategy(slicing=xt.Teapot(10), name='^qg.*'), # (10) Selection by name pattern
      xt.Strategy(slicing=xt.Teapot(10), name='^qh.*'), # (10) Selection by name pattern
      xt.Strategy(slicing=xt.Teapot(10), name='^qi.*'), # (10) Selection by name pattern
      xt.Strategy(slicing=xt.Teapot(10), name='^qr.*'), # (10) Selection by name pattern
      xt.Strategy(slicing=xt.Teapot(10), name='^qu.*'), # (10) Selection by name pattern
      xt.Strategy(slicing=xt.Teapot(10), name='^qy.*'), # (10) Selection by name pattern
      xt.Strategy(slicing=xt.Teapot(50), name='^qa.*'), # (50) Selection by name pattern
      xt.Strategy(slicing=xt.Teapot(50), name='^qc.*'), # (50) Selection by name pattern
      xt.Strategy(slicing=xt.Teapot(20), name='^sy.*'), # (50) Selection by name pattern

   ])
```

Results

- Tracked 2500 turns
- Plot log(turn survived)
- Significantly lowered DA
  - Very irregular beta*
  - Possible further correction
    - Phase advance between BPMs
    - Scan of IP beta knobs



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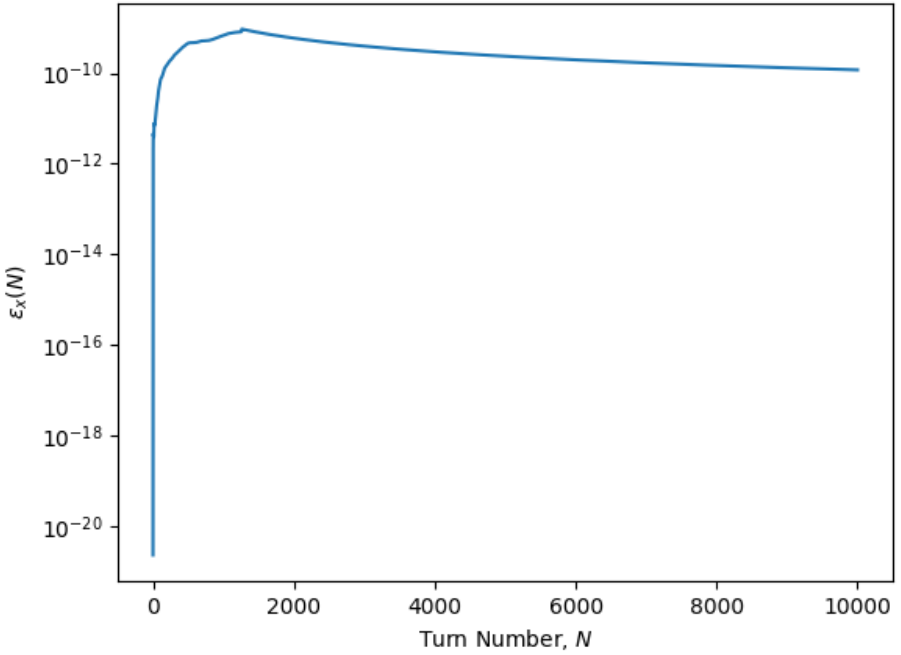
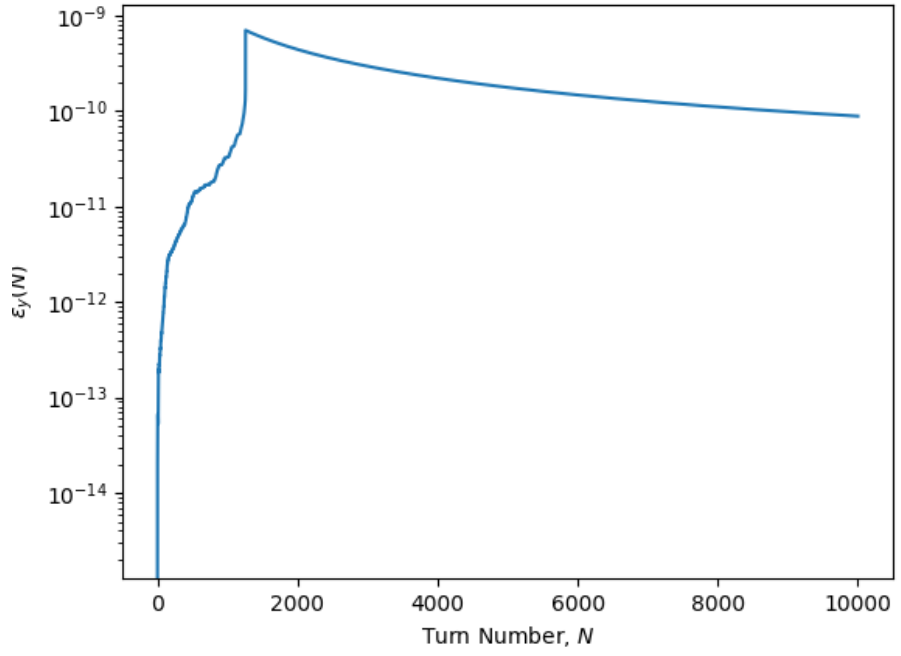
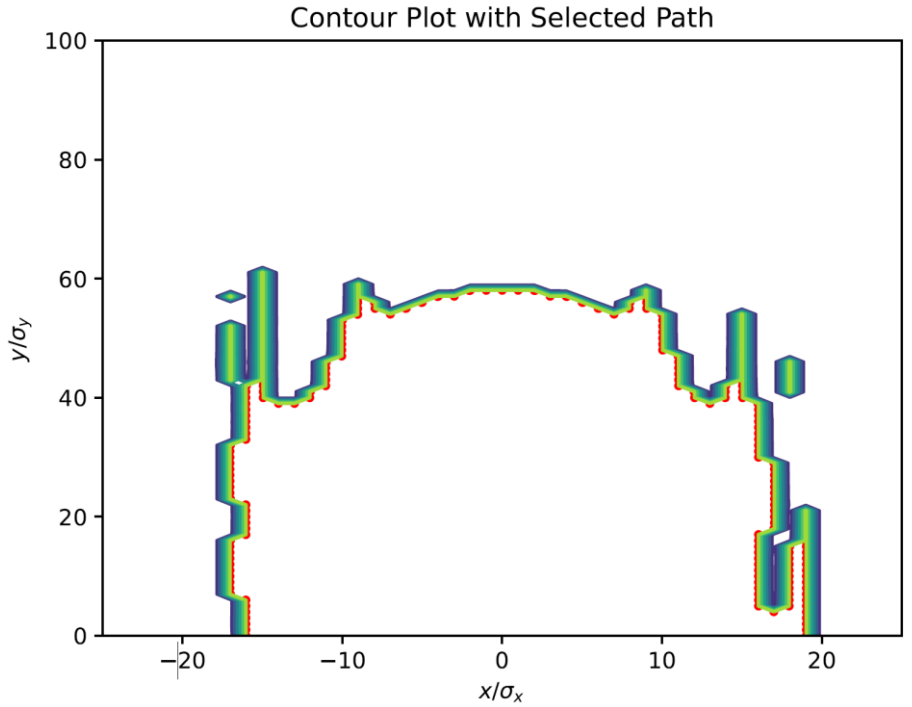
    - Phase advance between BPMs
    - Scan of IP beta knobs
- Emittance tracked over 10,000 turns
  - Compare to design:
    - EX = 0.71E-9, EY = 1.42E-12
  - Possible study of dispersion free steering

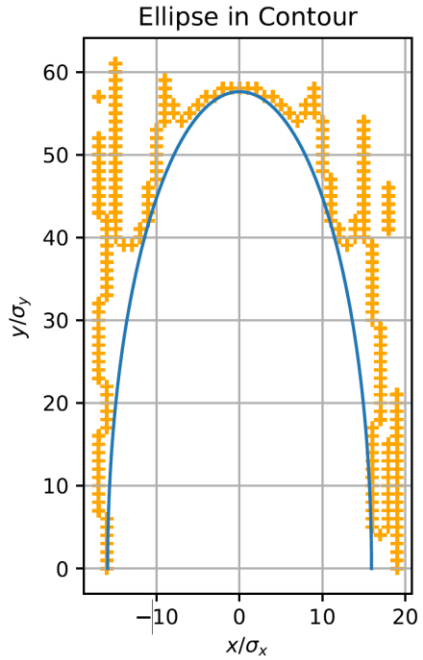




Glimpses of other activities

- Dynamic aperture scans with knobs and optics options
  - TPIV student Anne-Clemence Piveteau quantifying DA
    - Total continuous area but also largest possible ellipse
    - Scanning beta waist knob and observing DA
  - Apply method to other scans
- Optimisation of sextupoles for chromaticity and DA
  - Cristobal Garcia for his alternative lattices
  - Apply methods to improve DA of other cases (e.g. corrected lattices)





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