Update on the beam dynamics of the injector

R. Roux
J. Michaud
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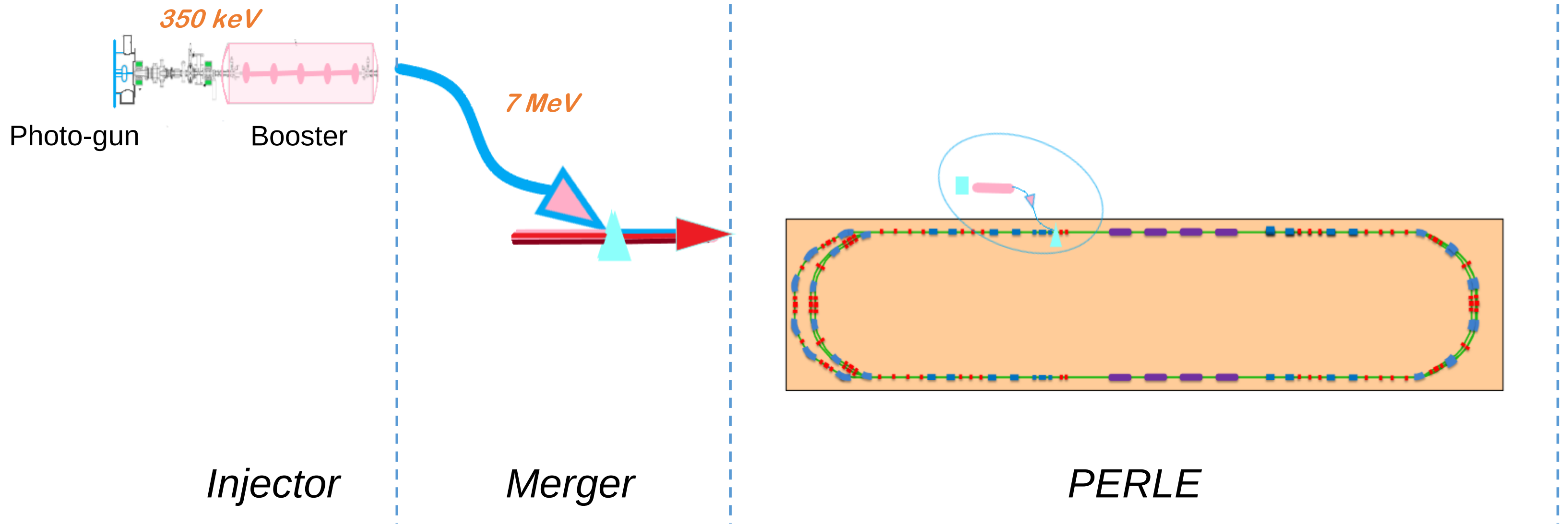
Outline

1. Injector with ALICE gun
    - Fulfilment of the specifications
    - Comparison with others codes
    - Variation with some parameters
2. Injector with RI gun (preliminary results)

PERLE injector purpose and specifications

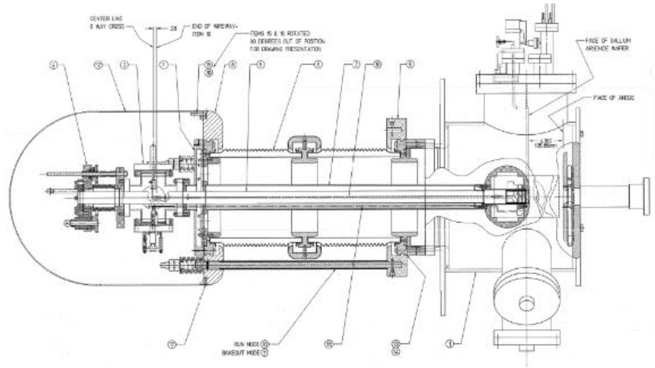
Role of injector: create the bunch of electrons and accelerate it to sufficient energy to be transported

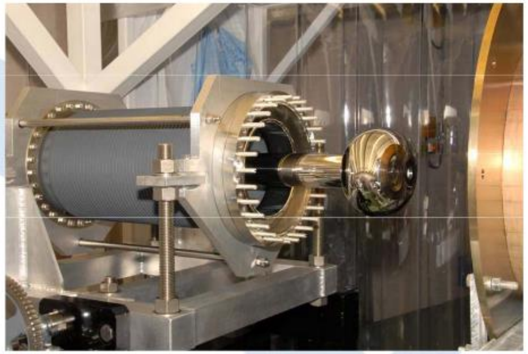


<u>It should match the Perle specifications initially set at :</u>

Emittance	Bunch charge	Rep. rate	Current	RMS bunch lenght	Total inj. energy
<6mm.mrad	500 pC	40.1 MHz	20 mA	3 mm	7 MeV

1. Alice Photoinjector



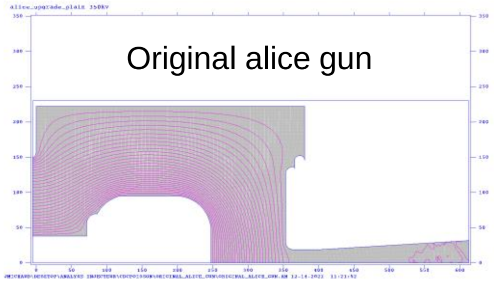


➔ Original gun under installation at IJCLab

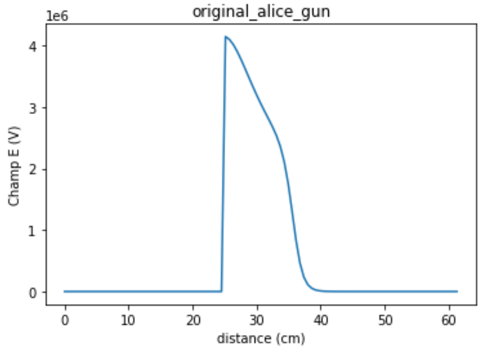
- R. Roux
- M. Baylac
- D. Reynet

- e⁻ bunch is produced by photoemission with a laser => big importance of laser parameters
- Acceleration with a DC voltage, 350 kV
- Concern: charge higher than in the ALICE gun => space charge force higher

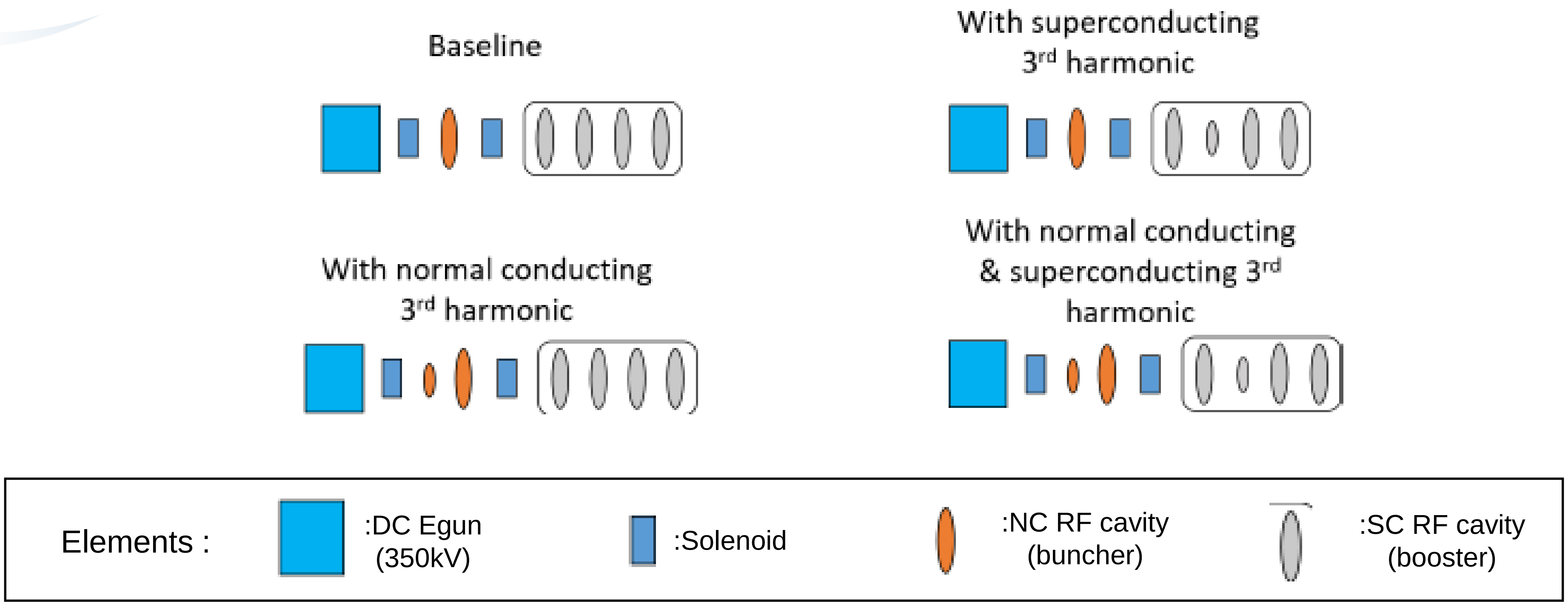
POISSON mesh



Field map



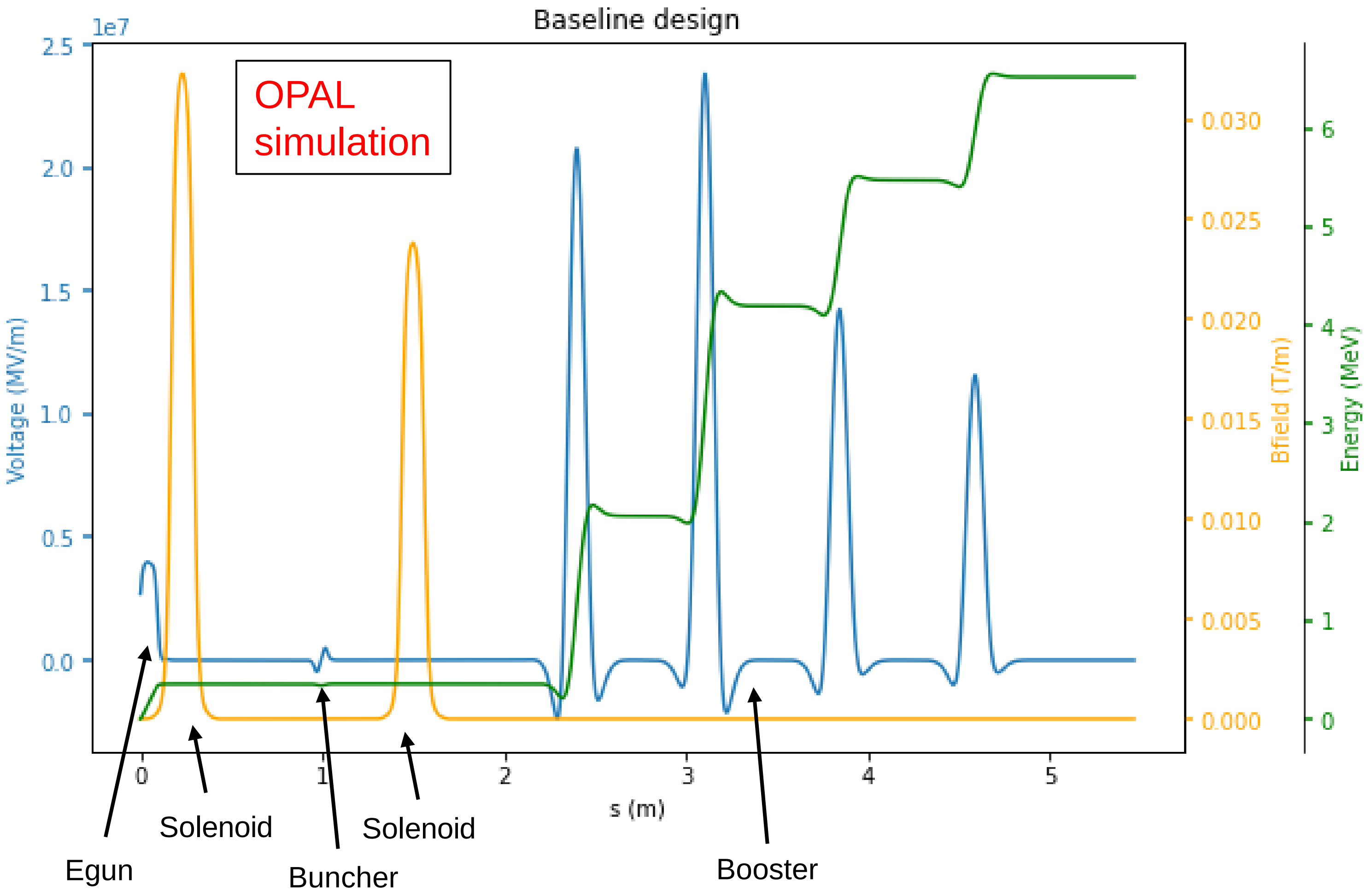
4 possible injector designs : from Ben Hounsell's PhD thesis



As all designs seem to meet the specifications, only Baseline design has been studied for the TDR

Studies by F. Bouly (LPSC), J. Michaud (IJCLab), R. Roux (IJCLab)

Injector Fields and energy



Good agreement with the specifications

Elem. attribute	Value
Egun Voltage	350 kV
Egun laser freq.	40 MHz
Bunch charge	500 pC
Solenoid 1 field	0.0323 T
Buncher Field	1,305 MV/m
Buncher freq	801 MHz
Solenoid 2 field	0.0238 T
Booster field	20.8/24.0/14.4/11.7 MV/m
Booster freq	801 MHz

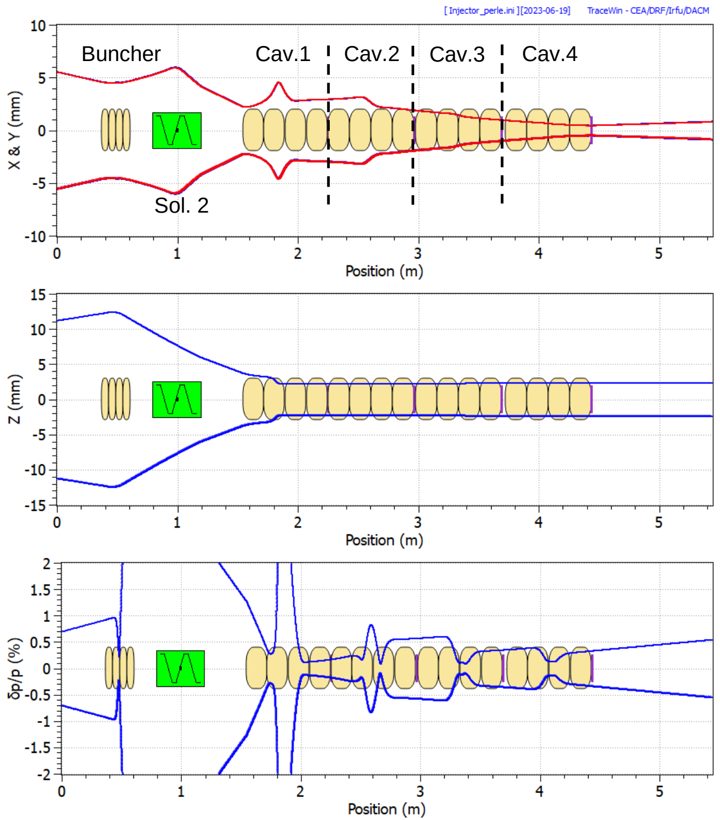
	Target	simu
ε (mmmrad)	< 6	3.7
Q (pC)	500	500
I (mA)	20	20
σ_z (mm)	3	2.97
E (MeV)	7	7.03

Current injector design meets Perle specification

Laser parameters:
Flat top; transverse, R = 2.2 mm; longitudinal, FWHM = 140 ps

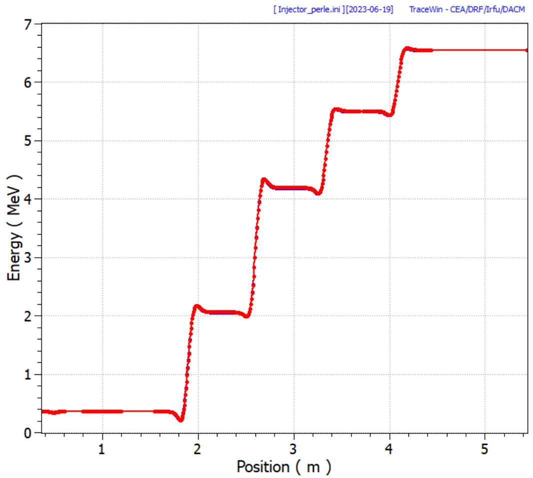
Benchmarking with TraceWin code

- TraceWin: 25 years old, developed at CEA and reliable results on Linac => ERL?
- Reference design provided by B. Hounsell (2022) :
  - *[Ref] : B. Hounsell, Conceptual design of the PERLE injector, PhD thesis, March 2022, Uni. Of Liverpool*



RMS envelopes in TraceWin (tracking)

Parameters	OPAL	TraceWin
σ_{X_RMS} (mm)	0.85	0.82
σ_{Z_RMS} (mm)	2.7	2.5
$\sigma_{\delta p/p\_RMS}$ (%)	0.3	0.5
$\varepsilon_{X\_RMS\_norm}$ (mm.mrad)	4.68	4.72
Ekin (MeV)	6.527	6.525
I (mA)	20	20

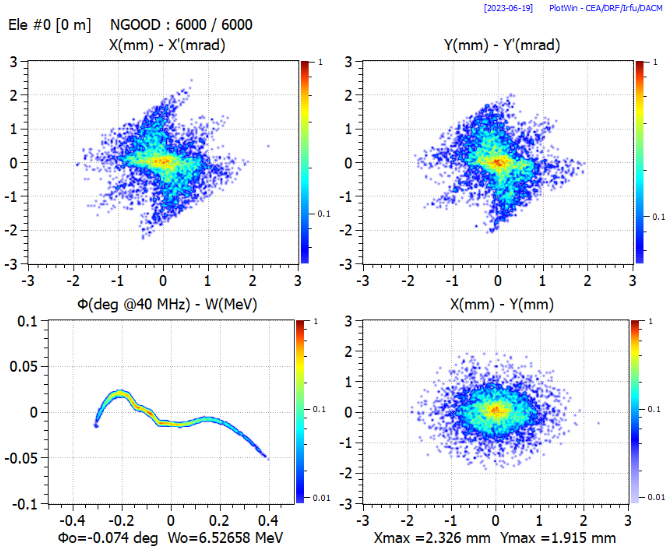


Kinetic Energy along the booster (TraceWin)

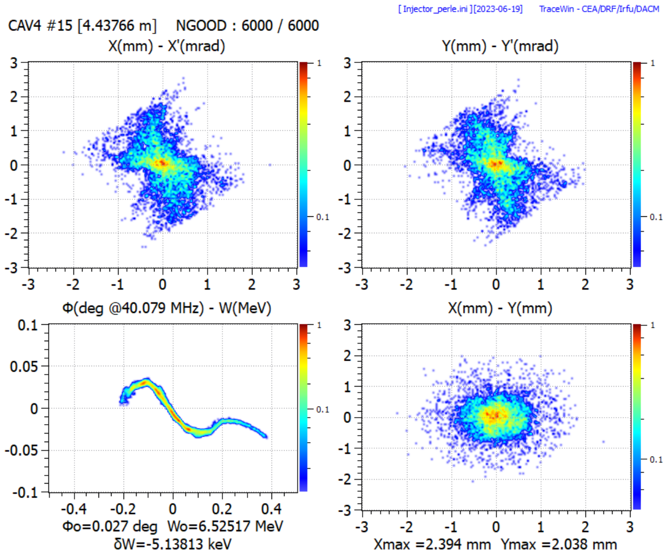
Benchmarking with TraceWin code

- First tracking study : beam dynamics in agreement between OPAL & TraceWin
- Beam distribution at exit of Cavity 4 (Booster)

OPAL

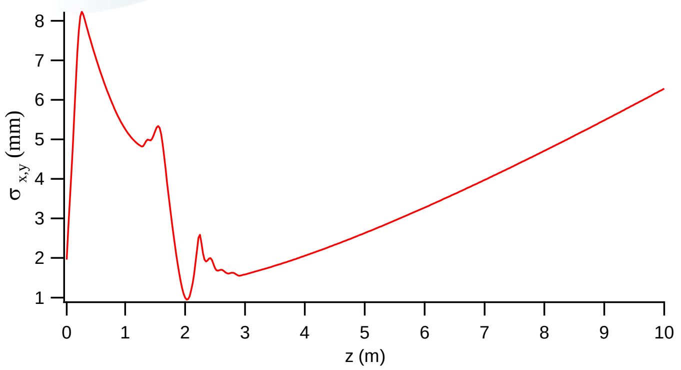


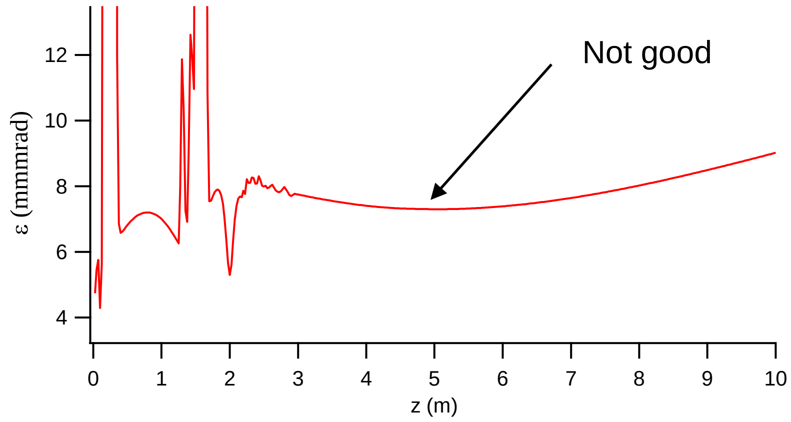
TRACEWIN

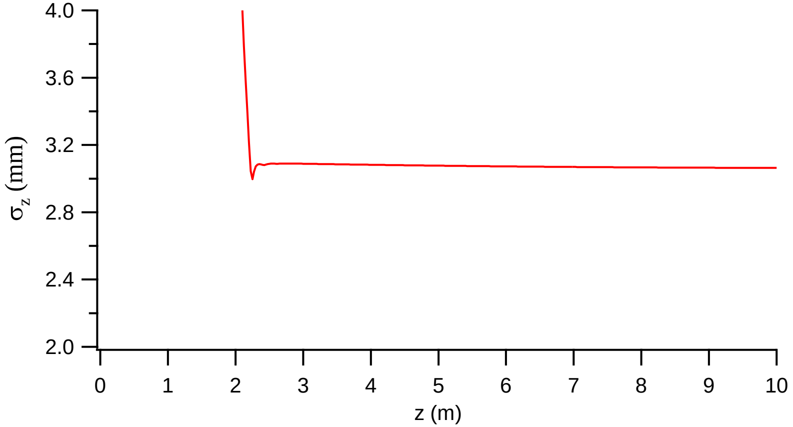


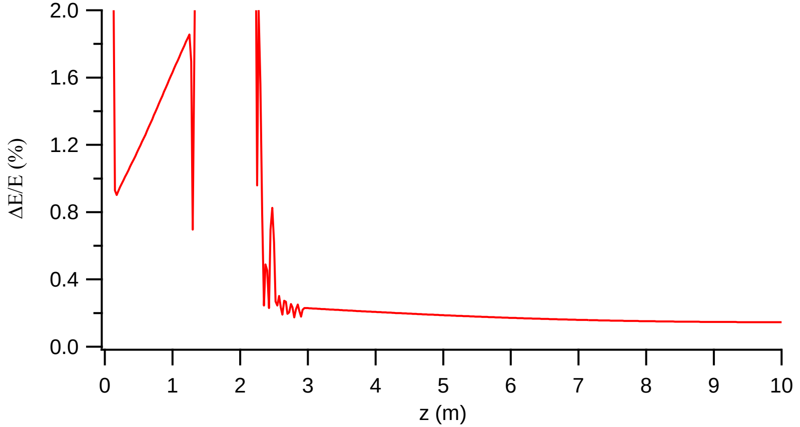
- Need further studies for complete understanding of longitudinal dynamics (space charge routines, phase tuning, Nbre of macro-particules, etc.)

Same parameters of simulation as the previous one but with $FWHM_{laser}$ = 35 ps



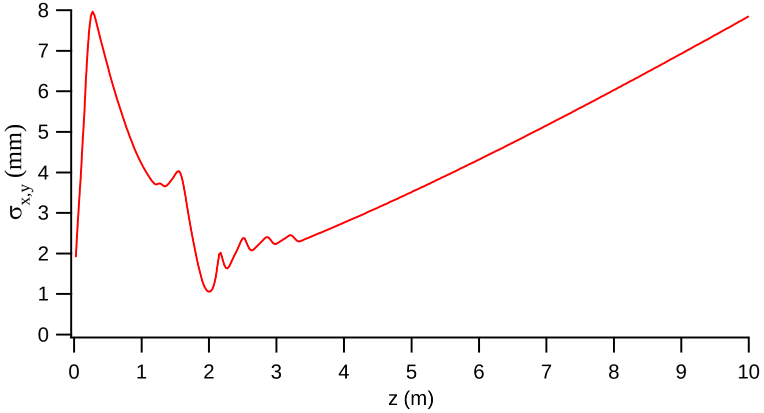


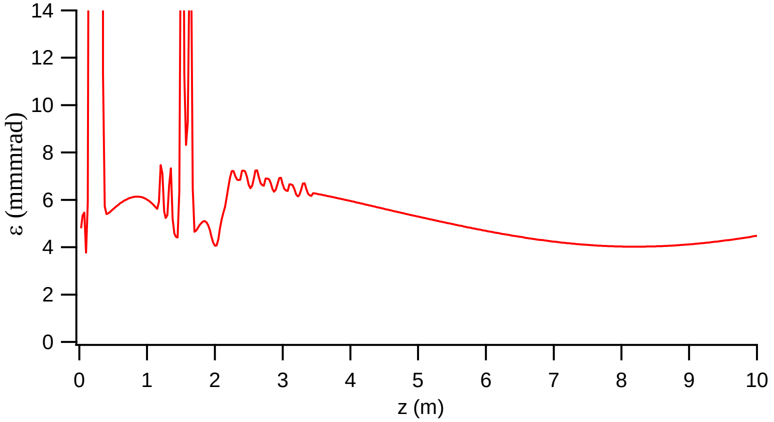




Simulations with ASTRA

Same parameters of simulation as the previous one but with $FWHM_{laser}$ = 50 ps





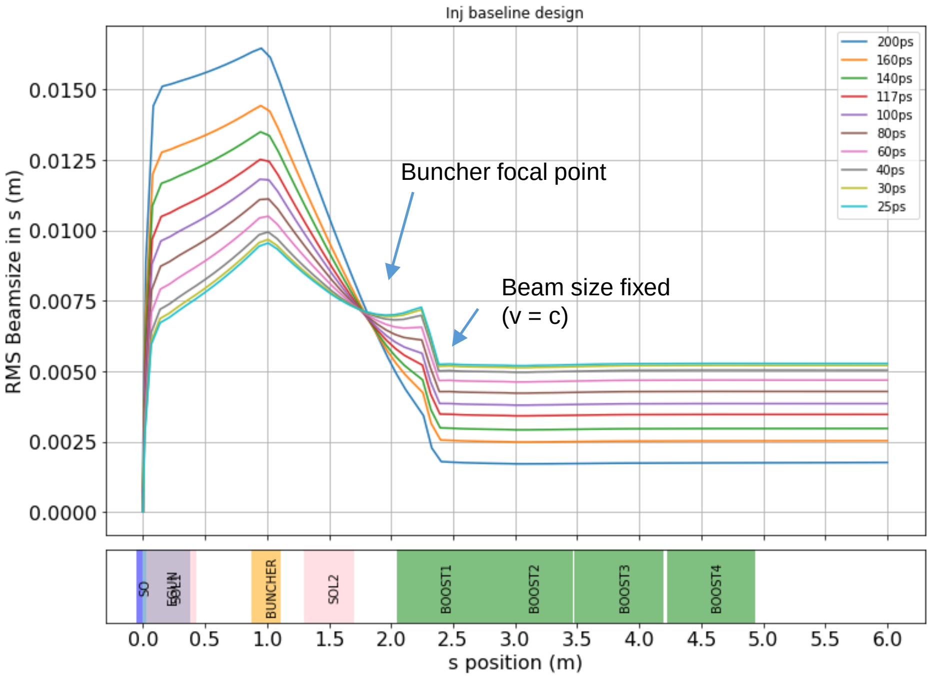
Bunch length and energy spread are OK

Better but is it the optimum?

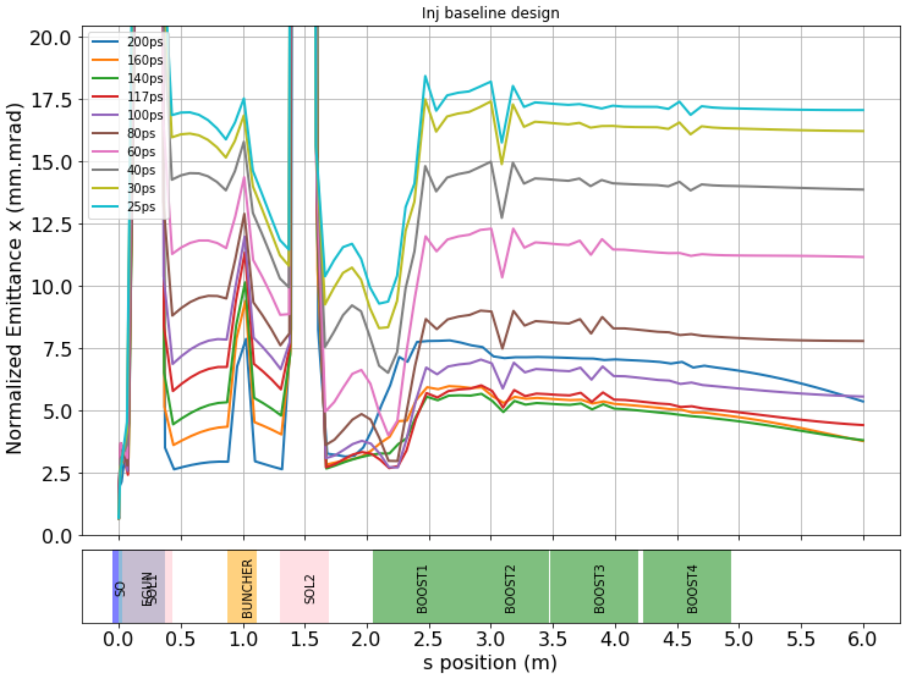
Try to play with different parameters

Exemple : effect of laser pulse length on the beam :

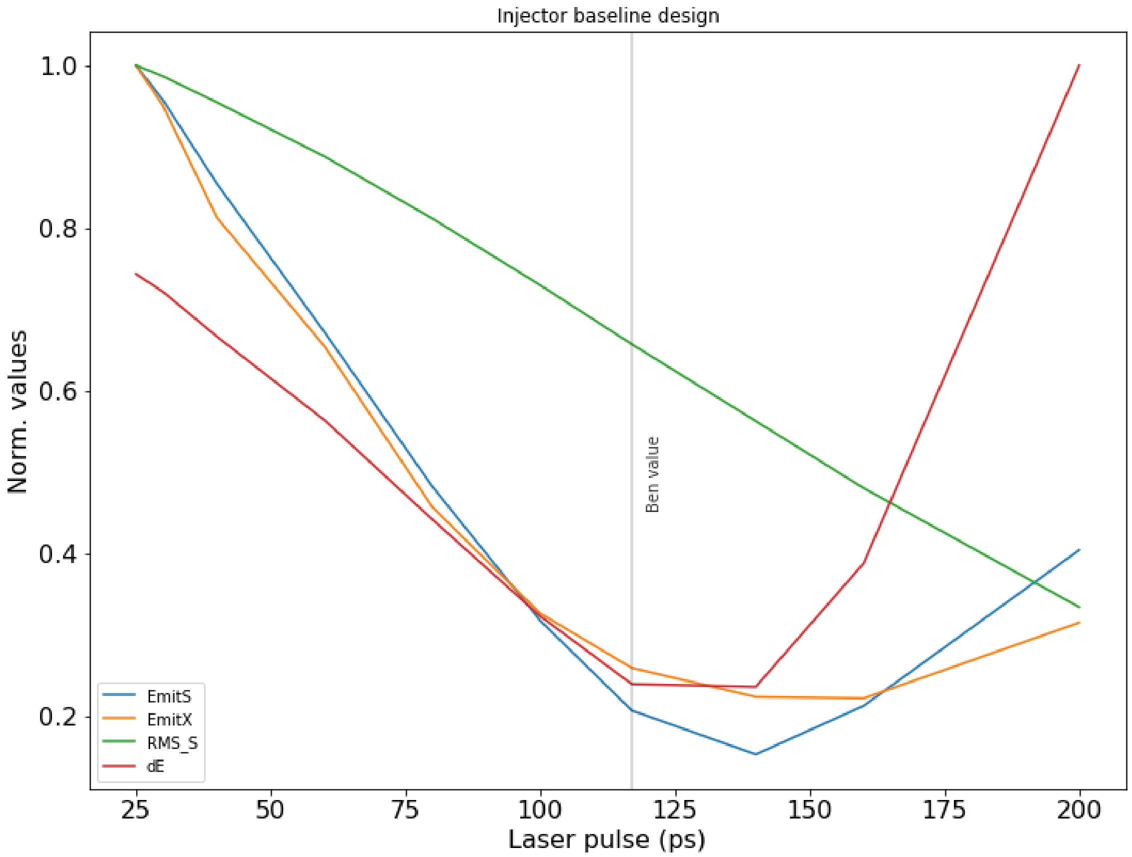
RMS bunch length



Transverse emittance



Try to play with different parameters



Range of values [100; 150] ps where the performances of beam are the best

2 Injector with RI gun

- DC gun as ALICE but with a slightly different geometry
- Solenoids are different (inner radius much larger)
- Positions on the beamline are different

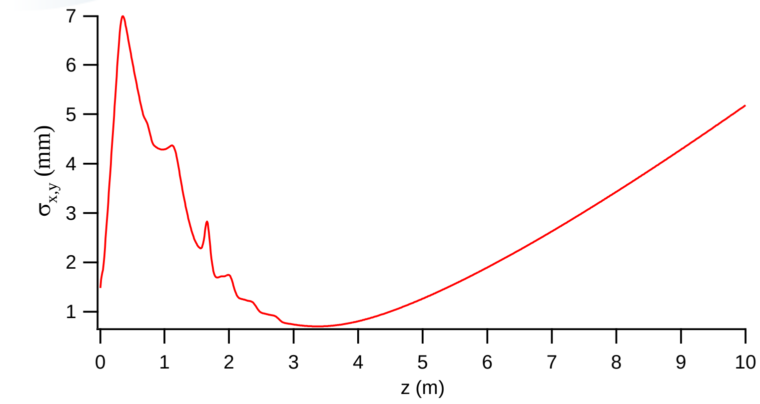
↓

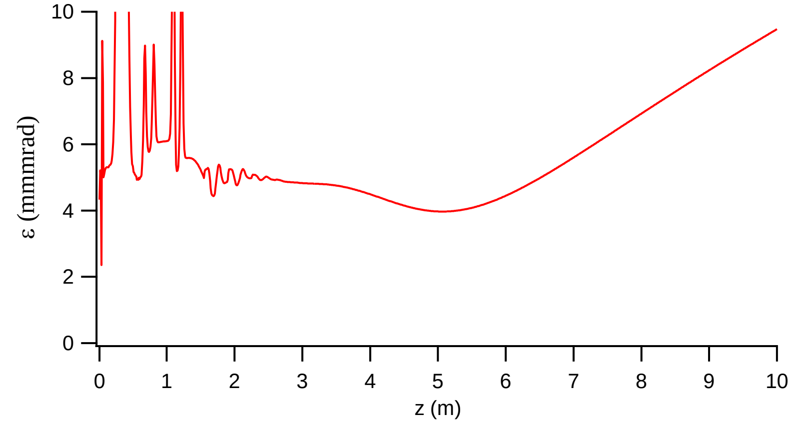
check the compatibility with PERLE specs

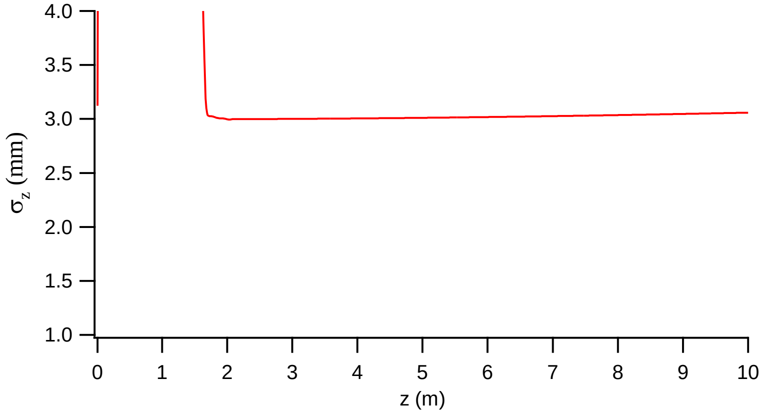
(sorry, NDA then no pictures or field map)

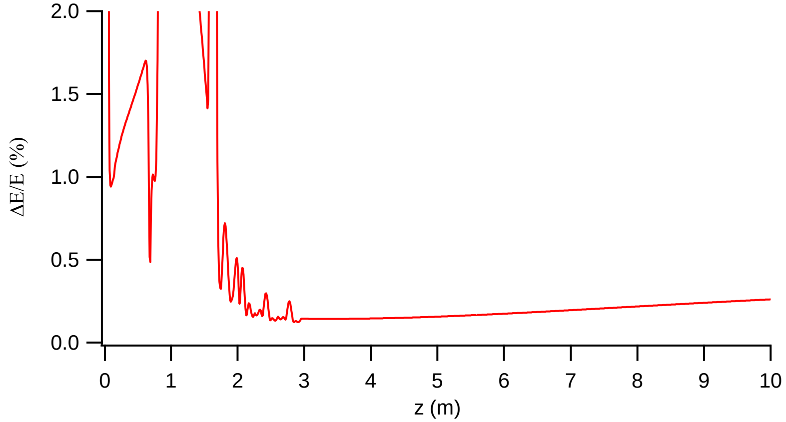
2 Injector with RI gun

First simulations with ASTRA with same simple models for RF cavities as before (laser, 35 ps)









OK with PERLE specs at the output of injector but ε and ΔE/E increase due to space charge force (> laser pulse)

CONCLUSION

- ALICE or RI gun give performances in agreement with specs
- OPALE and ASTRA give similars results as TRACEWIN but the latter needs more investigation
- Still some systematic simulations varying laser and RF parameters have to be performed

  > the best performances are for a laser pulse duration around 100 ps
- Simulations with more realistic electrical fields of RF cavities will have to be carried out
- Change of the PERLE specs because of results of beam dynamics in the ERL?