PERLE injector design

Electrons for the LHeC workshop

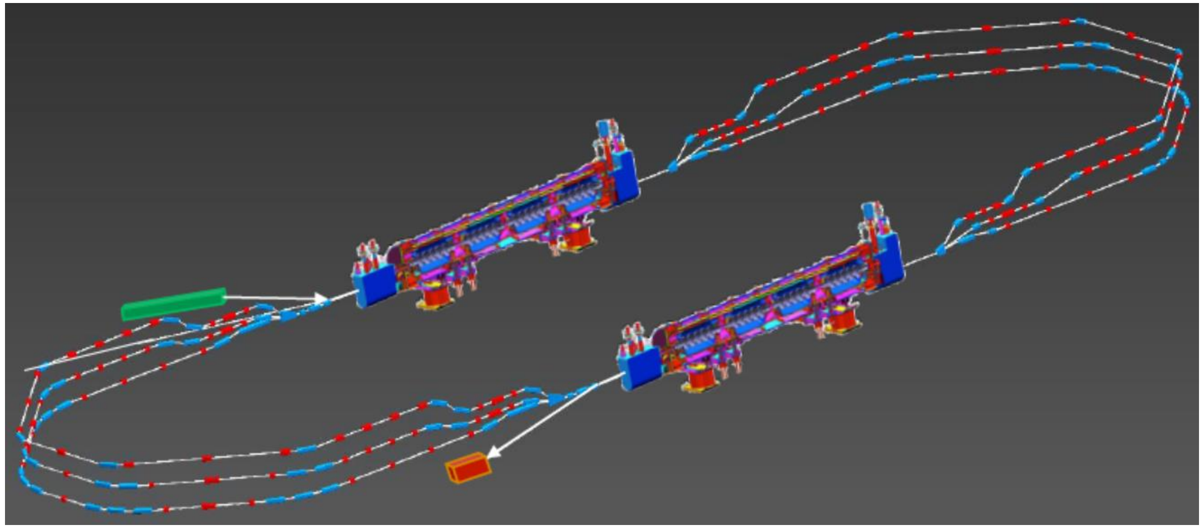
24/08/2019

Overview

- Overview of the PERLE injector
- Electron gun re-optimisation
- Injector optimisation
- Future work

PERLE (Powerful Energy Recovery Linac for Experiments)

- A 3 turn, 500 MeV, 20 mA (unpolarised) beam current ERL.
- Potential for 5 mA polarised operation.
- Uses 802 MHz SRF cavities.
- Is planned to be built at LAL Orsay.
- Test facility for the LHeC

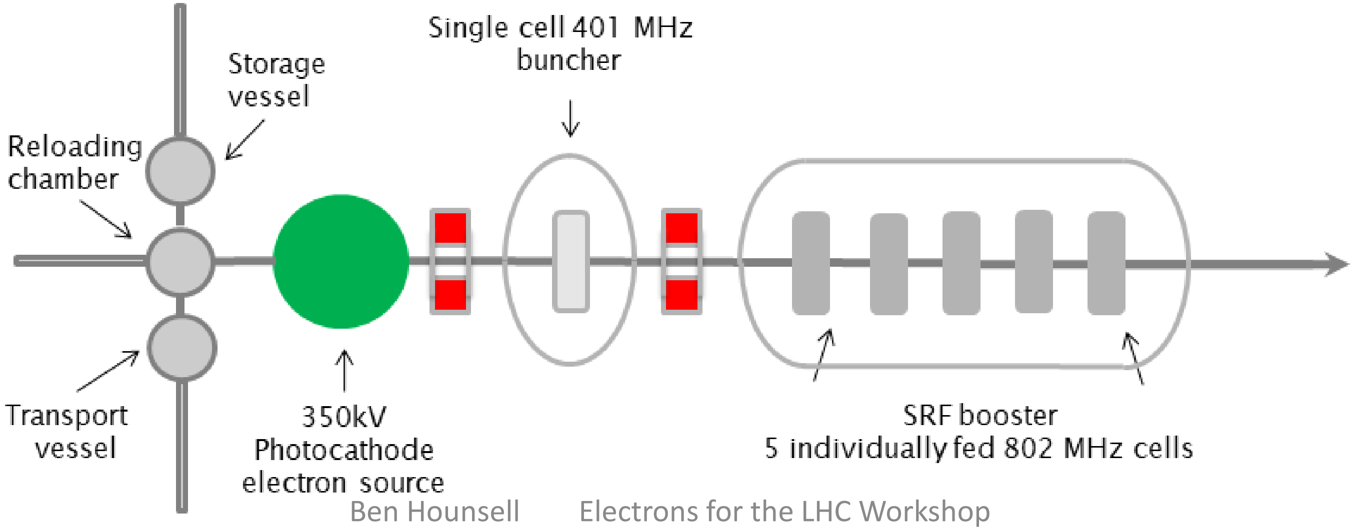


PERLE injector specification

	PERLE Parameters
Injection energy	7 MeV
Unpolarised bunch charge	500 pC
Bunch repetition rate	40.1 MHz
Unpolarised current	20 mA
Polarised current	5 mA
Polarised bunch charge	125 pC/ 500 pC
RMS bunch length	3 mm
Emittance	< 6 π·mm·mrad
Uncorrelated energy spread	< 10 keV

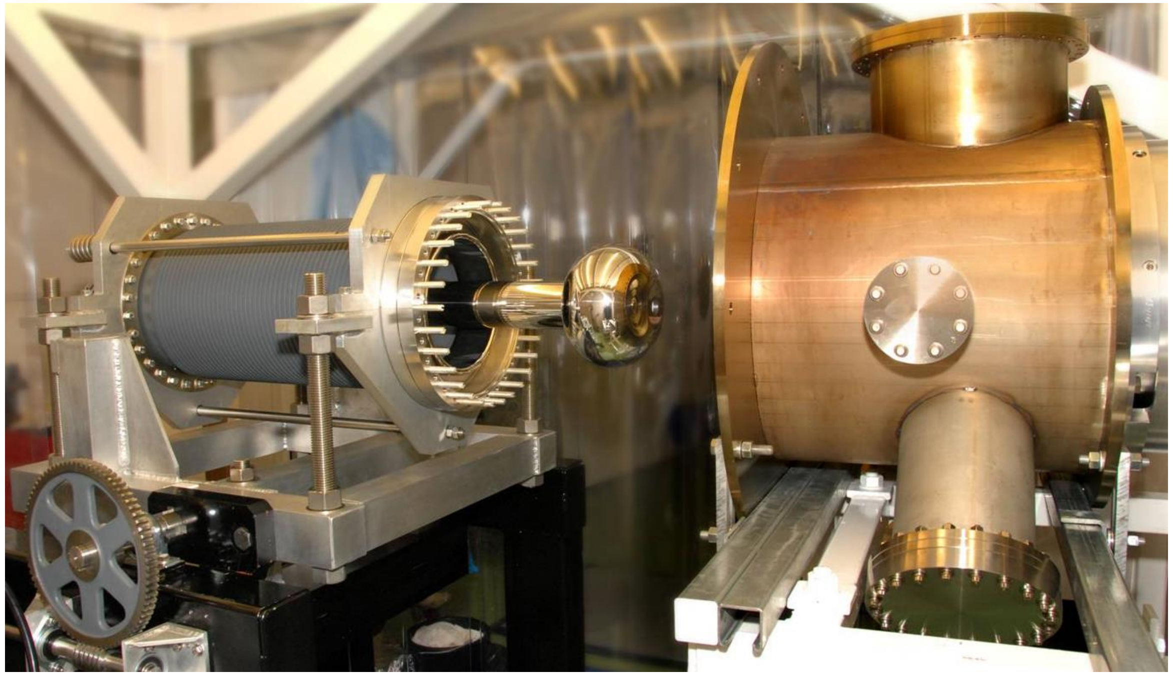
PERLE injector layout

- The PERLE injector consists of:
  - 350 kV DC photoemission electron gun.
  - A bunching and focusing section consisting of a solenoid, a 401 MHz normal conducting buncher cavity and then another solenoid.
  - A superconducting booster with 5 single or double cell 802 MHz cavities with individual control of the amplitudes and phases.
  - Merger to transport the beam into the main ERL.
- For polarised operation spin manipulation will also need to be added.



Re-optimisation of the ALICE electron gun

- The ALICE electron gun was re-optimised for PERLE's requirements.
- This is necessary for two reasons:
  - PERLE operates with a much higher bunch charge of 500 pC compared to the 80 pC of ALICE.
  - For polarised operation the gun needs to be operated at a lower voltage, 220 kV, so the gun should be effective at both 220 kV and 350 kV.
- Finding a compromise solution between 350 kV and 220 kV operation was the main goal of the work here.

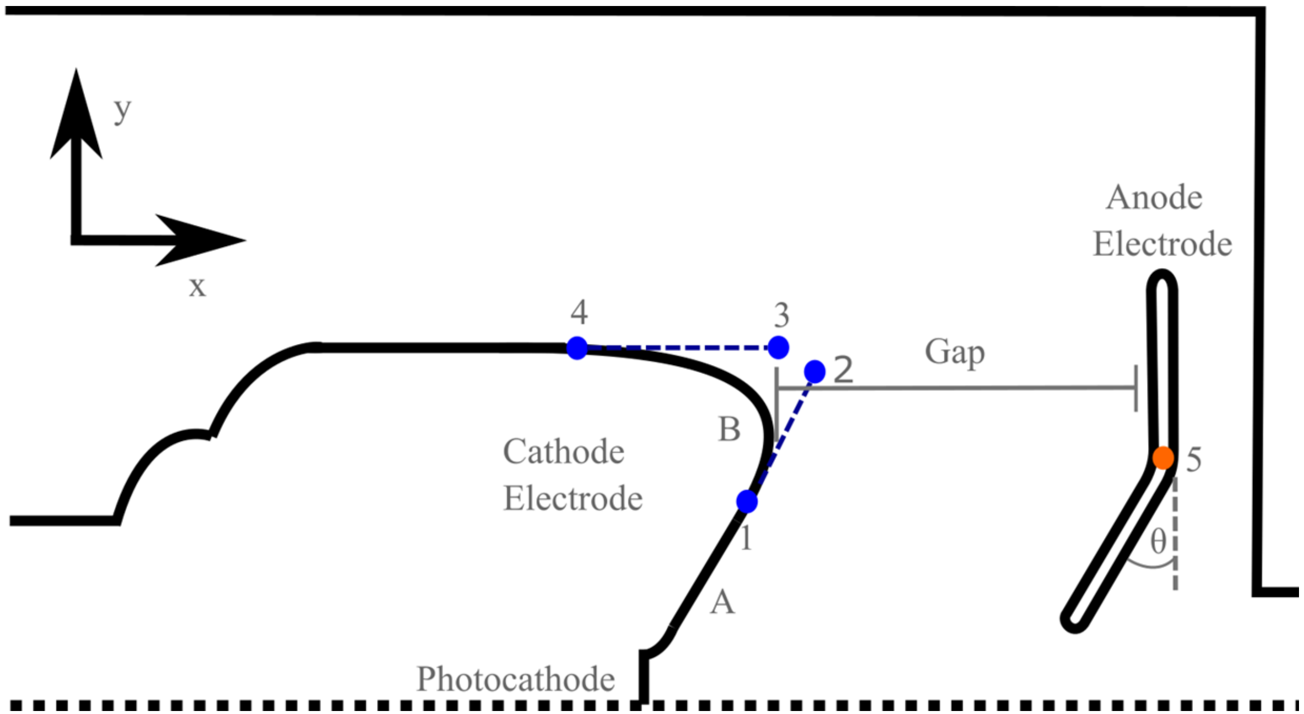


Re-optimisation procedure

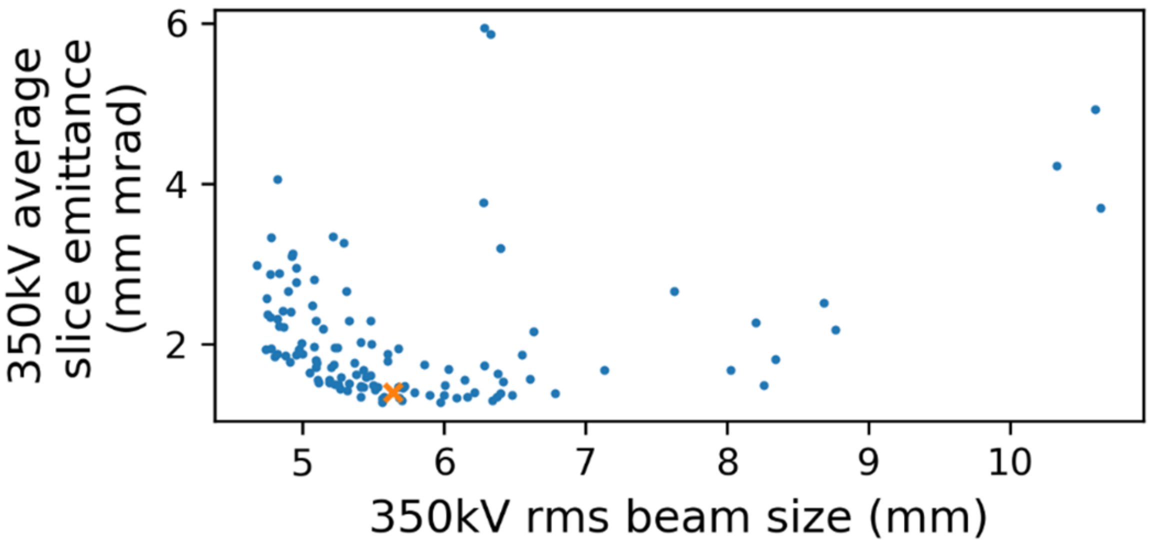
- The electron gun electrode geometry, laser parameters and first solenoid field were optimised together.
- The optimisation had four objectives. To minimise the average slice emittance and rms beamsize for both voltages 220 kV and 350 kV.
- The optimisation had four constraints to keep the electrode surface electric field below 10 MV/m (to prevent field emission) and to have no particle losses. These two objectives applied for both voltages.
- The electron gun electrostatic fields were simulated with POISSON and the beam dynamics with ASTRA.
- The optimisation was performed with the many objective optimisation algorithm NSGAIII.

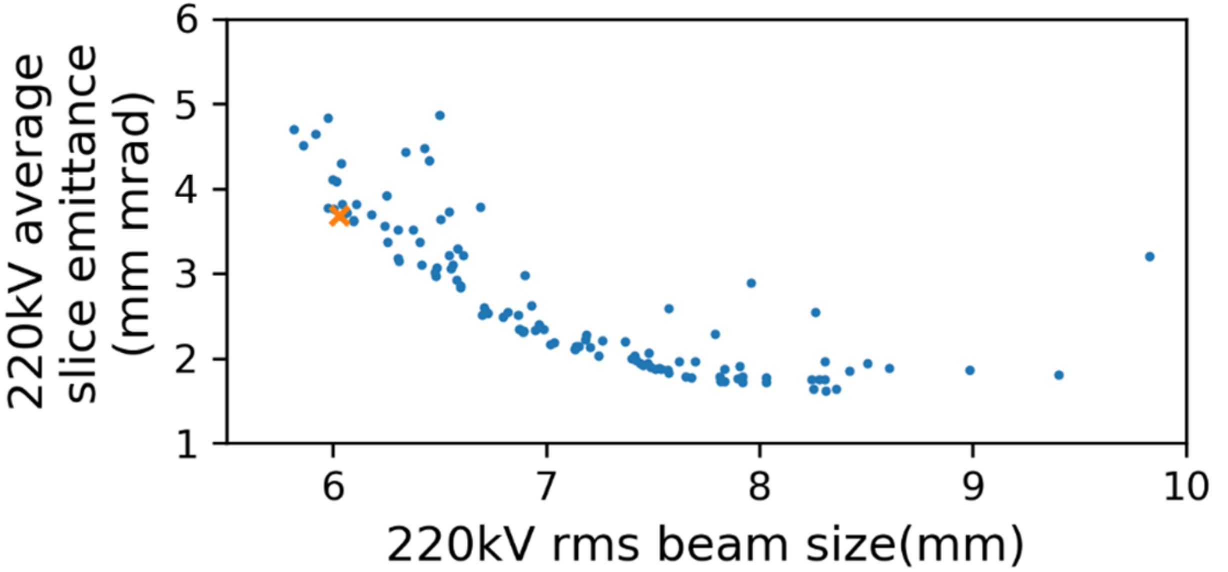
Geometry parameterisation

- The cathode and the anode electrodes geometry could both be varied.
- The cathode consisted of a flat focusing section and then a curved section modelled as a Bezier curve. It was described by 5 variables.
- The anode consisted of two straight sections with an angle between them and was described by 2 variables.



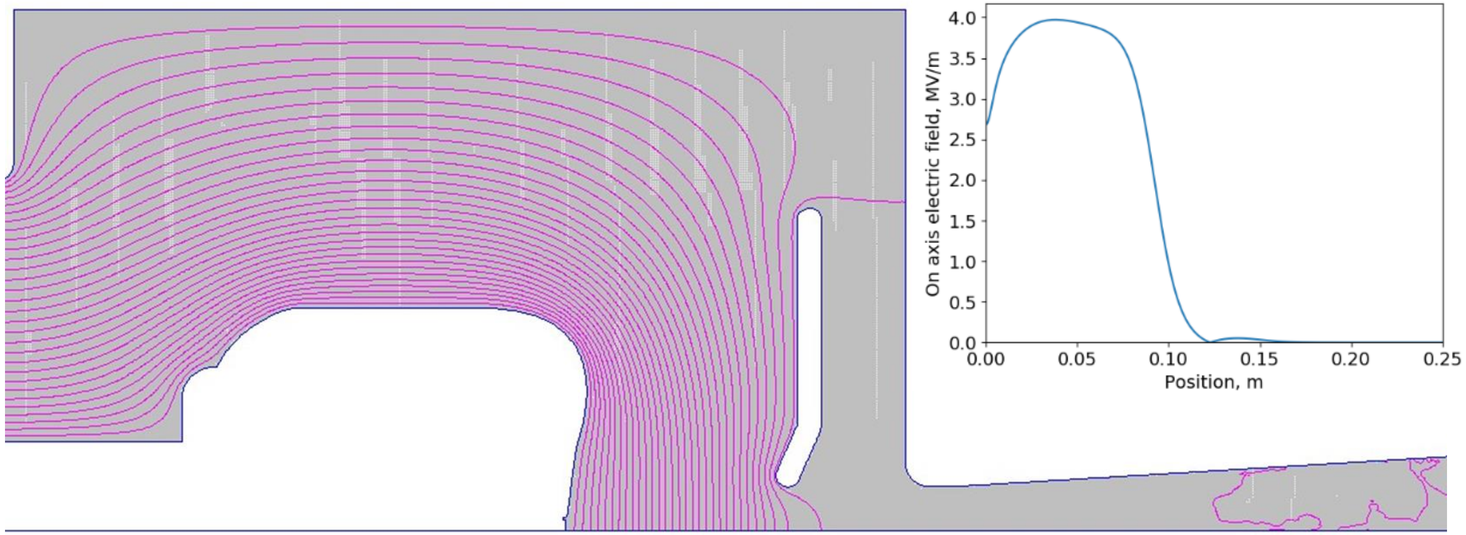
Pareto front projections





Selected electron gun

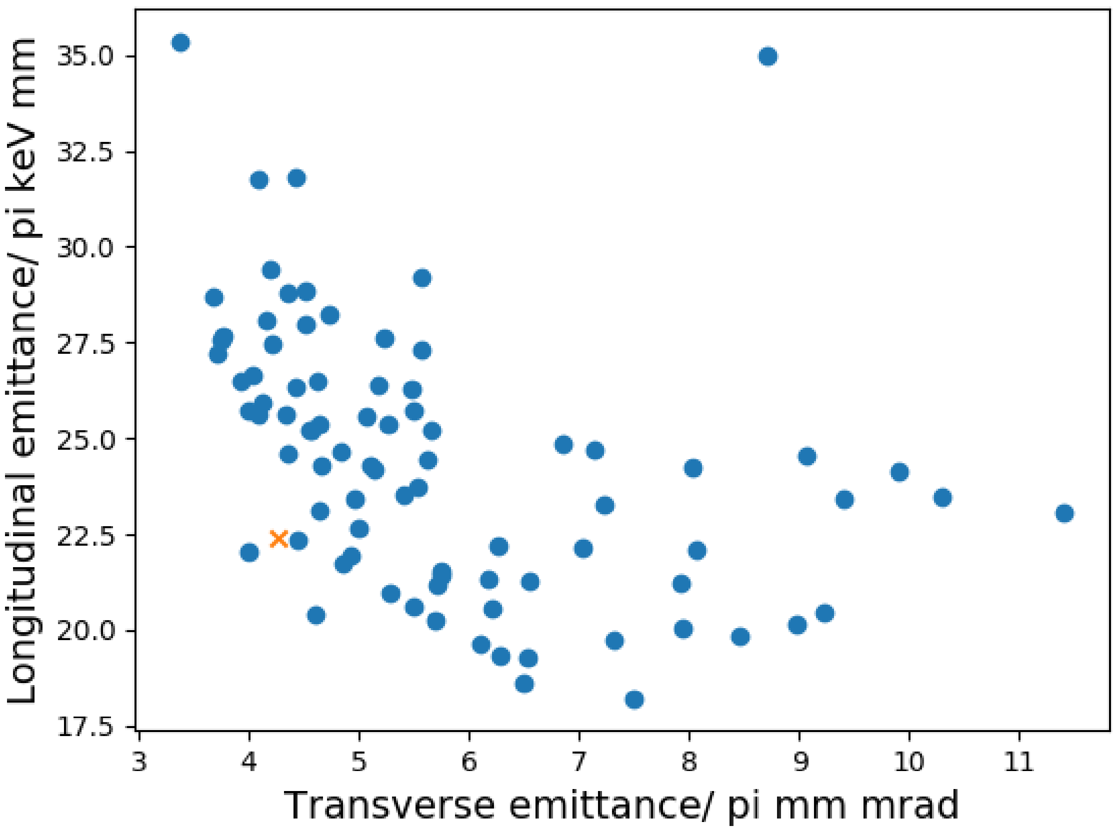
- The selected electron gun has a much low focusing angle than the 20 degree angle of the original design.
- The anode has been moved slightly in.
- These changes increase the cathode surface electrode field.

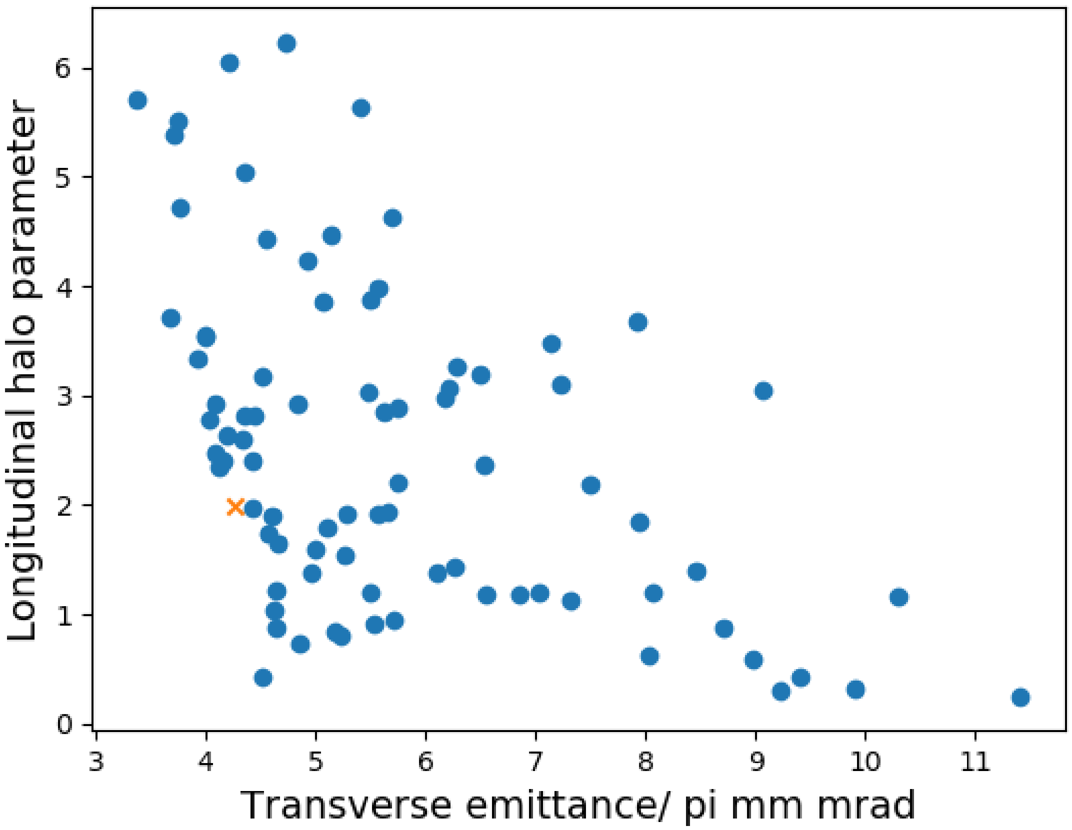


Injector re-optimisation

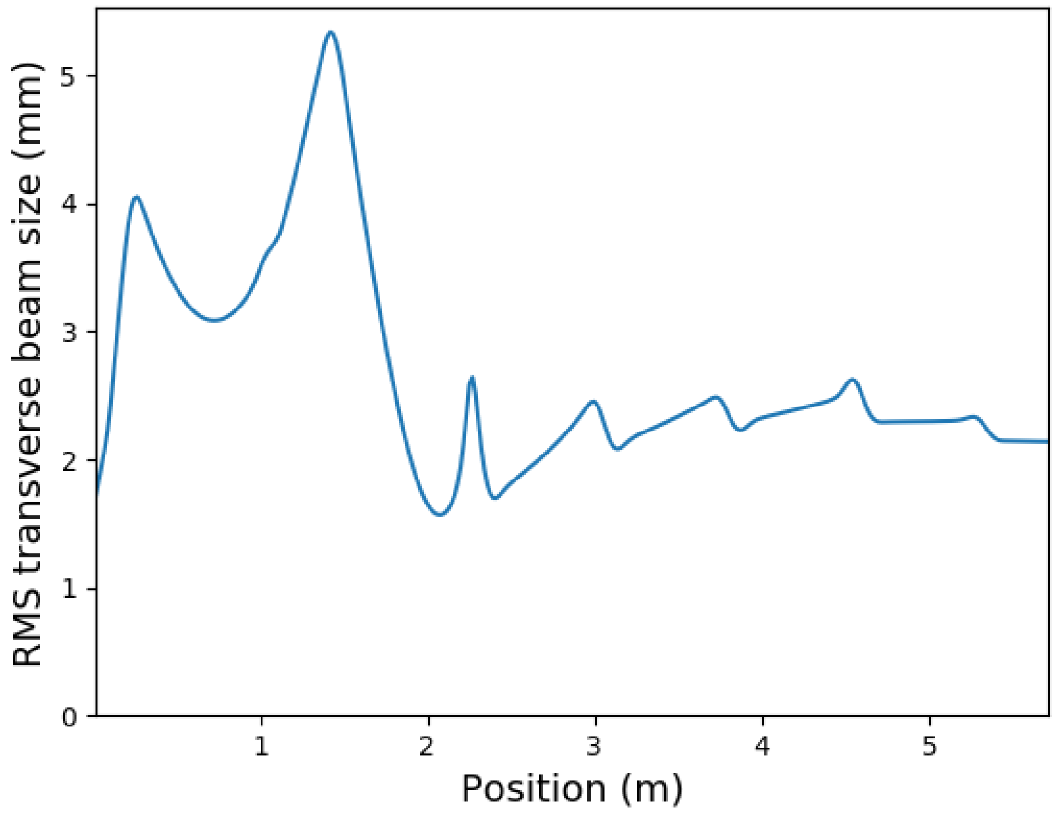
- The new gun design was then used as part of an optimisation of the injector up until the booster exit
- The optimisation had 5 objectives to minimise at the booster exit:
  - Transverse emittance
  - Longitudinal emittance
  - RMS energy spread
  - X halo parameter
  - Z halo parameter
- Constraints were used to keep the beam size below 6 mm as well as to achieve a final beam energy of 7 MeV and a final bunch length of 3 mm.
- The optimisation was performed using NSGAIII.

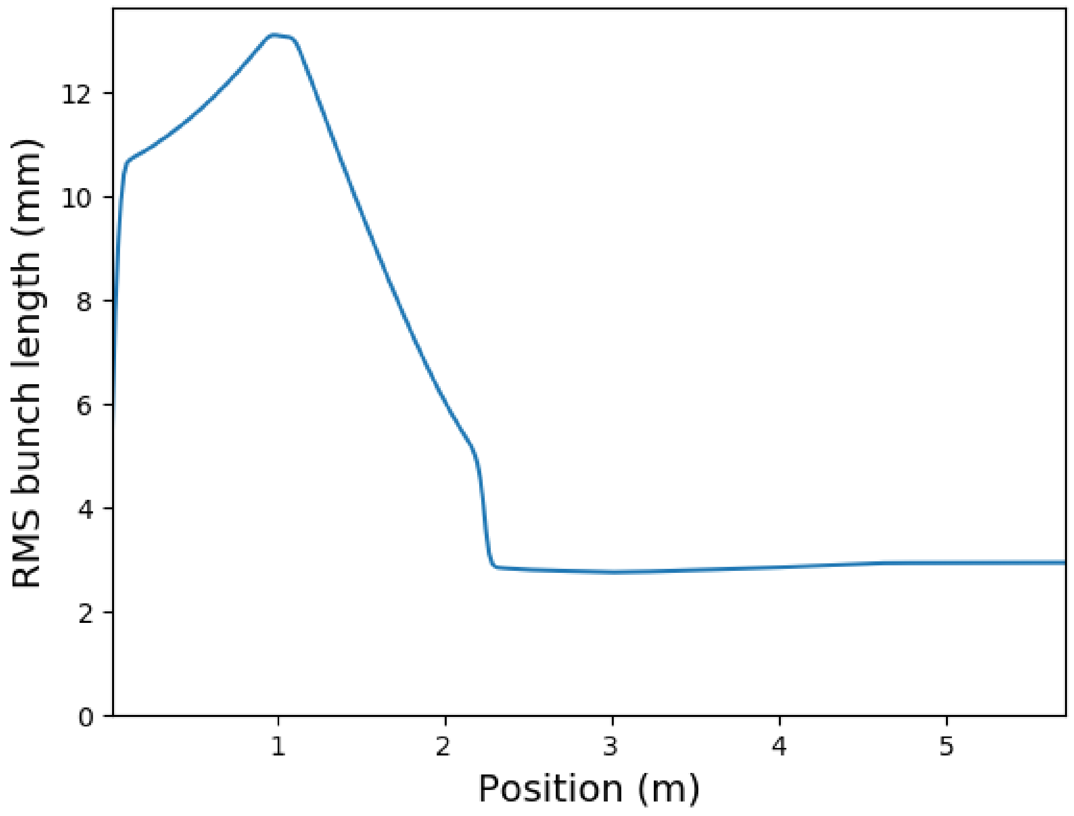
Pareto Front projections



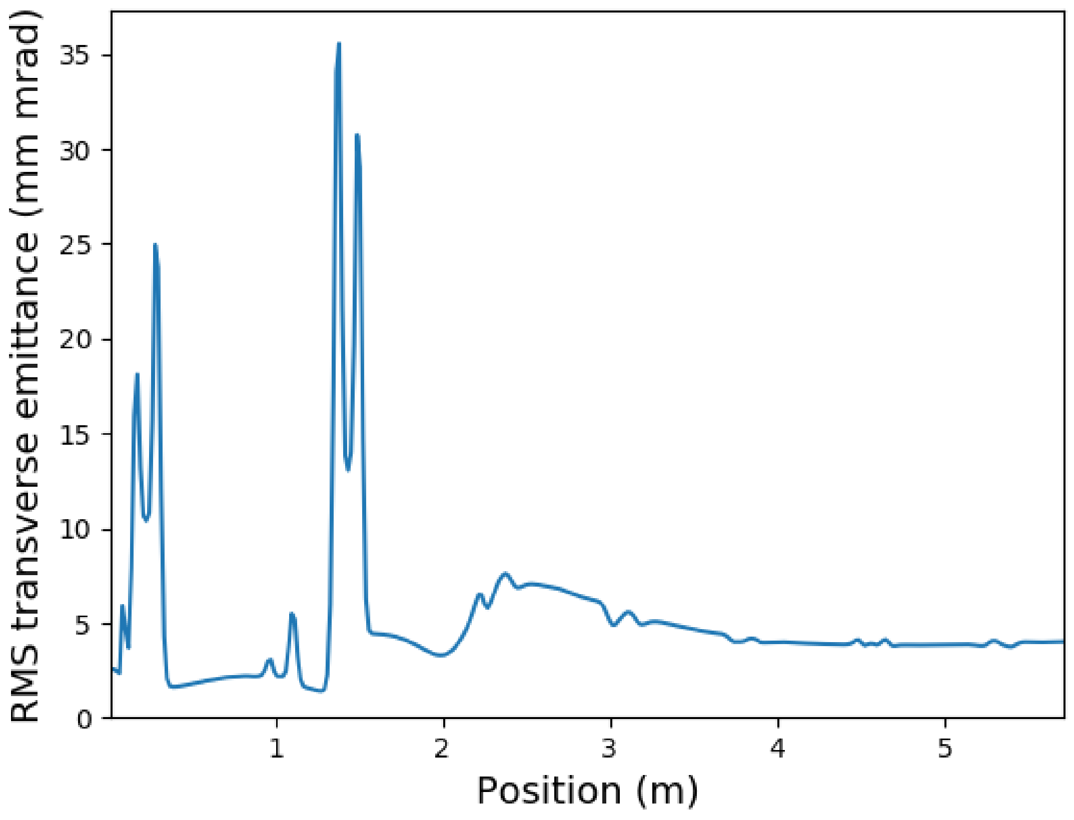


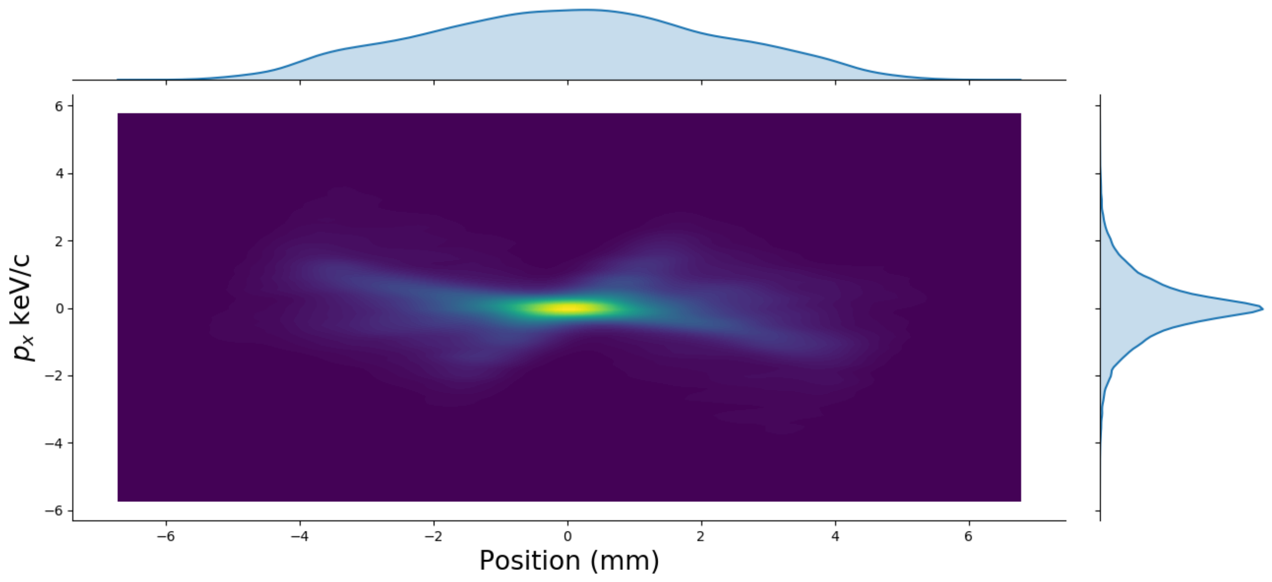
Beam sizes


RMS transverse beam size (mm)
0
1
2
3
4
5
1
2
3
4
5
Position (m)

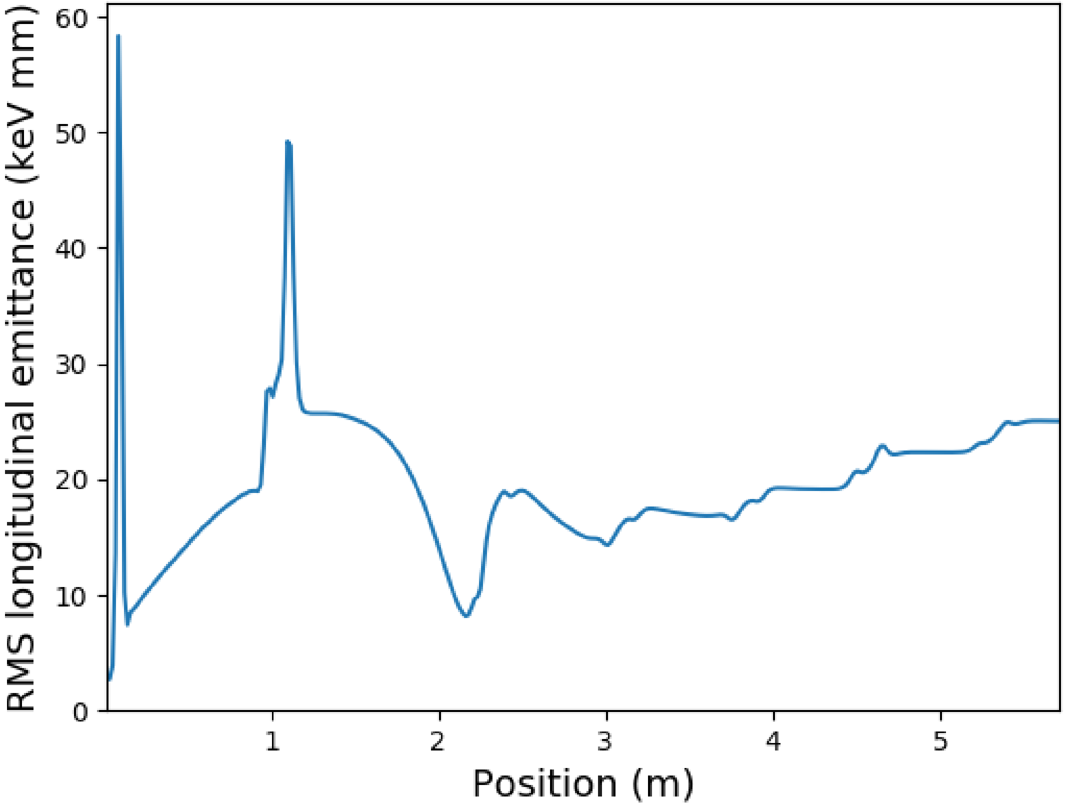

RMS bunch length (mm)
0
2
4
6
8
10
12
1
2
3
4
5
Position (m)

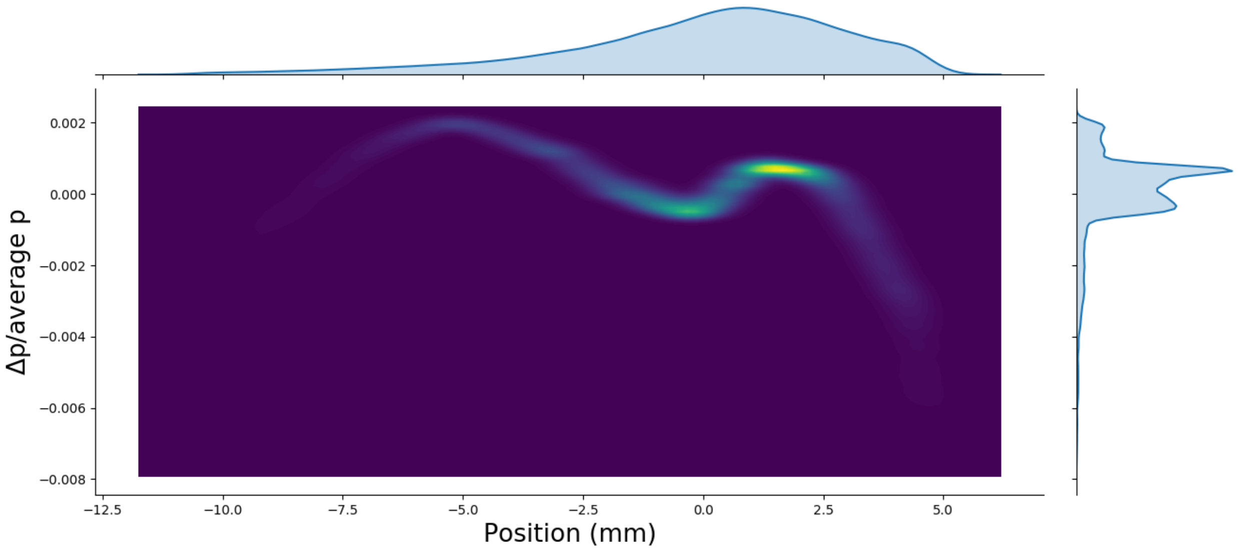
Transverse emittance and phase space





Longitudinal emittance and phase space





Conclusions

- The unpolarised PERLE injector is capable of meeting the required specification at the booster exit.
- The transverse emittance and phase space are satisfactory.
- The Longitudinal phase space is less linear than would be desired. The possibility of linearization will be investigated.

Achieved bunch parameters	
Transverse emittance	4.0 mm mrad
Longitudinal emittance	25.1 keV mm
Bunch length	3.0 mm
Energy	7.0 mm

Future work

- Design a merger between the injector and the main ERL loop. Work on this is currently ongoing.
- Investigate the possibility of adding a linearizer after the booster.
- Design and optimise polarised variant of the injector.
- Tolerance studies.
- Start to end simulations of the whole machine with space charge.