

Overview of ongoing mixed-beam simulation activities at GSI

1st Workshop on Mixed Ion Beam Delivery

08.10.2026, Vienna, Austria

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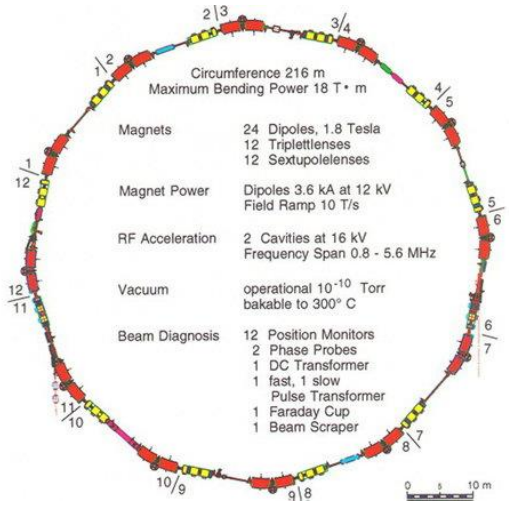
Mixed-beam simulation activities at GSI

For mixed beams, we simulate:

- ❑ Multi-turn injection into SIS18.
- ❑ Acceleration.
- ❑ Slow extraction.

+ simultaneous acceleration of the beams with different A/q but matching rigidities.



Tools:

- ❑ `Xsuite` is the main tracking framework.
- ❑ We run simulations both locally and on the cluster.

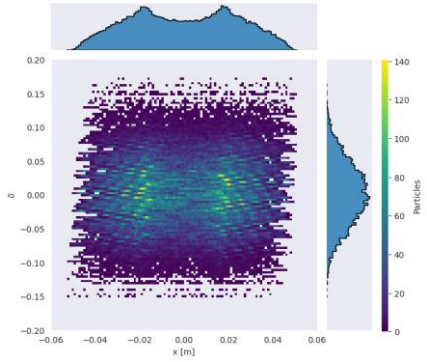


We run the simulations for

- ➢ mixed beams, $^{12}C^{3+}$ and $^{4}He^{+}$
- ➢ dual beams, same rigidity, different A/q

Use cases

❑ Multi-turn injection



- Phase space difference
- Dependence on the kicker settings

gets more interesting with 2 MTI injection.

❑ Acceleration.

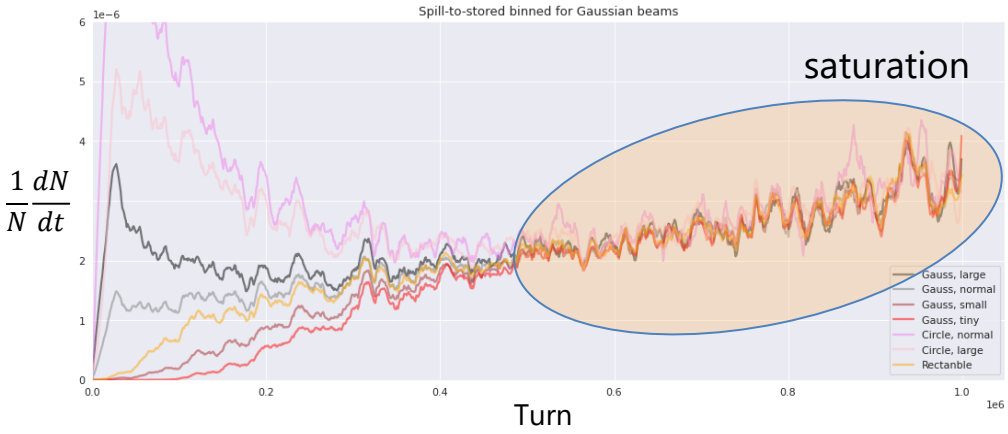
- Losses/emittance growth studies.

Limitation: non-reference beam tracking on a ramp does not work.

❑ Slow extraction.

- Main large-scale (cluster) tracking use case.
- Typical run: **200k particles × 1M turns**.
- Parameter scans of the He/C extraction ratio
  - Initial phase space
  - Chromaticity
  - RF-KO/machine parameters.

❑ Recent example: dependence on initial distribution



Simulation tools

Shared Python package for Xsuite-based simulations at GSI*.

❑ Multi-GPU tracking

```
p_tracked = track_multigpu(
    p,
    line_constructor = line,
    num_turns = 1_000_000,
    num_gpus = 8
)
```

- Automatic particle splitting and merging.
- GPU contexts / workers handled internally.
- Optional particle-monitor snapshots to HDF5.
- Prebuilt Docker images for cluster use.

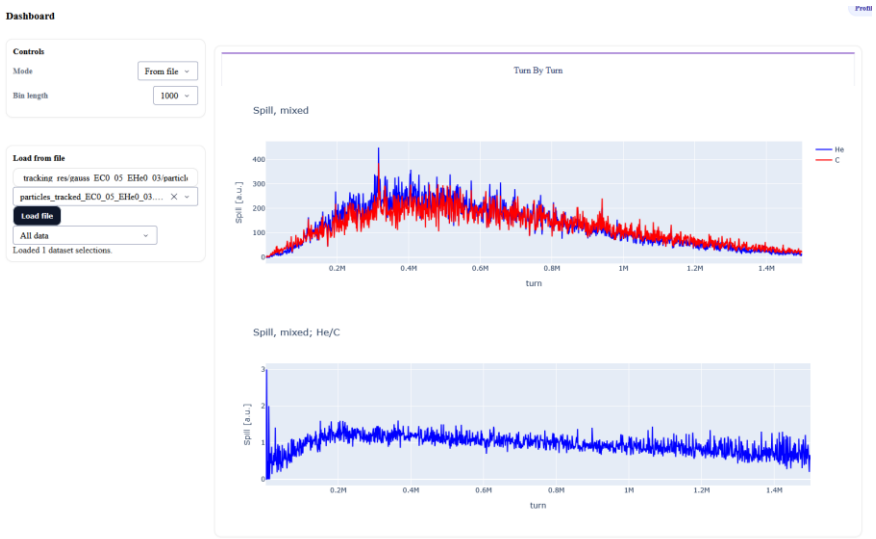
❑ Visualisation/analysis

```
server = Dashboard(
    profile = SIS18extraction_mixed_beam(
        ion1 = {'name': "He", 'chi': 0.99934958},
        ion2 = {'name': "C", 'chi': 1.0},
        start_count_at_turn = 500
    ),
    data_to_monitor = [
        "spill:mixed",
        "spill:mixed:ratio"
    ]
)

server.run_dash_server()
```

Dashboard built with Plotly Dash:

- Interactive visualization of tracking data.
- Automatic calculation of derived quantities.
- Reusable analysis profiles
- Direct export of processed/binned traces and figures.



❑ Other tools

- SIS18 BPSK excitation and rigidity ramps.
- Dual-beam setup.
- Tune / phase-space / SIS18 analysis utilities.

*public mirror: https://github.com/drozzoff/toolbox

Current challenges / open questions

❑ Mixed beam creation.

Xsuite issue#631: `line.build_particles(…)` ignores chi, mass ratio, charge_ratio.

```
p = xt.Particles(
    mass0 = line.particle_ref.mass0,
    q0 = line.particle_ref.q0,
    gamma0 = line.particle_ref.gamma0,
    x = x,
    mass_ratio = mass_ratio,
    charge_ratio = charge_ratio,
    delta = delta,
)
```

❑ Dual beam acceleration.

There appears to be a problem with “clocking” the secondary beam.

- zeta is evaluated correctly, but time delay uses p0. Secondary beam is immediately lost on the ramp.

Current way: no secondary beam during the tracking, only secondary RF.