Injector Beam Dynamics

PERLE Injector: Buncher design review

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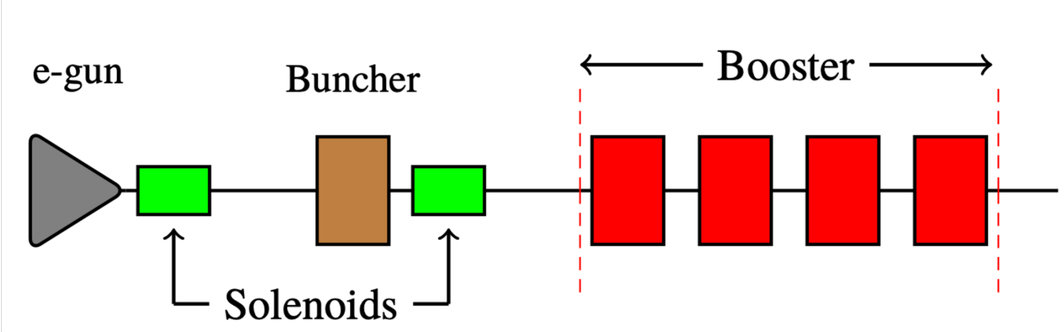
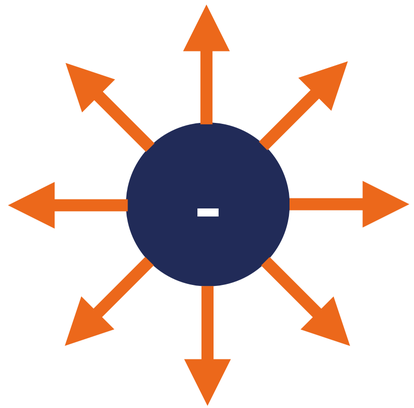
Introduction

- PERLE injector has several competing requirements.
- There is the possibility to tune the setup of the components to achieve the requirements.
- Not a straightforward solution - there are many possibilities.
- How to decide which is the best one?
- And how to find them…



Key challenges with PERLE

The space charge effect



REPULSION *Coulomb field of elections* → **MUTAL REPULSION** *Increase beam size* → **SC DOMINATED EMITTANCE GROWTH** → *Large size and energy spread*; *Formation of tails and halo*

- Injection at low energy combined with high charge means a space charge dominated beam.
- Formation of long bunch tail and a halo may lead to losses in the ERL.
- Many possible solutions - How to decide which is the best one?
- And how to find them…

Multi-Objective Optimisation (…briefly)

Applying genetic algorithms

- Heuristic optimisation -> Many solutions are tried.
- Ability to search a large and complex parameter space.
- **Objectives:**
  - Minimise: longitudinal emittance ϵ_s; transverse emittance ϵ_x; and uncorrelated energy spread d*E.*
- **Constrains:**
  - Max. Emit; Min/Max; RMS size/length; Energy = 7 MeV.

Simulation Code

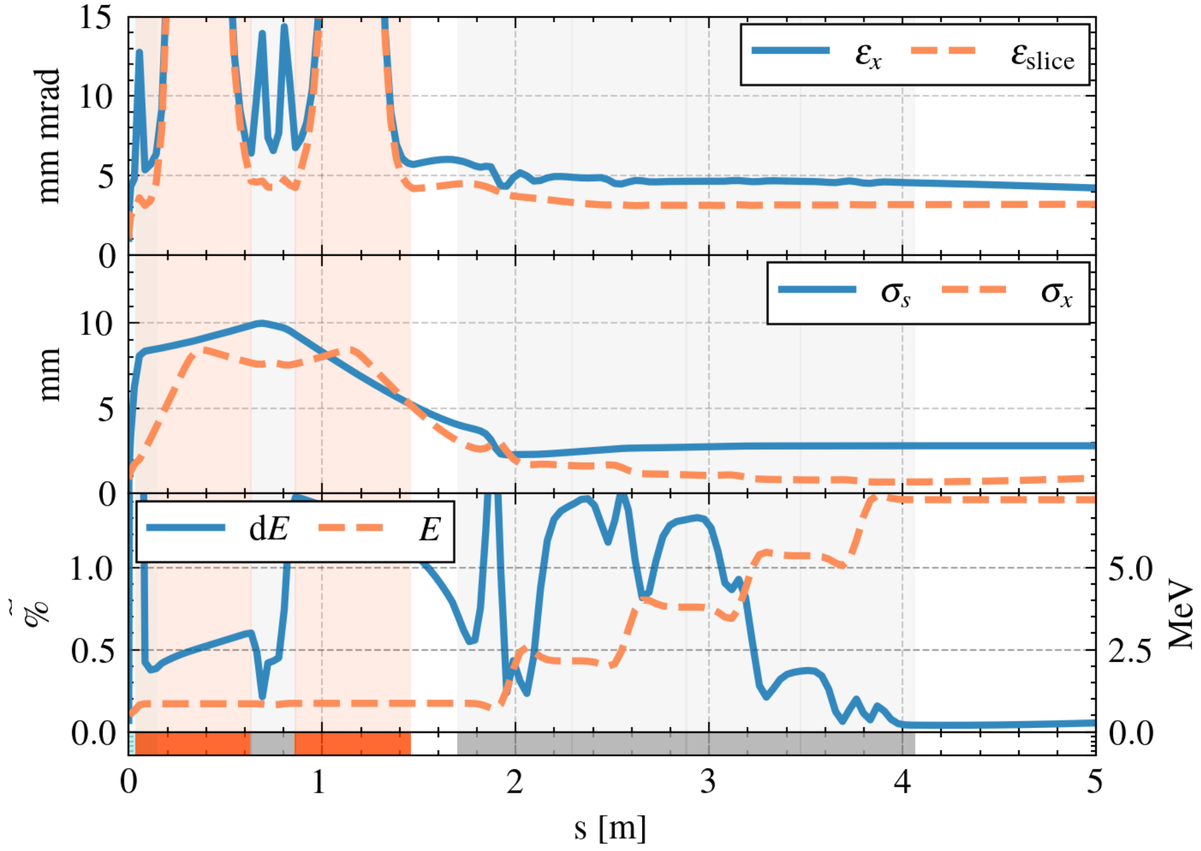
- OPAL used for all simulations.
- Leverages **high throughput computing** → Many OPAL simulations at once.

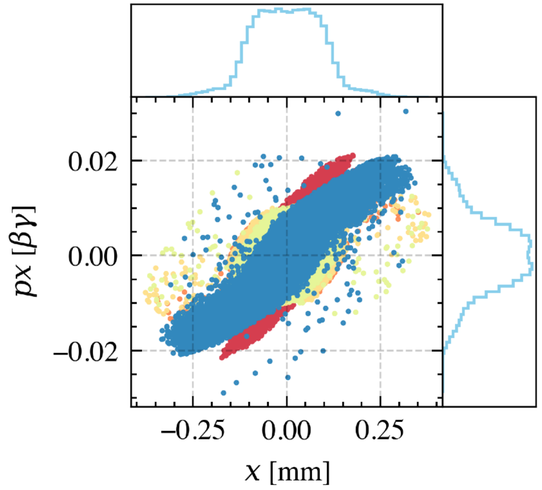
What about ASTRA?

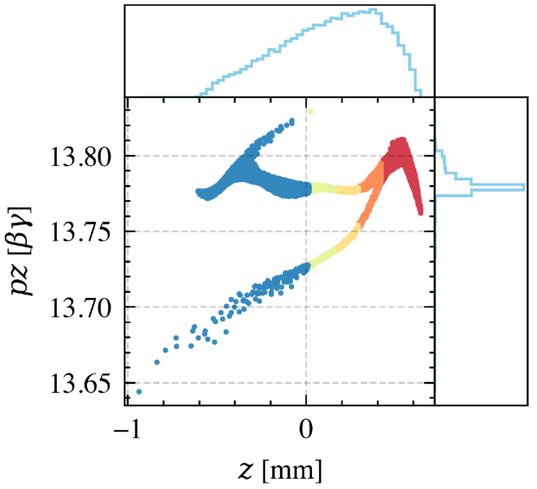
- Space Charge modelling!
  - OPAL has a full 3D adaptive mesh and uses Fast Fourier Transform for solving.
  - ASTRA uses linear interpolation in grid cells, less accuracy for non-linear effects.

The resulting solution

- Tail formed right after emission.
- Halo particles correspond to the same particles as present in the tail.







ϵ

ε_x = 4.2 mm mrad

$\varepsilon_{\text{slice}}$ = 2.63 mm mrad

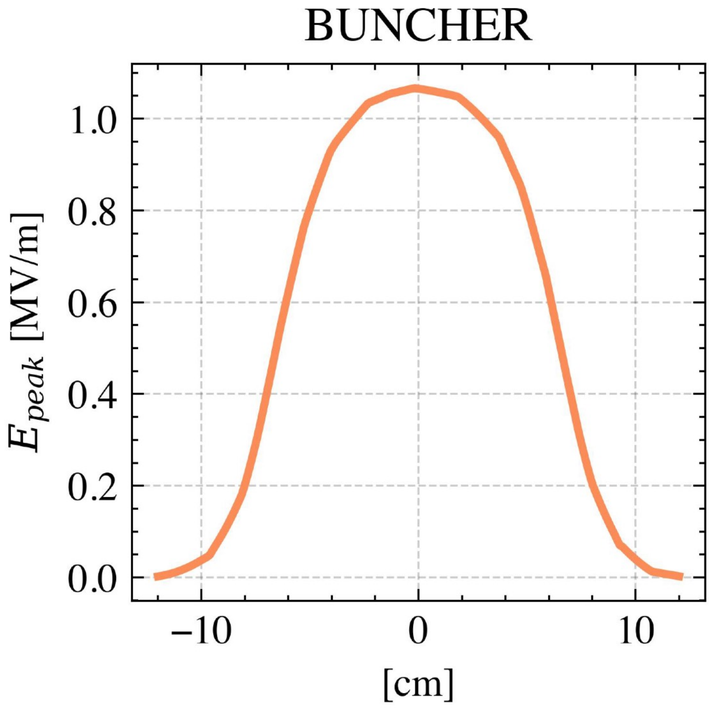
σ_x = 0.9 mm

σ_s = 2.8 mm

dE = 3.863 keV
0.055%

The buncher

- **Phase lag = -1.57 rad** ***(-π/2 rad)***
  The amount off-peak
- **Peak on-axis voltage = 1.06 MV/m**
- **Energy gain = 90 keV**



Conclusion

- With fully optimised parameters it is possible to achieve the PERLE specifications.
  - Most importantly of bunch length less than 3mm and emittance less than 6 mm mrad.
- **What is next?**
  - To assess tolerances of injector to misalignments (ongoing).
  - Space charge tracking in the merger.