# Improving beam tracking using a hybrid code strategy

## LhARA Collaboration meeting

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# Beam tracking workflow: Previous

TNSA beam production → LhARAlinearOptics ✓

Injection: Nozzle with Space Charge effect → GPT ✓

Stage 1 beamline → BDSIM ✓ / GPT

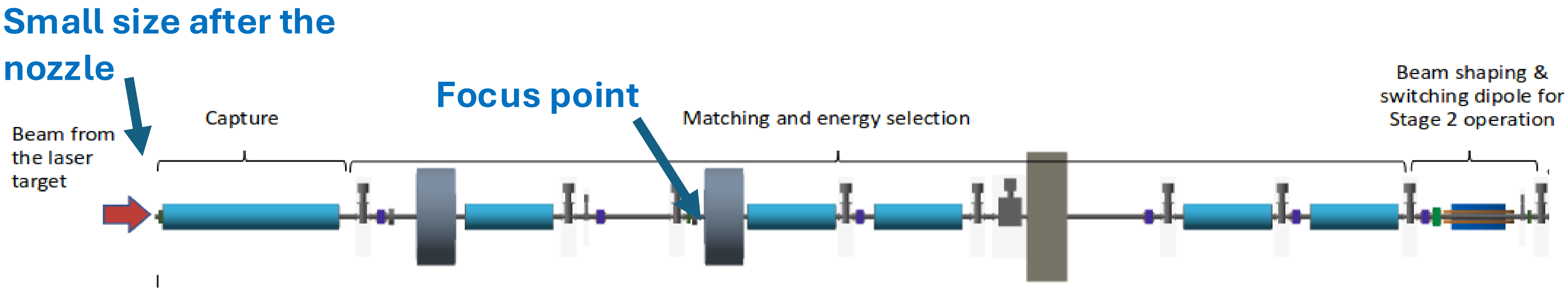
LhARAlinearOptics → GPT → BDSIM

GPT → GPT

BDSIM: **Space charge effect missing**

GPT: **Dispersion missing + tricky way to handle magnets**

**Space charge effect significant where the beam density is high**

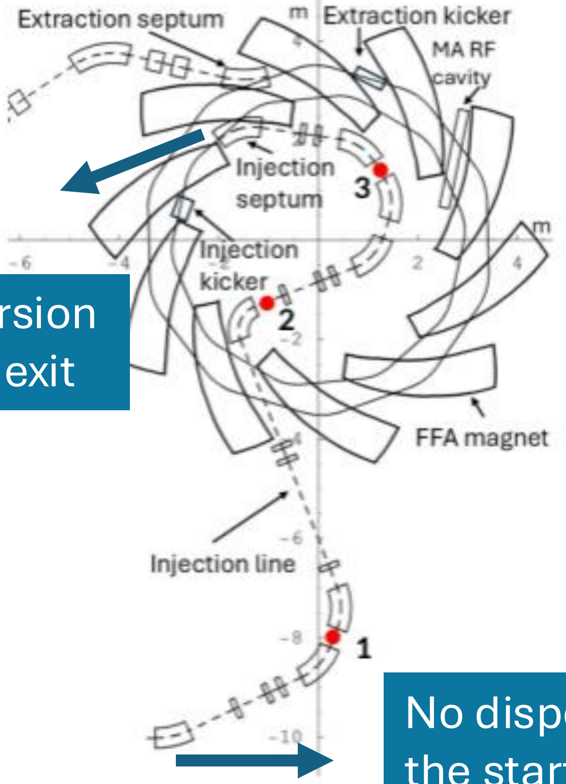


# RF-Track: particle tracking code

- **Collective effects:** space charge, wakefield,…
- **Beam of different particle species**
- **User friendly** (python code)
- **Dispersion**
- **…**

developed at CERN for the design and optimisation of particle accelerators

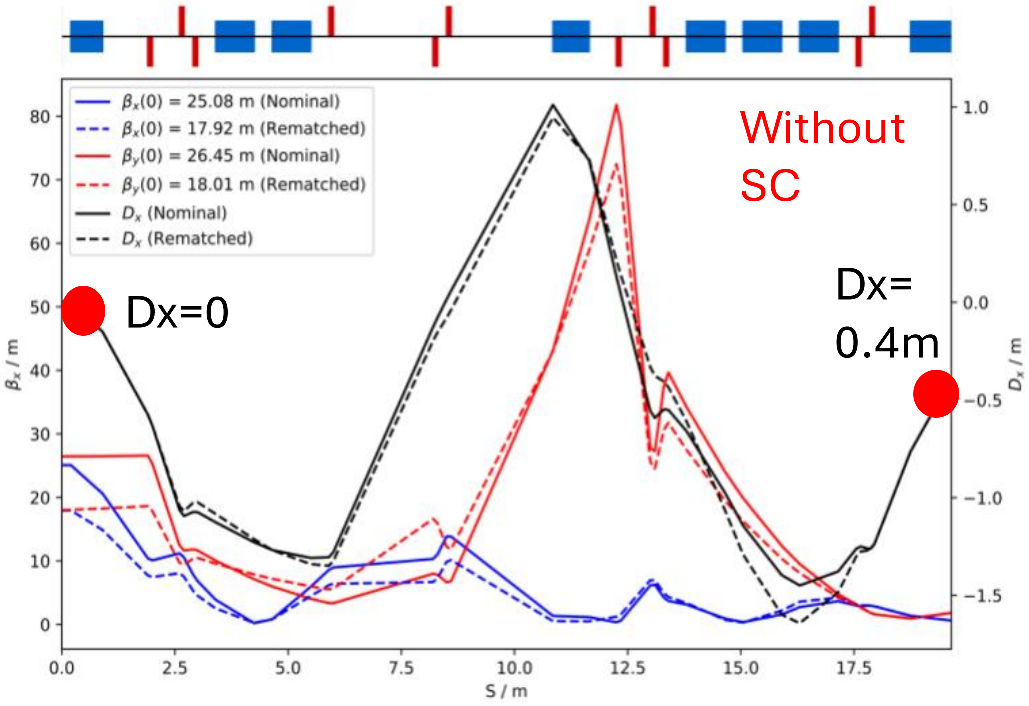
# FFA injection line design with dispersion

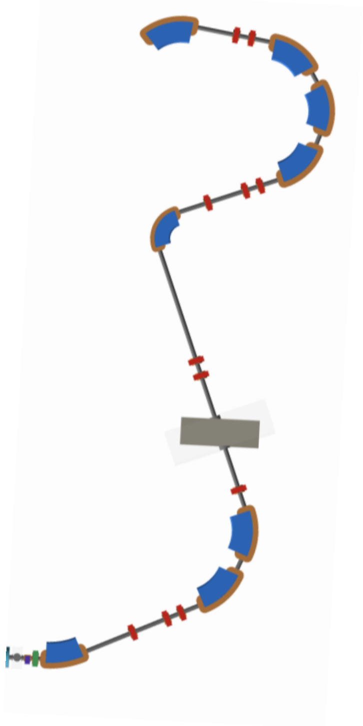



Dispersion at the exit

No dispersion at the start

| Beam Parameter | Switching Dipole Entrance | Injection Septum Exit | Unit |
|---|---|---|---|
| $\beta_x$ | 25.08 | 0.622 | m |
| $\beta_y$ | 26.45 | 1.819 | m |
| $\alpha_x$ | 0 | 0.074 | |
| $\alpha_y$ | 0 | -0.963 | |
| $D_x$ | 0 | 0.392 | m |



Various physical effects to simulate

- **Losses** (BDSIM: ✓, RF-Track: ✗ , GPT: ✗ )
- **Space-charge effect** (RF-Track: ✓, GPT: ✓, BDSIM: ✗)
- **Dispersion** ( BDSIM: ✓, RF-Track: ✓, GPT: ✗)

# Beam tracking workflow: Next

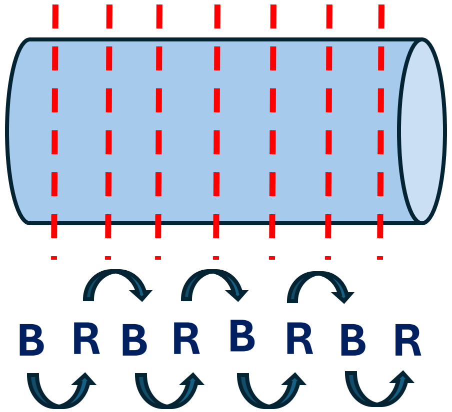
LhARAlinearOptics → RFTrack ⇄ INTERFACE ⇄ BDSIM

TNSA beam production ✓

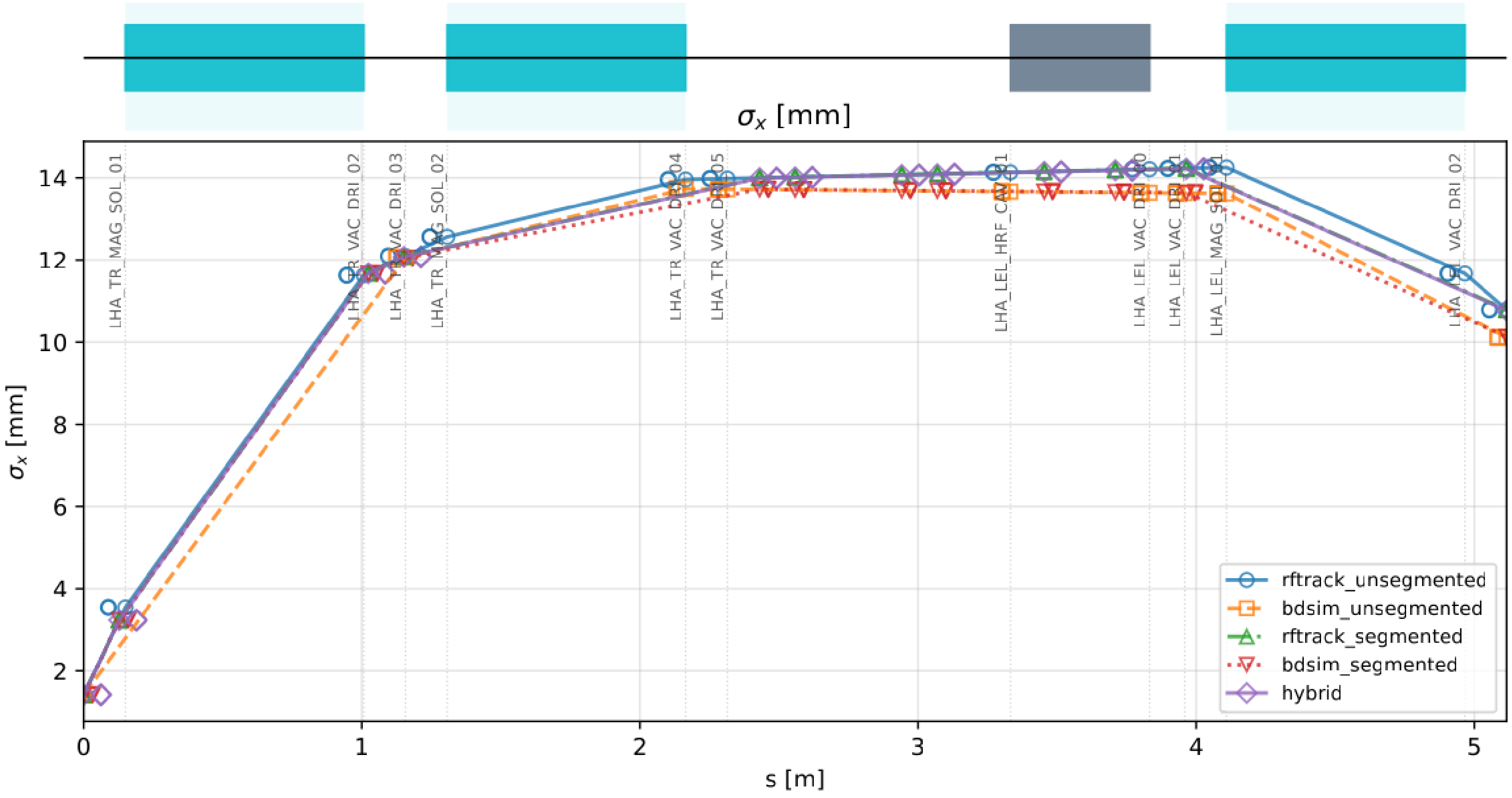
RFTrack / INTERFACE / BDSIM → Full Stage 1 beamline **with Space Charge effect**

**Discretised element**

**Software used:**



# Preliminary simulation results: validation




Comparison without space charge effect

GPT VS RF-Track space charge effect: work in progress.

# Conclusion

- BDSIM is well suited for particle–matter interactions, but not sufficient alone for accurate collective beam tracking.

- GPT presents limitations, especially in dispersive regions and magnetic elements for long beams.

- A hybrid strategy combining BDSIM and RF-Track appears to be the most appropriate solution.

**Next steps:**

- Extend tracking in RF-Track by using time integration instead of space.

- Validate space-charge simulations in RF-Track against GPT.

Thank you for your attention!