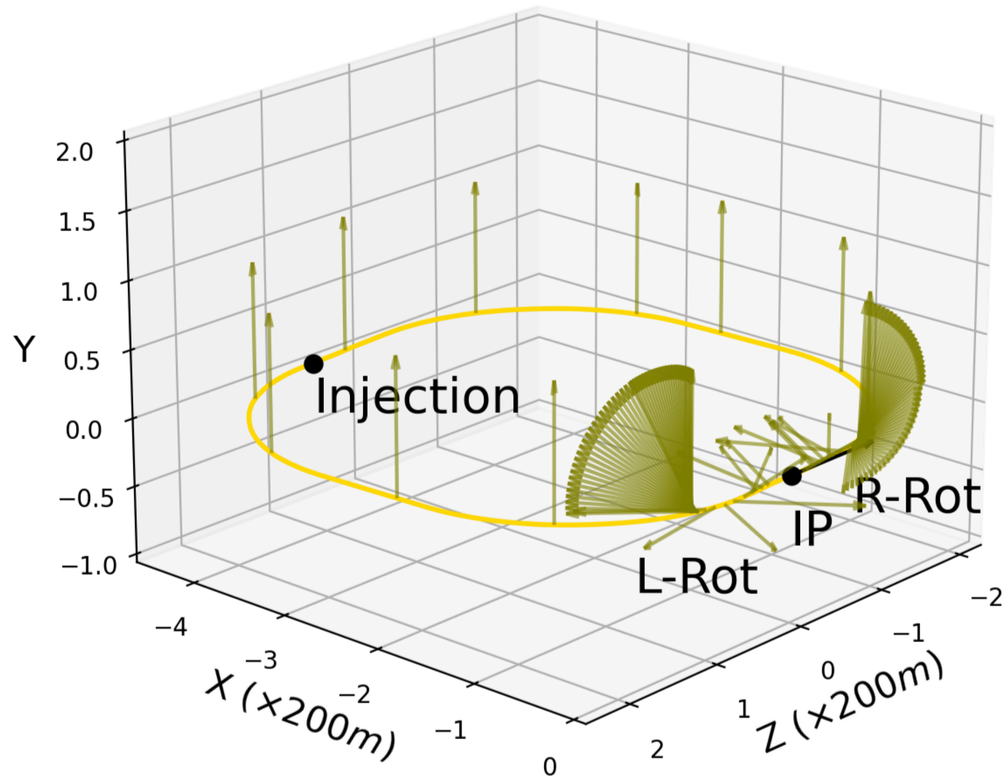
Beam-Beam Tracking Studies for Chiral Belle with Bmad

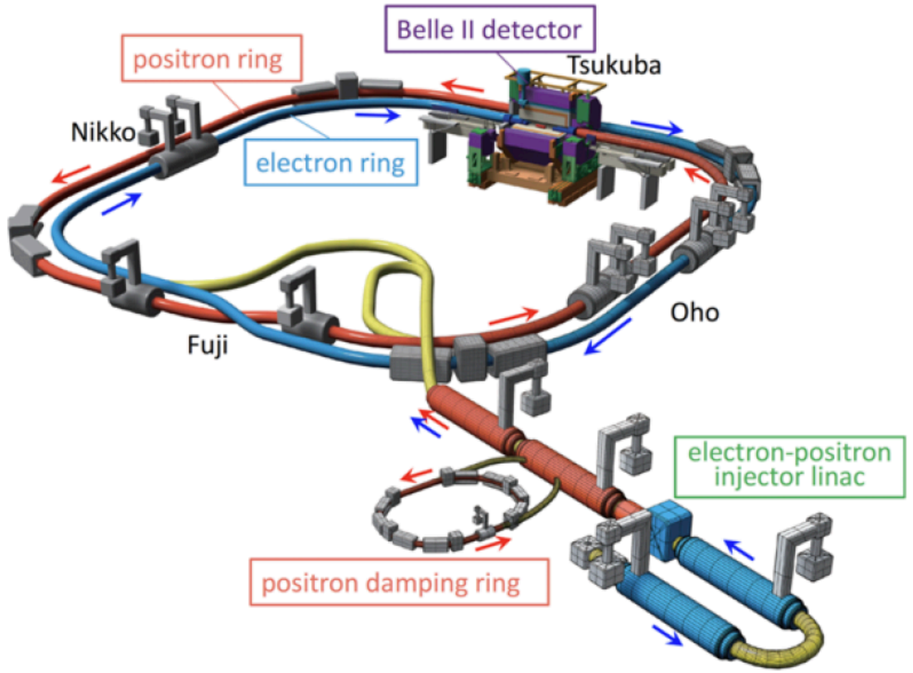


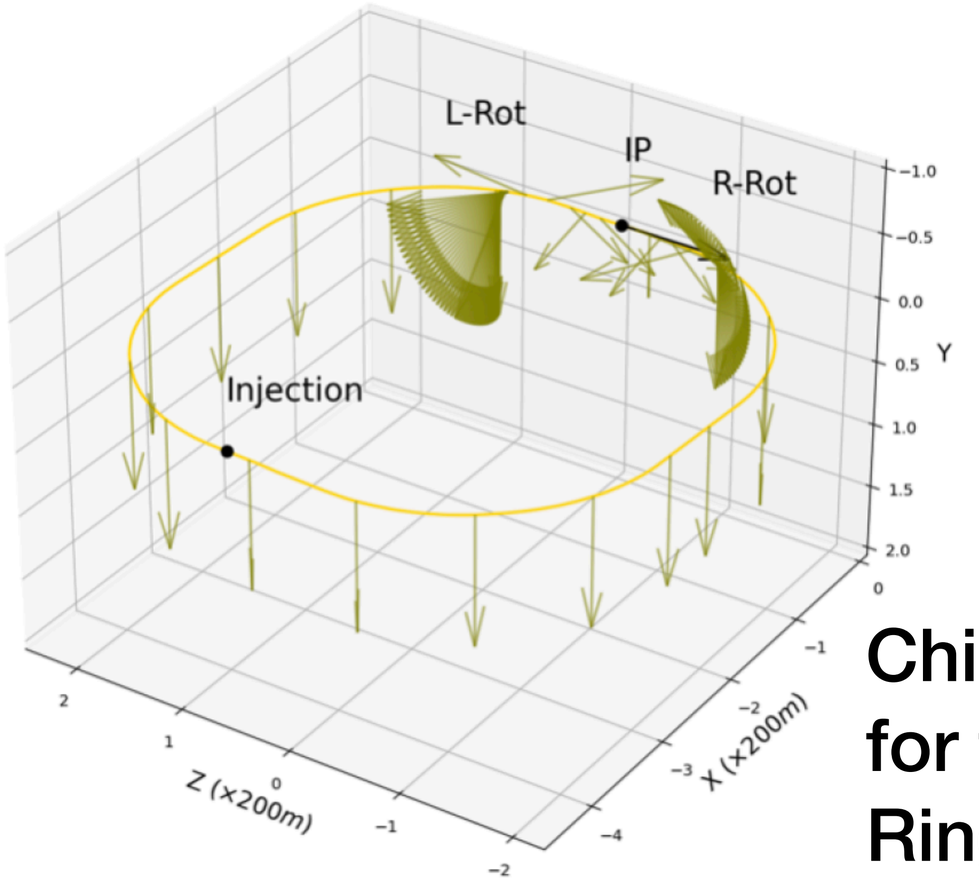
Yuhao Peng

2026.02.02

Purpose of Study

Study Beam-beam effect on the polarization lifetime and the beam lifetime for the SuperKEKB High Energy Ring (HER) and the Rotator Ring (Rot).





Chiral Belle Upgrade for the High Energy Ring: Rotator Ring

Beam-Beam simulation on Bmad

Bmad uses the beam-beam element at the interaction point (IP) to simulate an interaction with a strong beam traveling in the opposite direction.

The strong beam is assumed to be Gaussian in shape.

In the bmad_standard calculation, the beam–beam kick is computed using the Bassetti–Erskine complex error function formula.

Note: In Bmad simulation, the default particle type is positron (In the HER, positron travels in the opposite direction to model the electron). Thus, in Bmad simulation, the strong beam particle type is electron (corresponds to the LER).

Beam-Beam Element parameter

- sig_x: Horizontal strong beam sigma at the centre
- sig_y: Vertical strong beam sigma at the centre
- sig_z: strong beam length
- charge: charge of strong beam charge. Default = -1
- species_strong: strong beam species
- n_particle: number of particles in strong beam
- n_slice: number of strong beam slices in the calculation (to be determined)
- E_tot_strong: strong beam particle energy.
- beta_a_strong: strong beam beta_x
- alpha_a_strong: strong beam alpha_x
- beta_b_strong: strong beam beta_y
- alpha_b_strong: strong beam alpha_y
- ks: solenoid strength
- bs_field: solenoid field strength
- repetition_frequency: Strong beam repetition rate

Benchmark Setting of Beam-Beam Element

The benchmark setting is listed as following:

- e_tot_strong = 4E9 eV; strong beam is the SuperKEKB Low Energy Ring (LER) beam in our case
- n_particle = 5E10 (2A current run) for the strong beam
- Twiss parameters of the strong beam at the IP acquired from the LER lattice provided by Ohnishi-san: beta_a_strong =0.031949144917020 6, beta_b_strong= 0.000263431827463 6, alpha_a_strong = -0.000238978815345, ,alpha_b_strong = -0.000864214532142 7 (a: horizontal, b: vertical)
- bs_field = 1.5T, repetition_frequency = 1/1e-5 Hz
- sig_x = 10.1E-6m, sig_y = 48E-14m, sig_z = 5.19314E-03m (size of the strong beam)

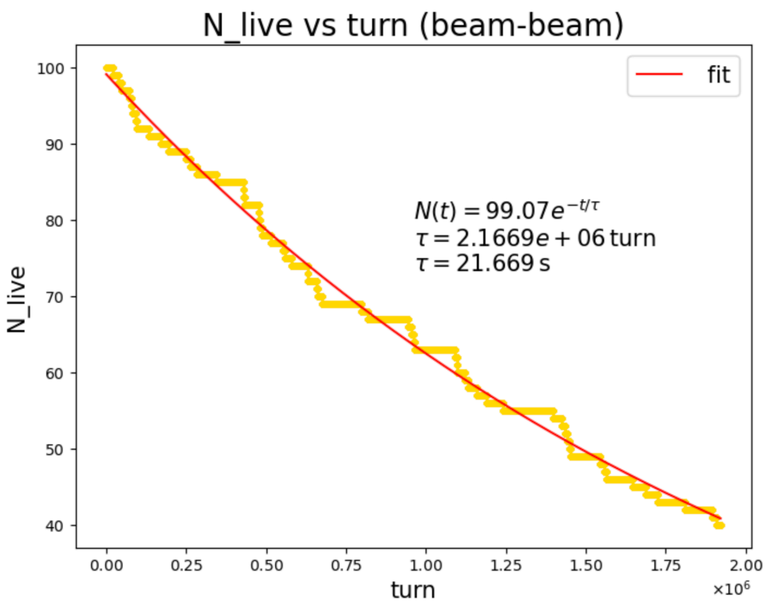
Tracking Setting

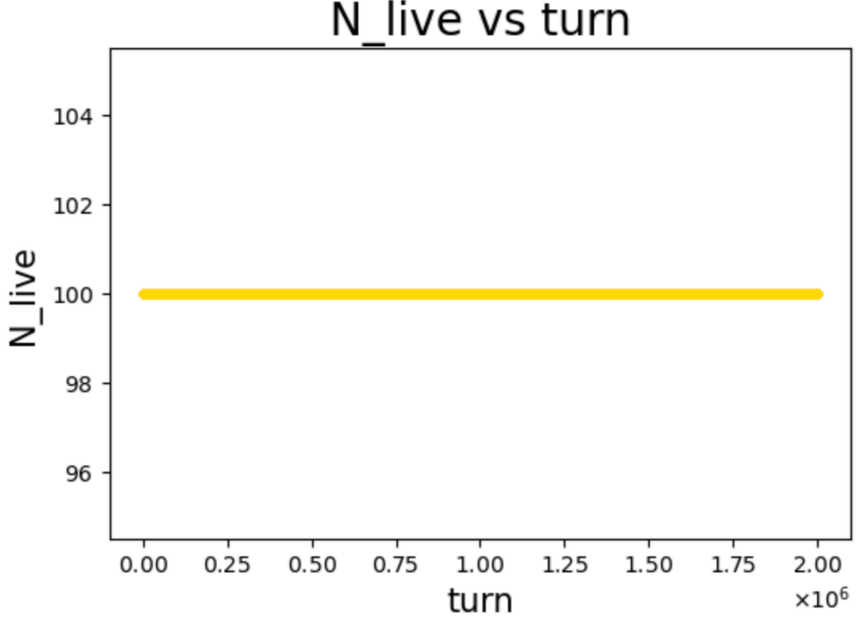
The benchmark setting is listed as following:

- For the beam-beam elements: n_slice = 100, n_particle = 5E10
- Initial beam momentum p0c = 7.00729 GeV for the HER and Rot, some studies(e.g. longer polarization lifetime) requires p0c = 7.07729 GeV for the Rot
- If not specified, the setting of tracking parameters will be same as the benchmark

Tracking Studies

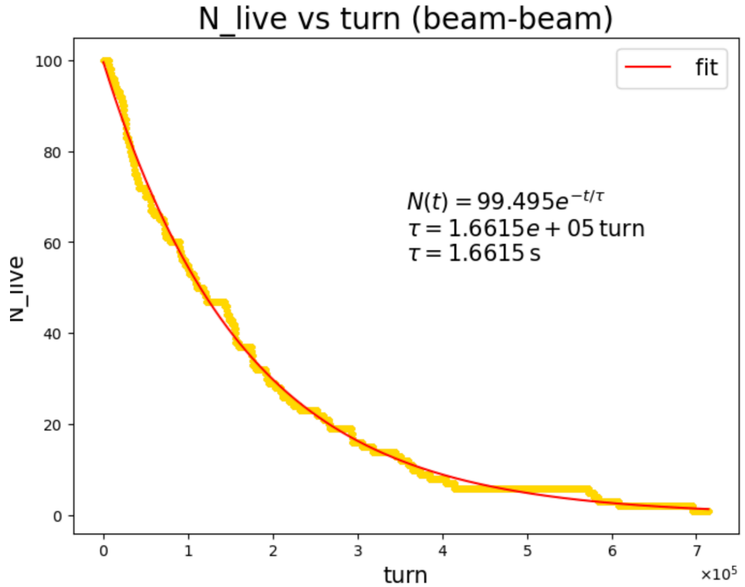
- Test n_slice, find a reasonable value
- Keep n_particles, decreasing the sigma_y
- Change n_particles to the design value, increasing the sigma_y



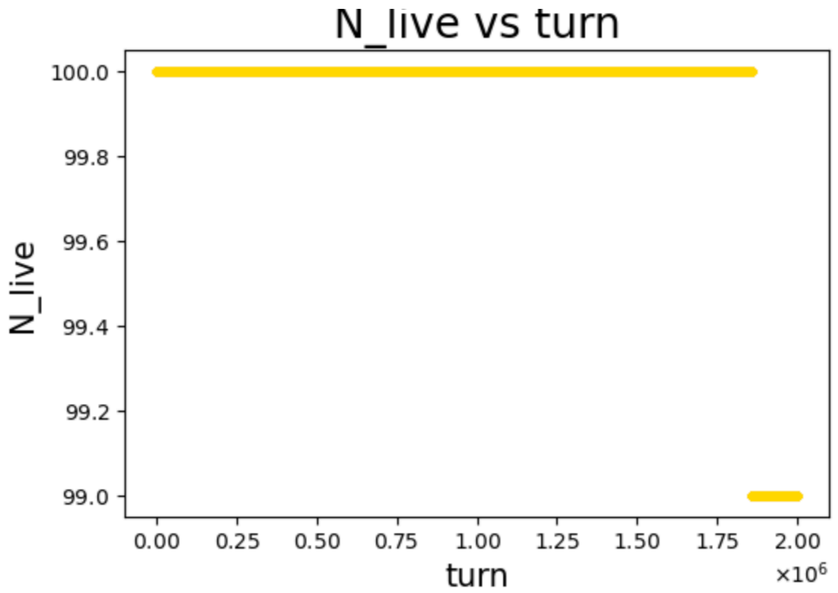


HER

(Up to 2M turns)



n_slice =10



Rot

n_slice =100

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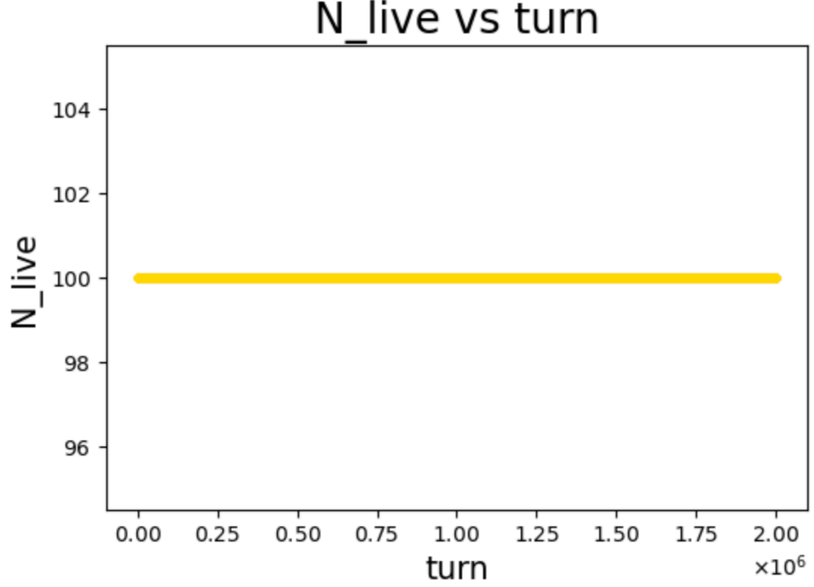
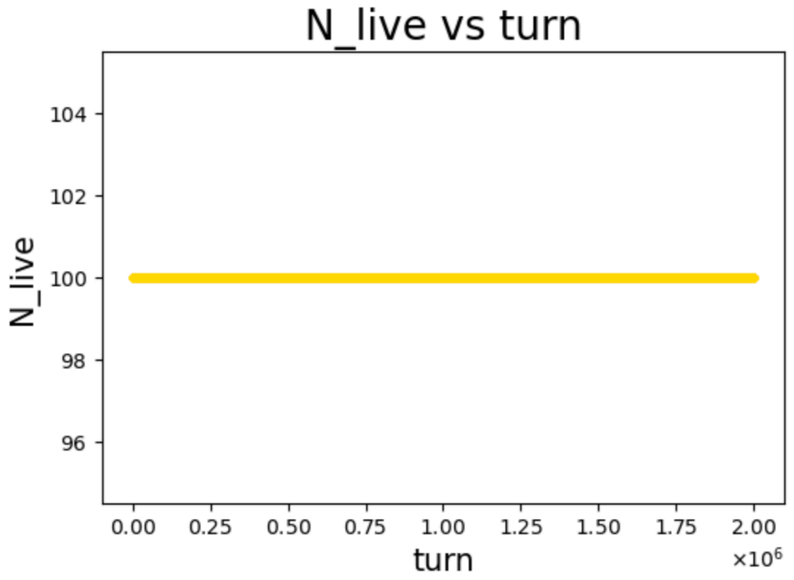
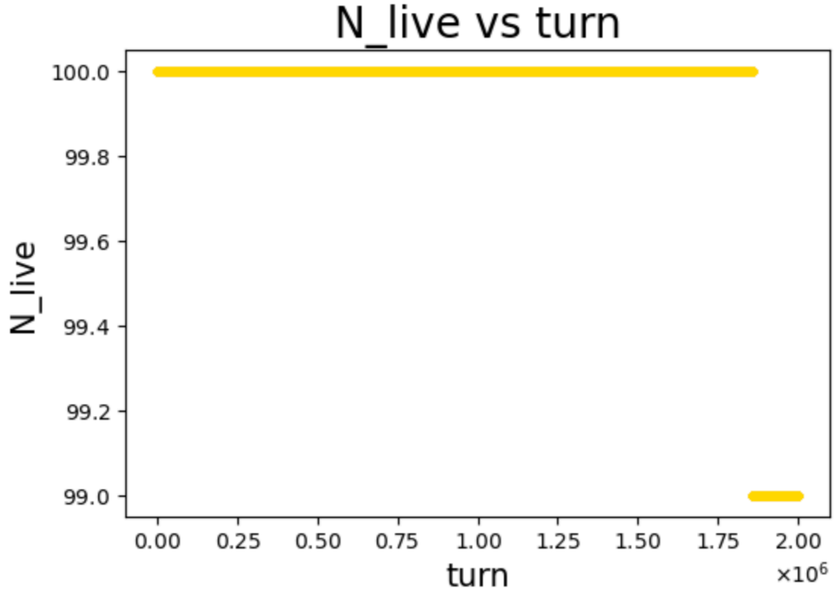


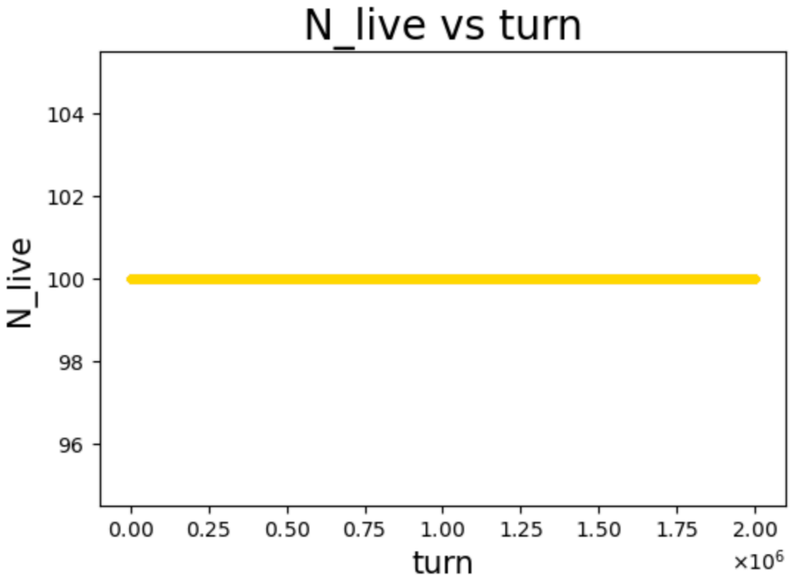


HER

(Up to 2M turns)

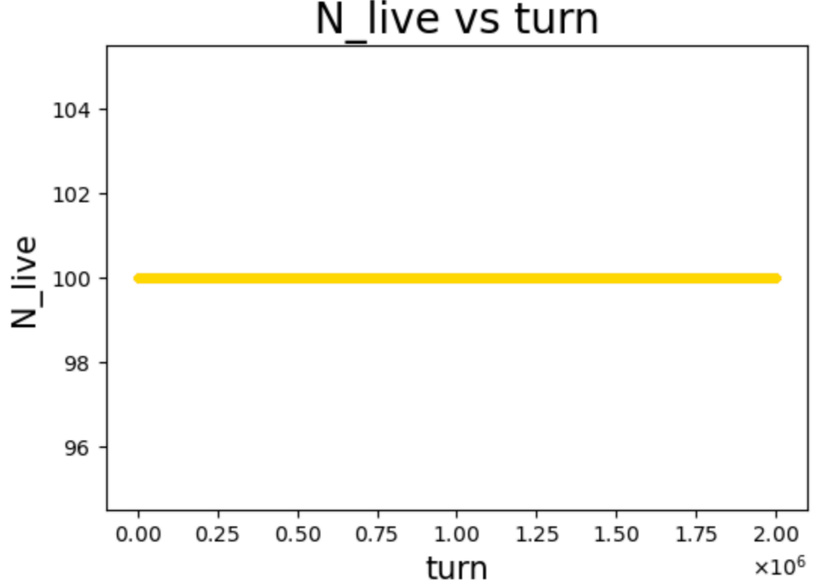


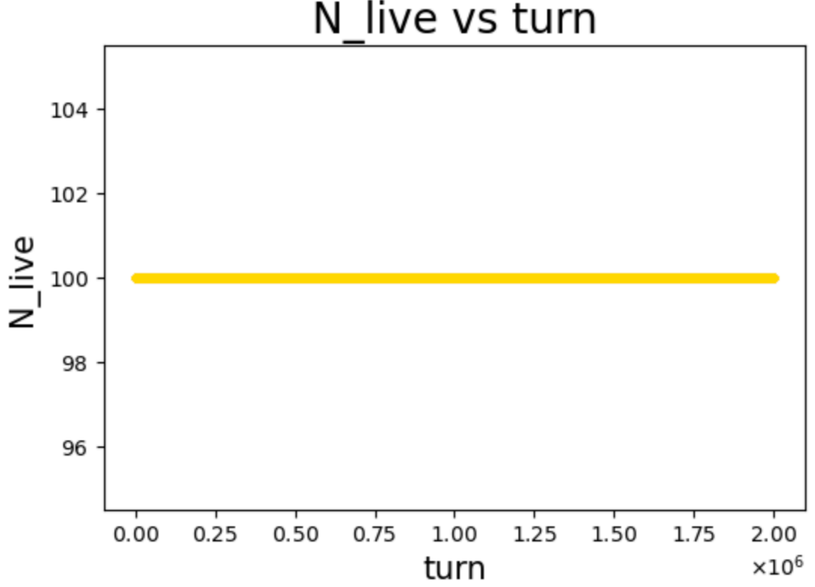
n_particle = 5E10, 1*sigma_y



Rot

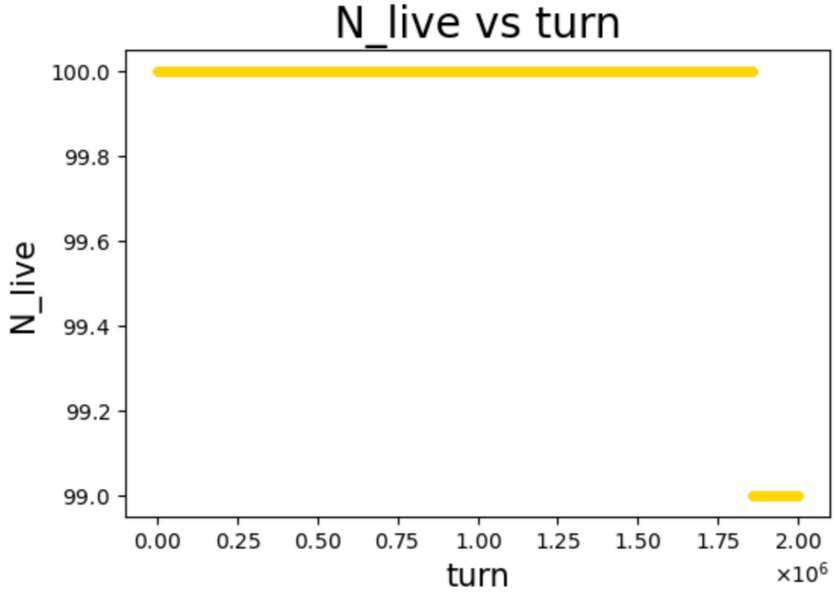
n_particle = 5E10, 0.5*sigma_y



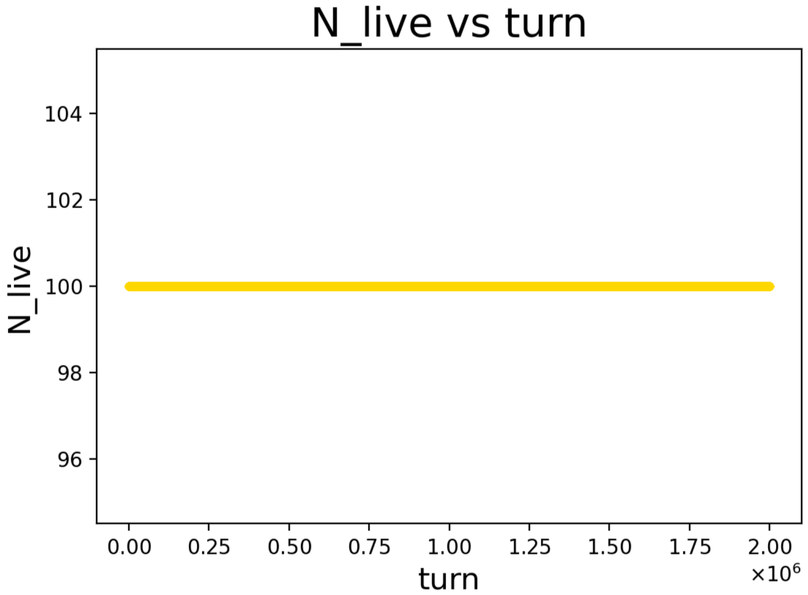


HER

(Up to 2M turns)



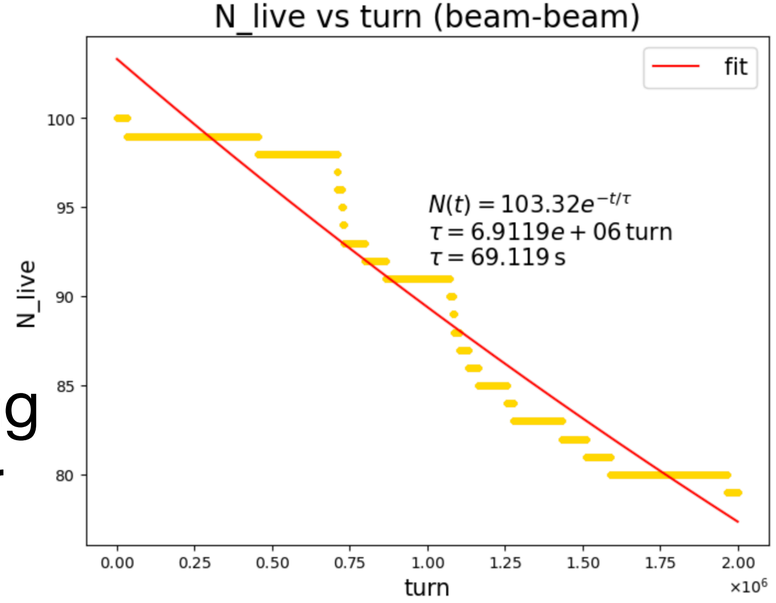
n_particle = 5E10, 1*sigma_y

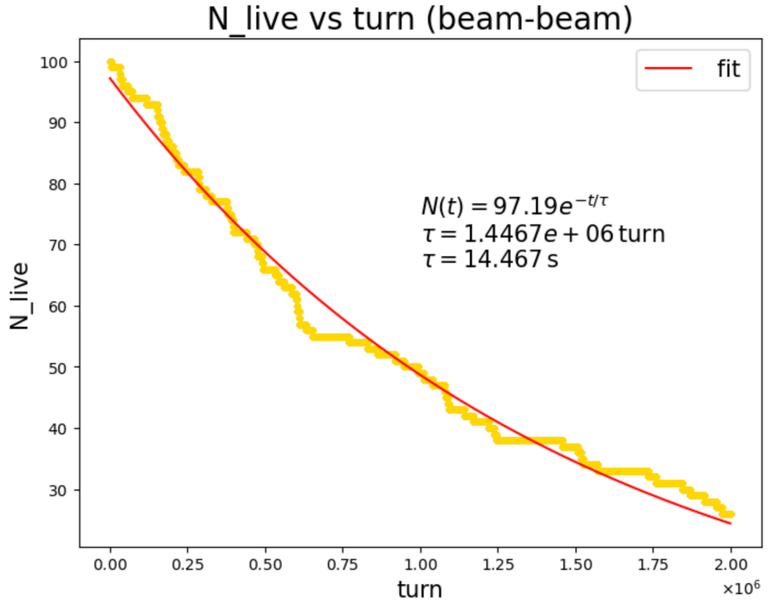


n_particle = 5E10, 0.001*sigma_y

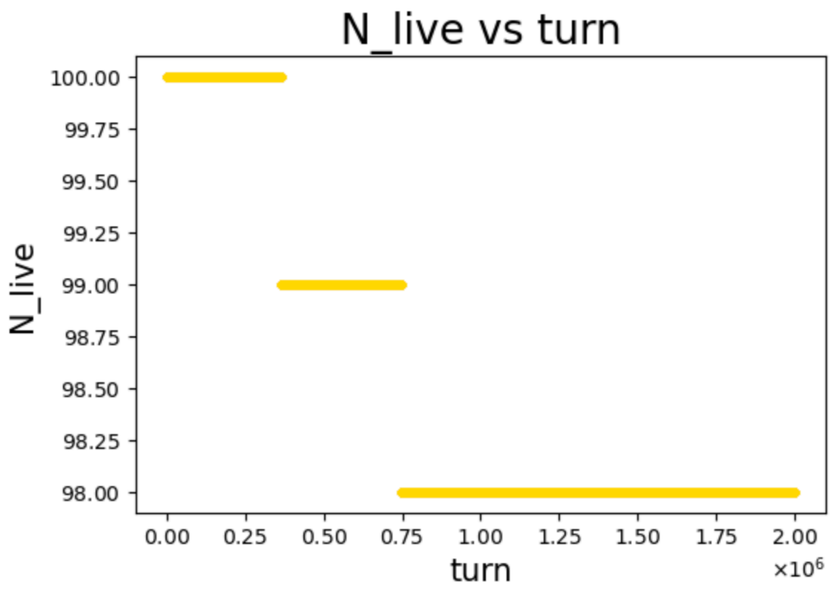
Rot

Doubling number of LER particle in the bunch



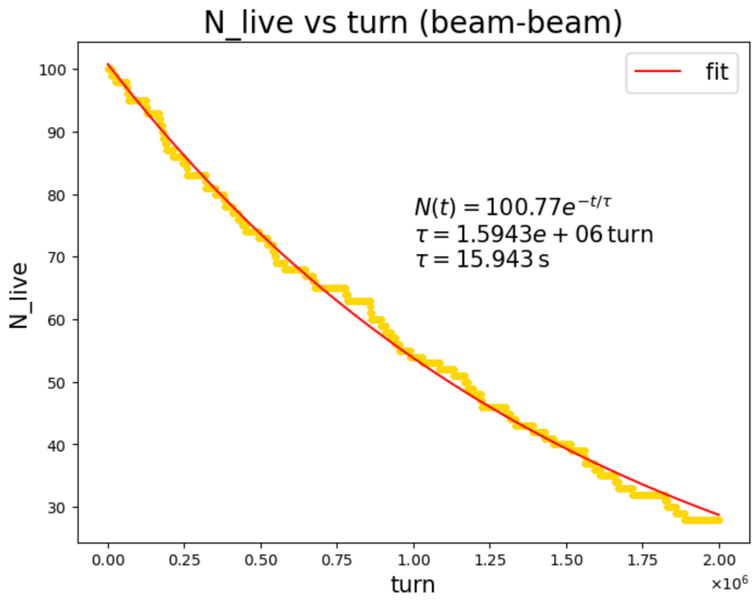


n_particle = 9E10 (design value), 1*sigma_y



HER

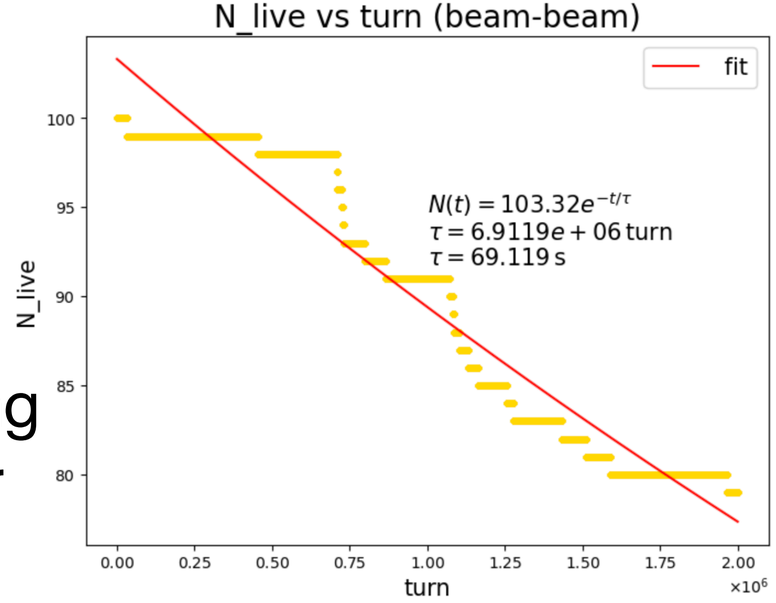
(Up to 2M turns)

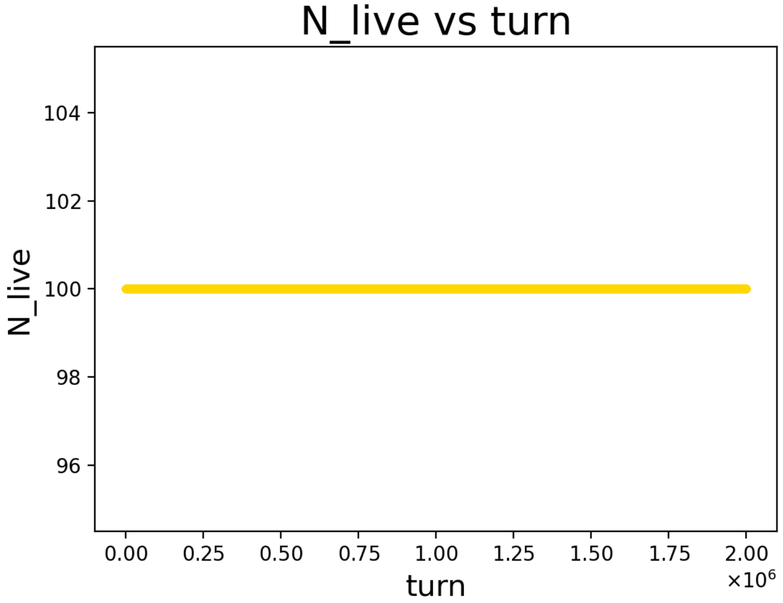


Rot

n_particle = 9E10(design value), 2*sigma_y

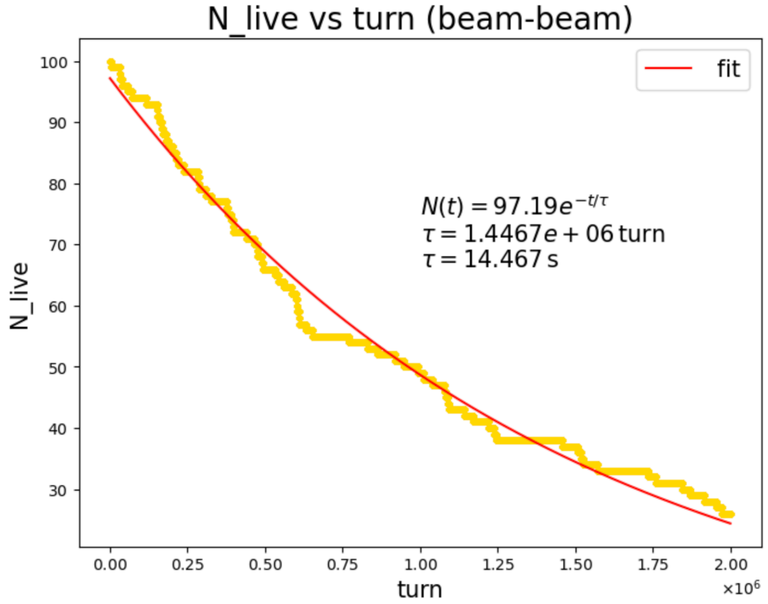
Doubling number of LER particle in the bunch

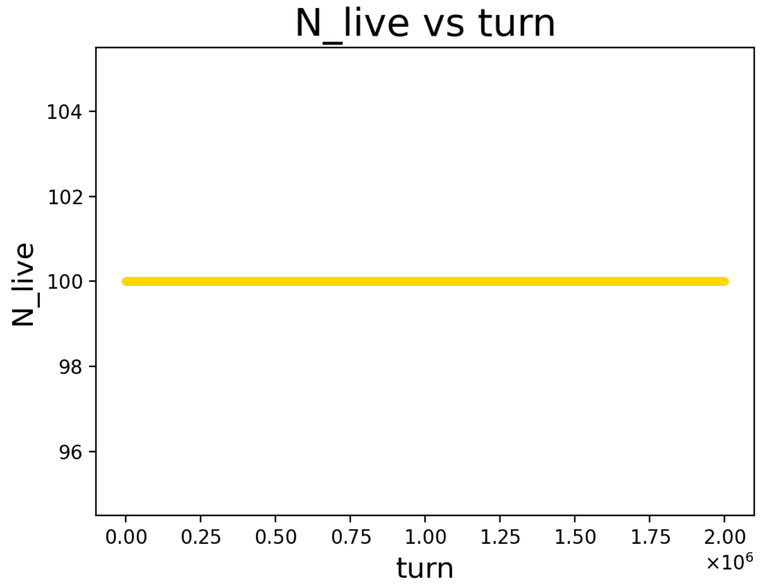




HER

(Up to 2M turns)





Rot

n_particle = 9E10 (design value), 1*sigma_y

n_particle = 9E10 (design value), 10*sigma_y

Conclusion & Next steps

The number of slice for the beam-beam element should set to 100

Keeping the number of particles fixed while reducing the beam size does not reduce the beam lifetime.

Doubling the number of particles decreases the beam lifetime as expected.

Increasing the beam size leads to an increased beam lifetime.

The beam-beam element also simulates the crabbing, which might be included in the future