OPTIMIZATION OF THE CLIC POSITRON SOURCE FOR THE FIRST STAGE AT 380 GEV

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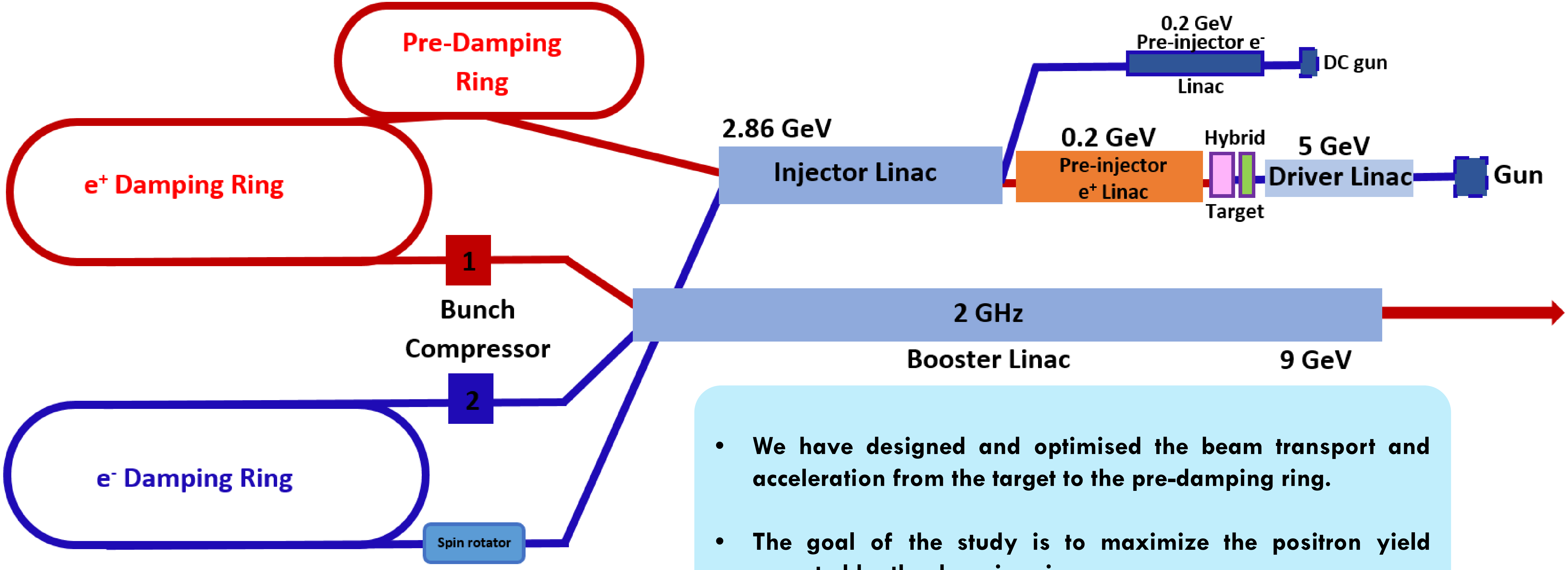
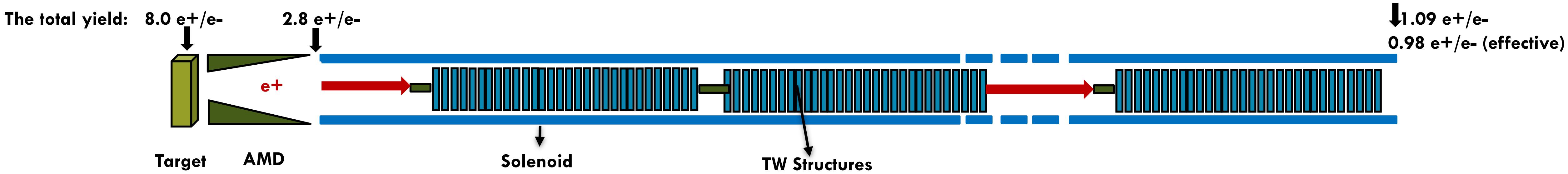
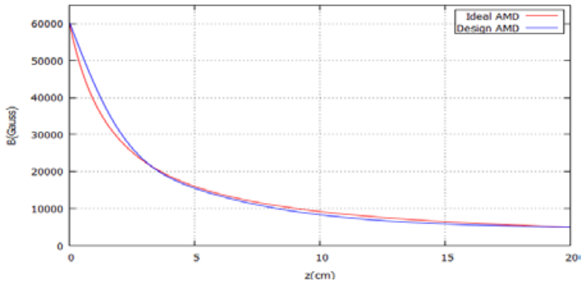
THE CLIC INJECTOR COMPLEX

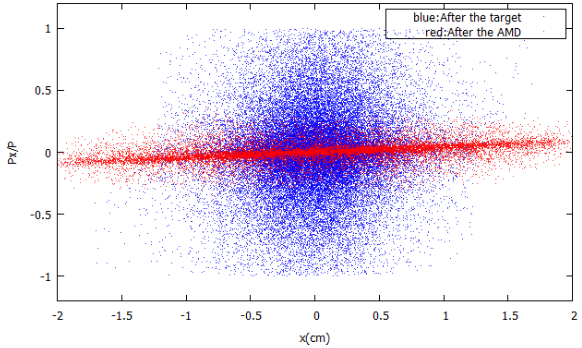


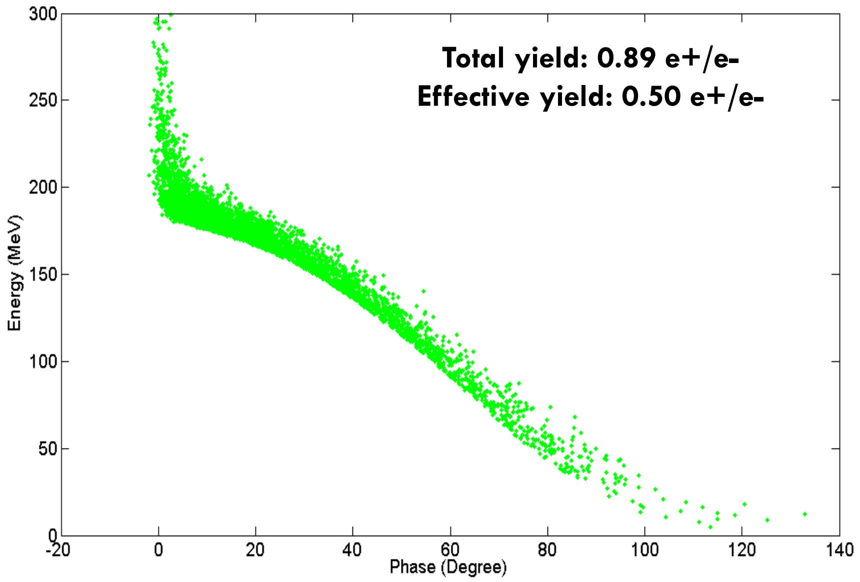
- We have designed and optimised the beam transport and acceleration from the target to the pre-damping ring.
- The goal of the study is to maximize the positron yield accepted by the damping ring.

THE PRE-INJECTOR LINAC : CAPTURE AND ACCELERATING SECTION

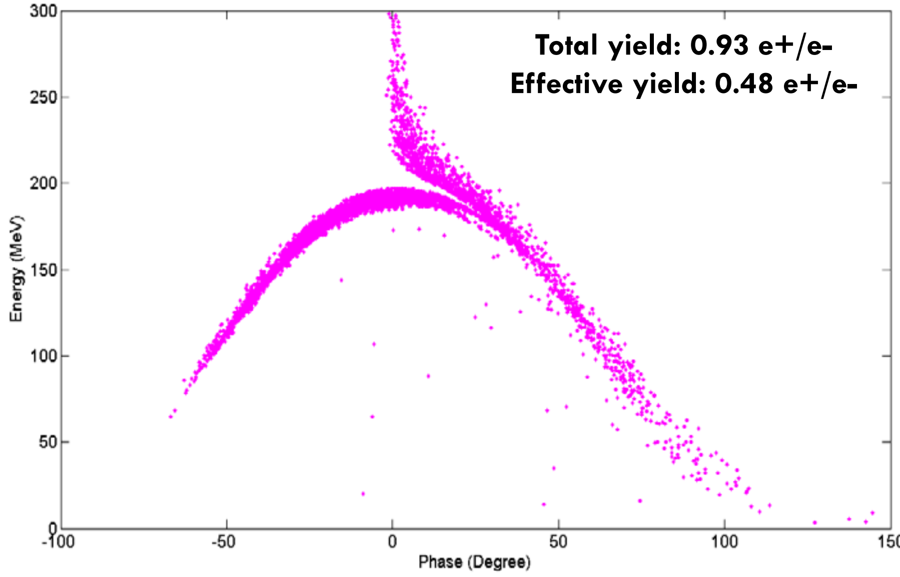








Acceleration



Deceleration

Parameters of the accelerating structures in the Pre-Injector linac

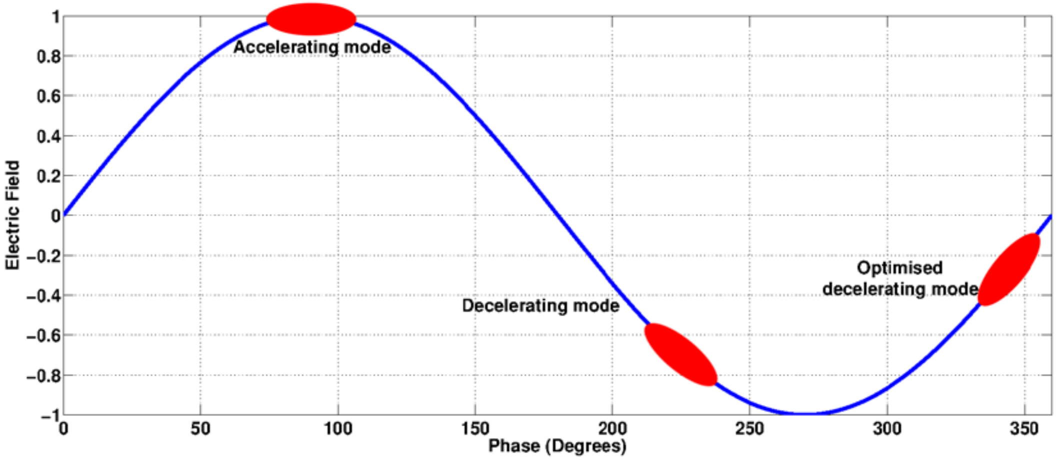
Parameters	Unit	Value
Cell length	cm	5
Frequency	GHz	2
Phase advance per cell	π	2/3
Average axial electric field	MV/m	15

The effective yield : (-20,20) degrees in phase and (150,250) MeV in energy

The yield is defined as the total number of positrons at the exit of the amorphous target compared to the number of electrons impinging onto the crystal target

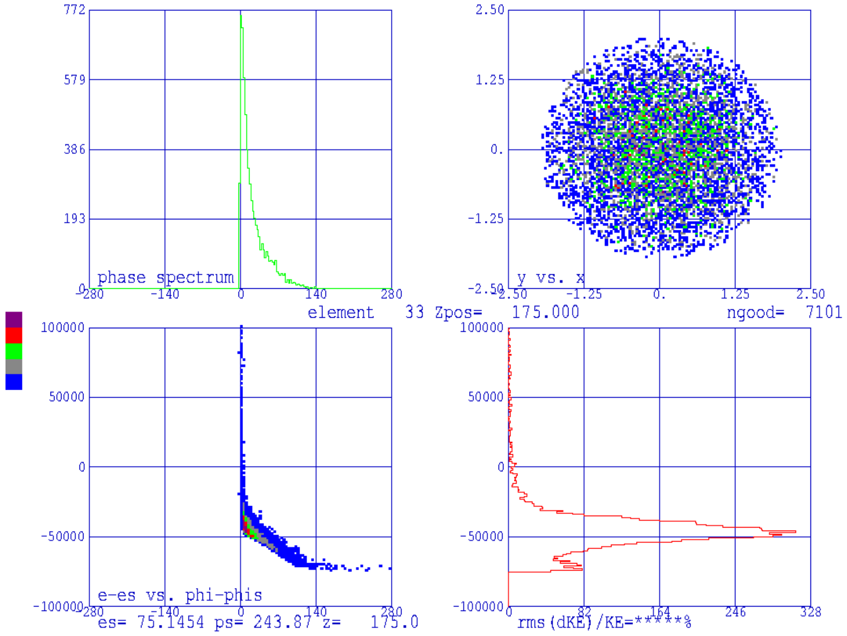
Optimization in the decelerating mode: PARMELA

- The decelerating mode creates a second peak in the phase spectrum.

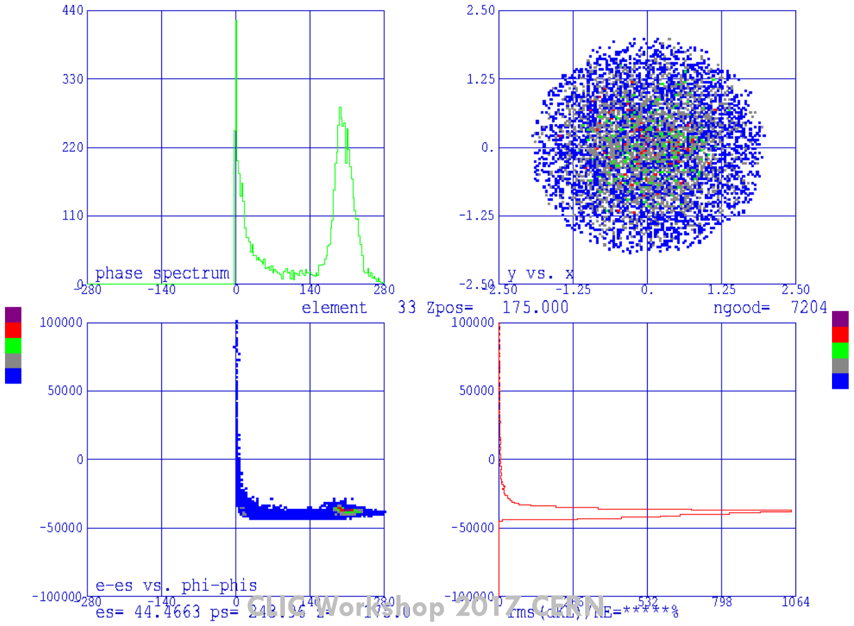


- For the optimization, a phase of 60 degrees after maximum deceleration is optimum.

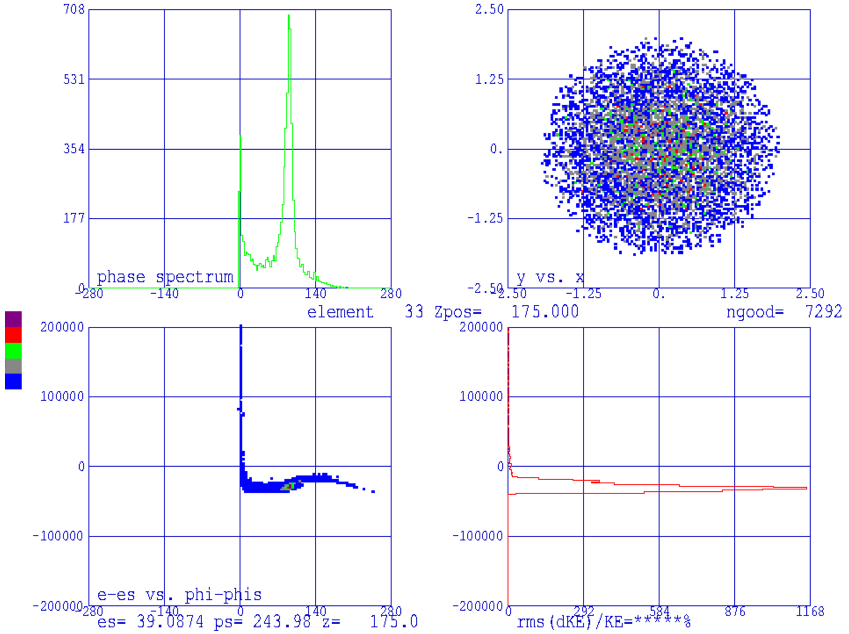
Accelerating mode



Decelerating mode

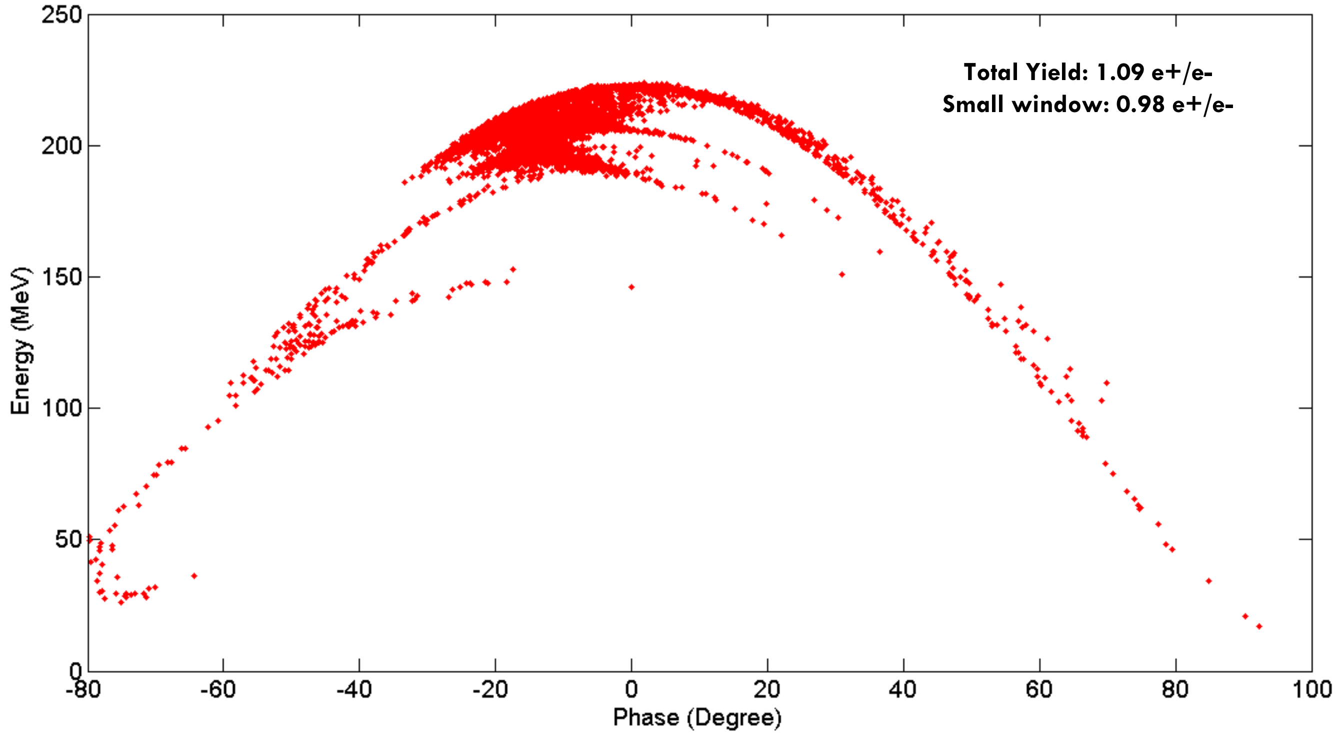


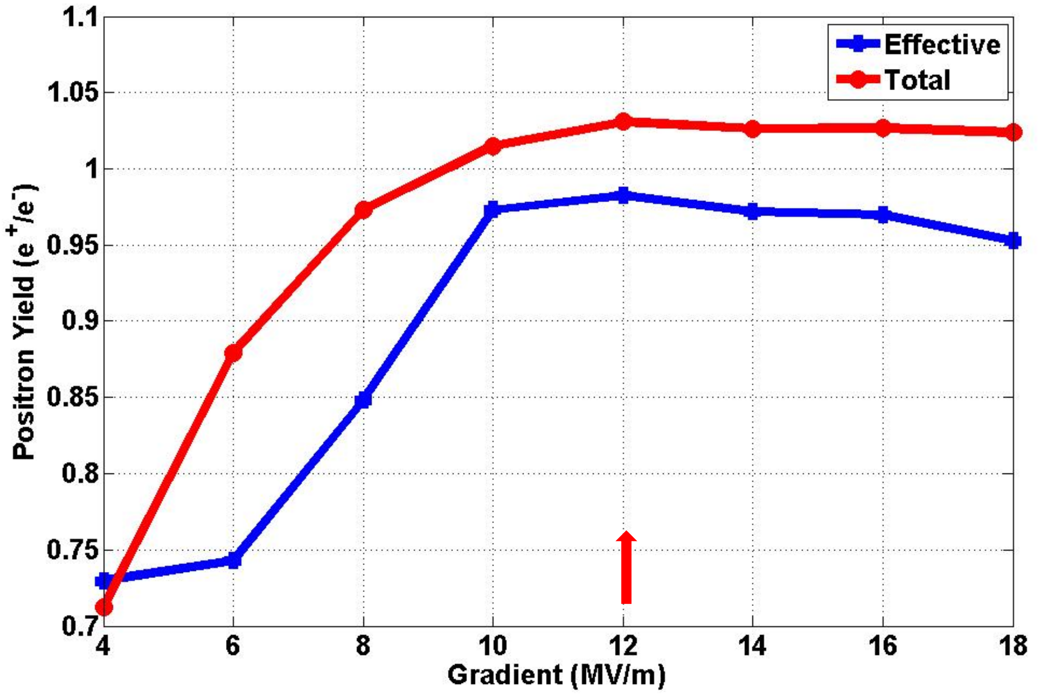
Optimized Decelerating mode



Optimization in the decelerating mode: PARMELA

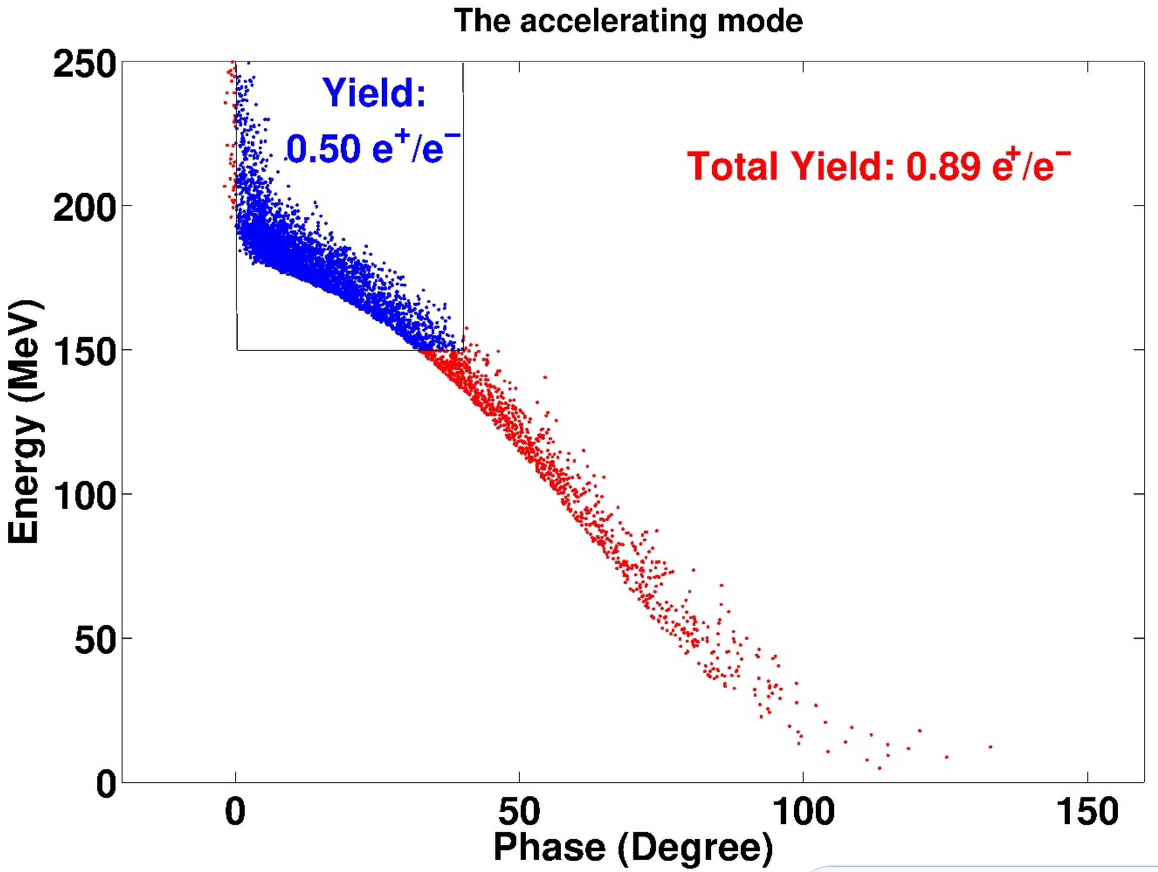
small window: (-20,20) degrees in phase and (150,250) MeV in energy

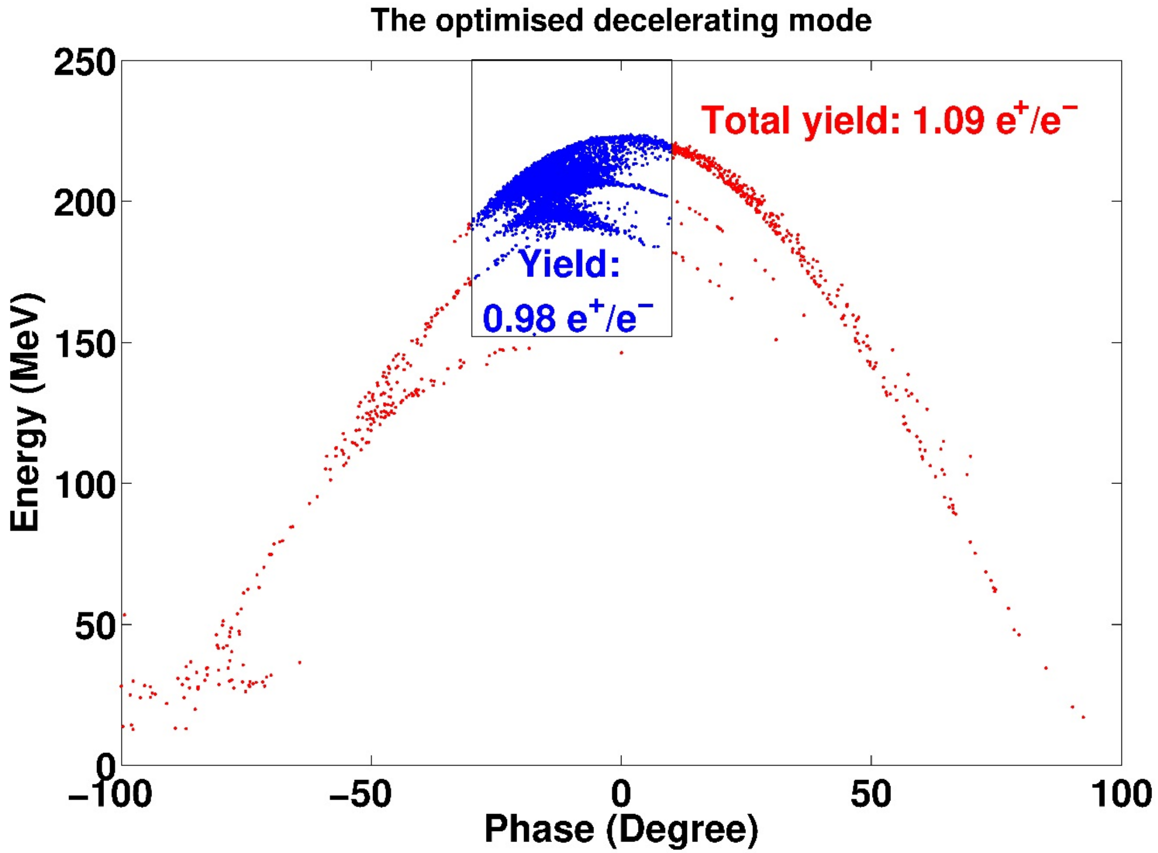




- A phase of 60 degrees after maximum deceleration
- After the first structure:
  The maximum acceleration is applied in the second peak.
- The deceleration gradient of first tank: 12 MV/m

Accelerating and optimized decelerating modes: PARMELA

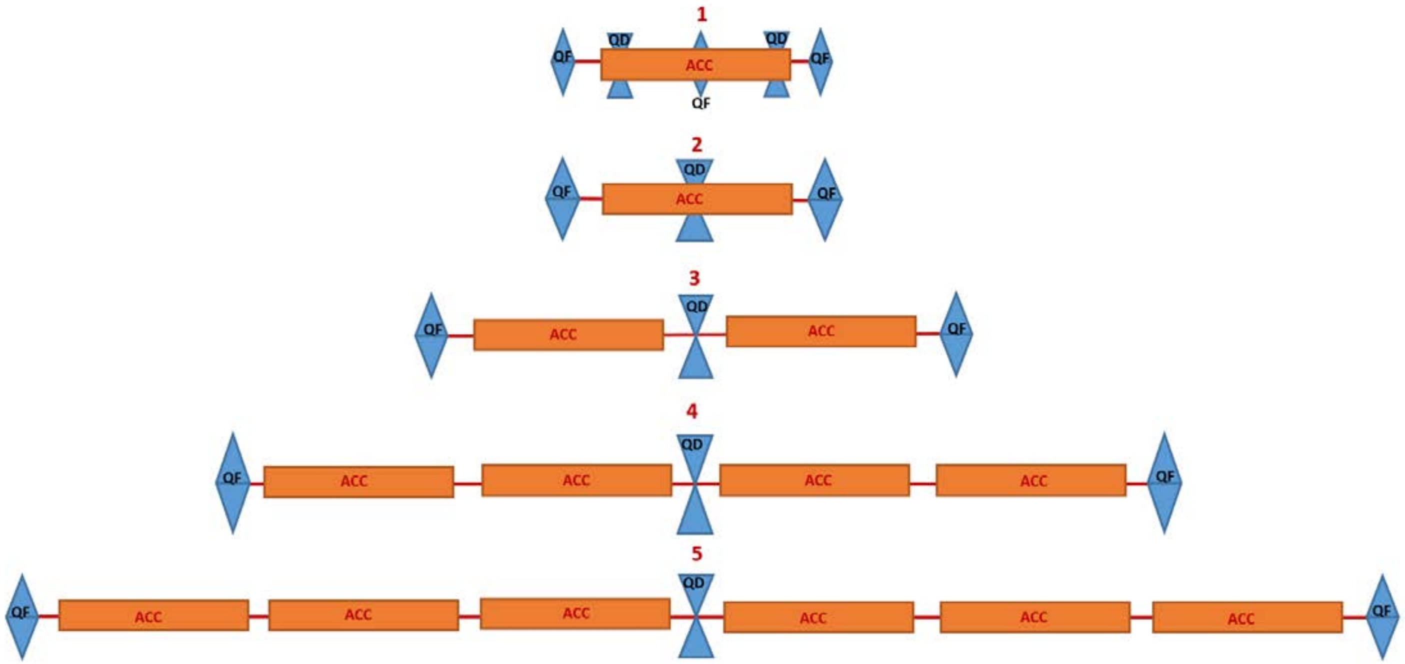




The optimised decelerating mode result in almost a factor two higher yield compared to the accelerating mode which has a yield of 0.5 e+/e.

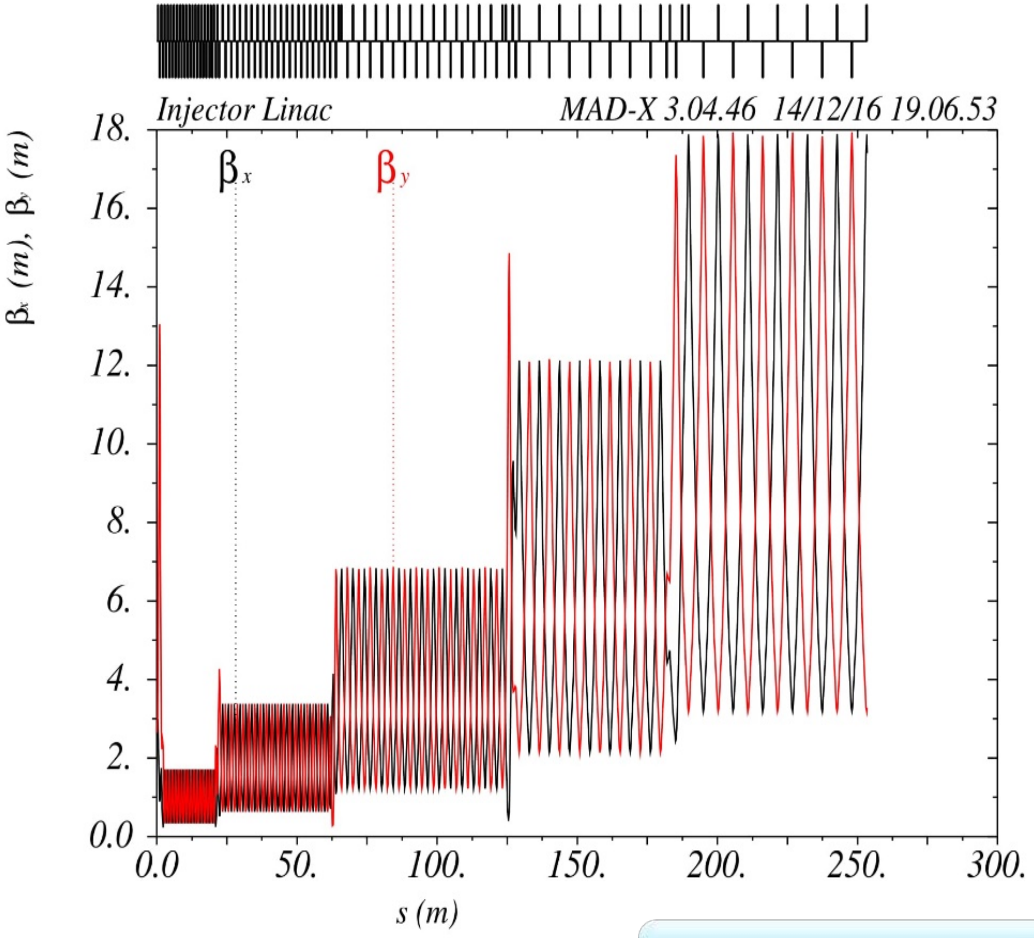
INJECTOR LINAC: FODO sections

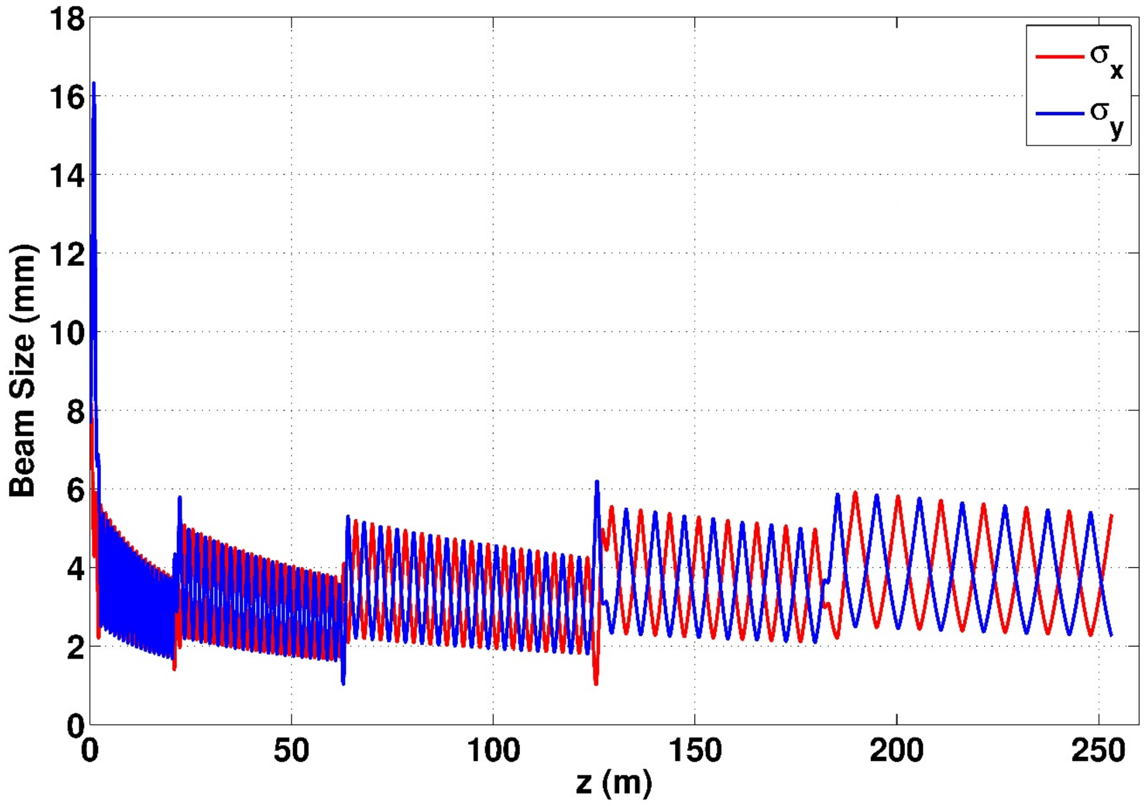
MAD-X and PLACET						
Section numbers	Quadrupole length (m)	Quadrupole strength (m^{-2})	Beta max (m)	Cell length (m)	Starting energy (GeV)	End energy (GeV)
1	0.4	9.00	1.7160	1.10	0.2065	0.3865
2	0.4	3.95	3.3860	2.08	0.3865	0.7915
3	0.4	1.85	6.8252	4.10	0.7915	1.4215
4	0.4	1.02	12.1250	7.20	1.4215	2.0515
5	0.4	0.68	17.8860	10.60	2.0515	2.8615



- To accelerate positrons from 200 MeV up to 2.86 GeV
- Quadrupoles are used as surrounding RF structures in the first and second sections.
- Minimum aperture of quadrupole is around 10 cm.
- It gives a limit in energy.
- A phase advance of 90 degrees is chosen in FODO.

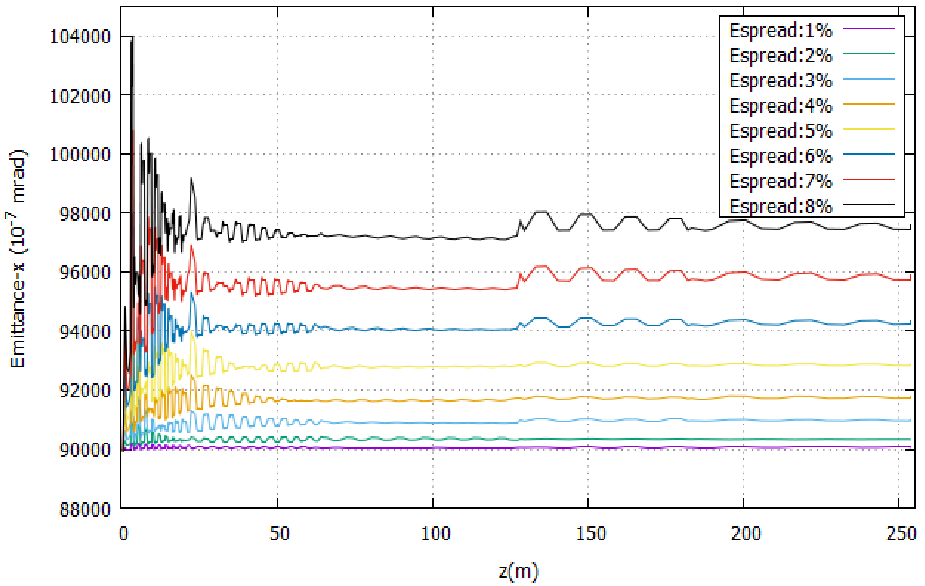
INJECTOR LINAC: MADX

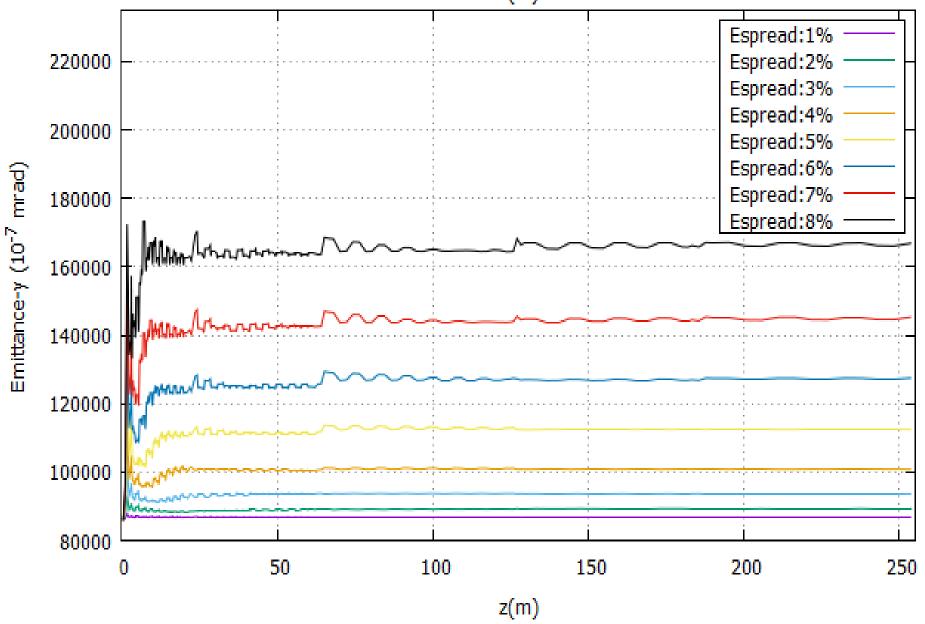




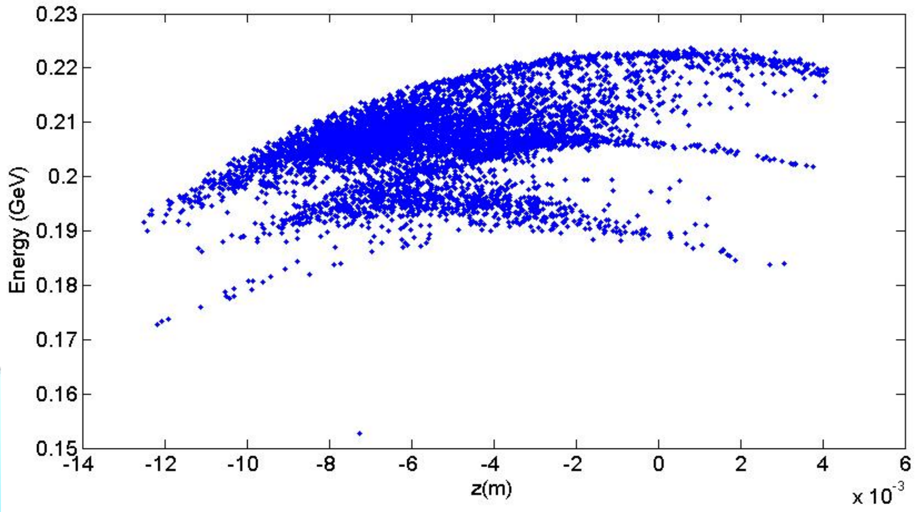
The 3σ beam size does not exceed the iris aperture (2 cm) along the beam line with the exception of the first matching section.

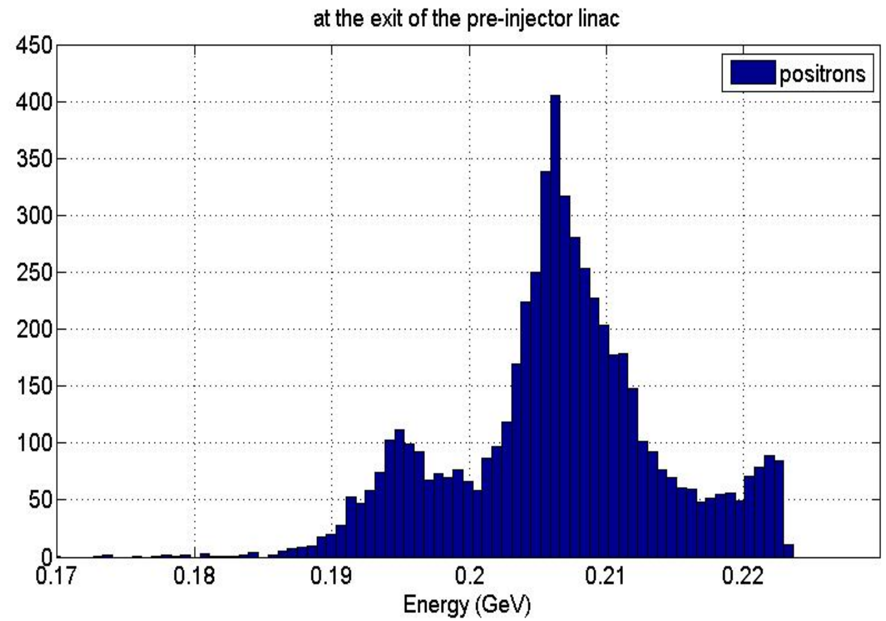
INJECTOR LINAC: EMITTANCE GROWTH



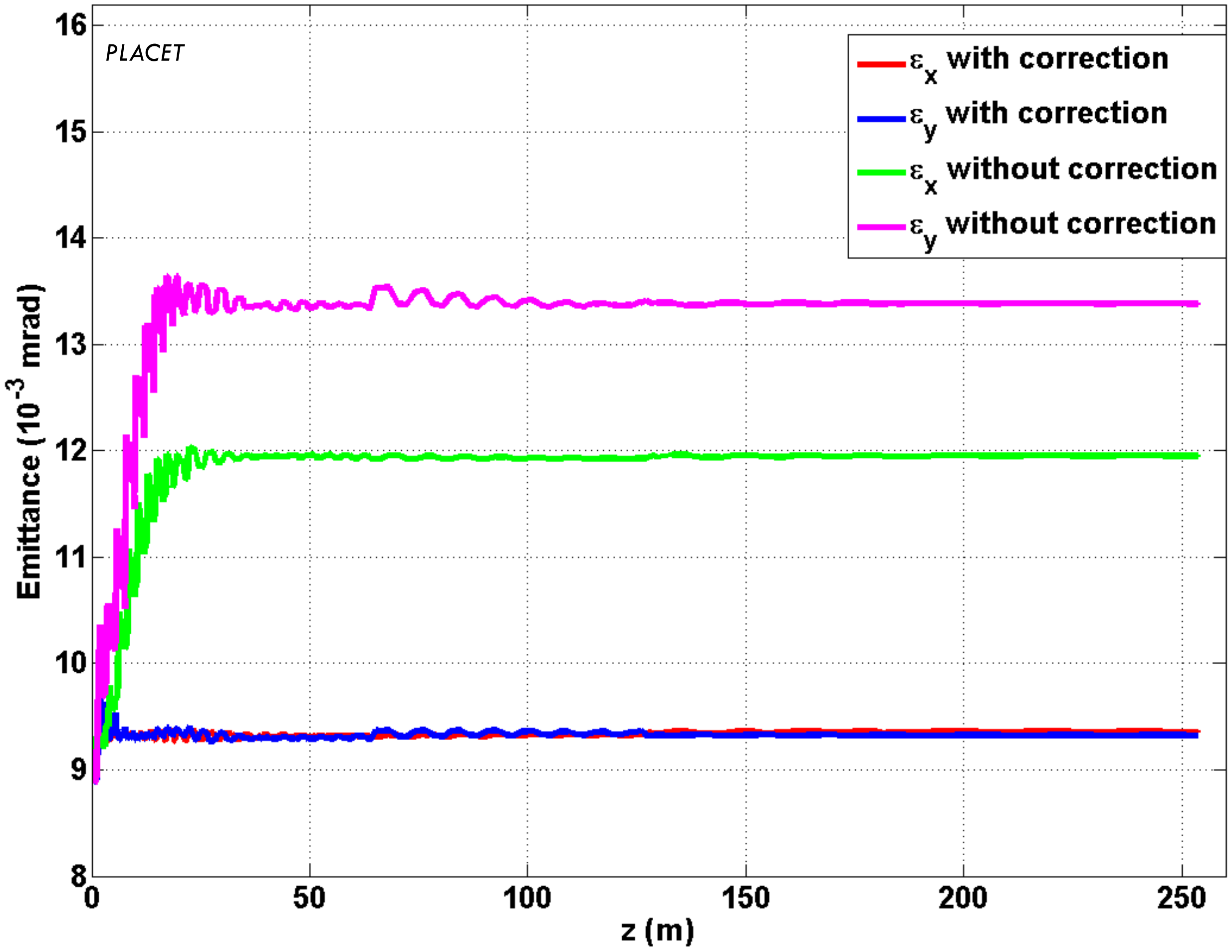


- Realistic beam cause the emittance growth especially in the first section due to the large energy spread

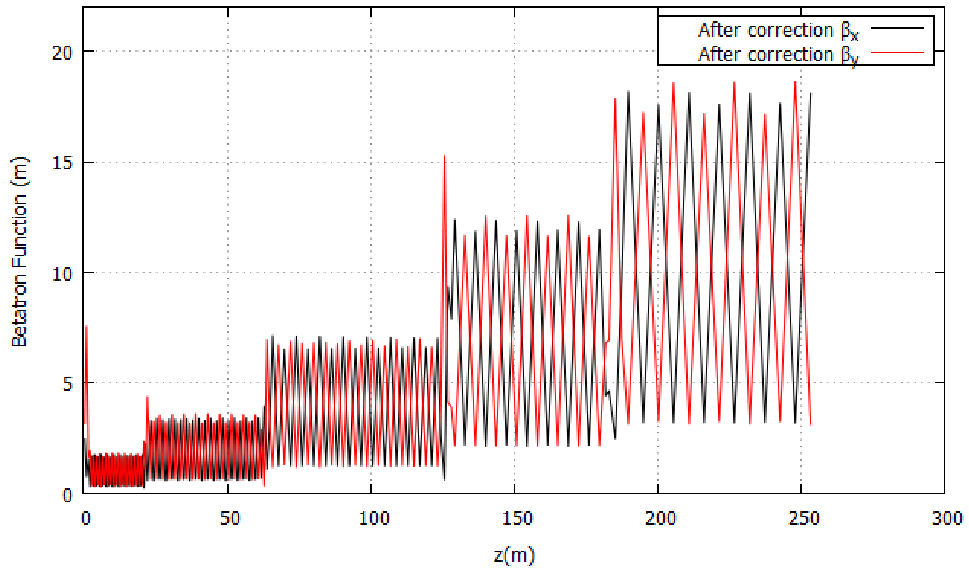




INJECTOR LINAC: EMITTANCE CORRECTION



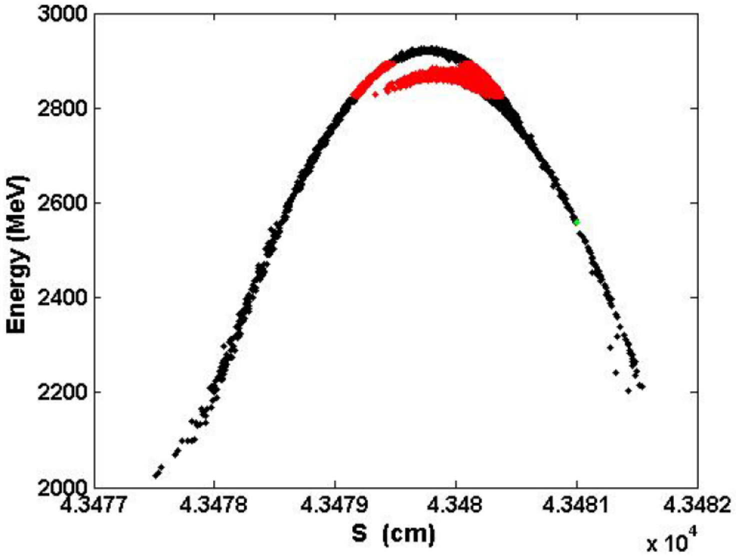
- To solve the emittance growth issue, the matching process is applied again in PLACET by using our particle distribution at the entrance of the injector linac.
- As a result, the emittance growth is mitigated along the beam line.
- The corrected betatron functions computed with PLACET are compatible with MAD-X results.



INJECTOR LINAC: POSITRON YIELD

*CDR

*Positron yield (CDR): 0.70 e^+/e^-



Energy acceptance → 1%: → yield: 0.39 e^+/e^-

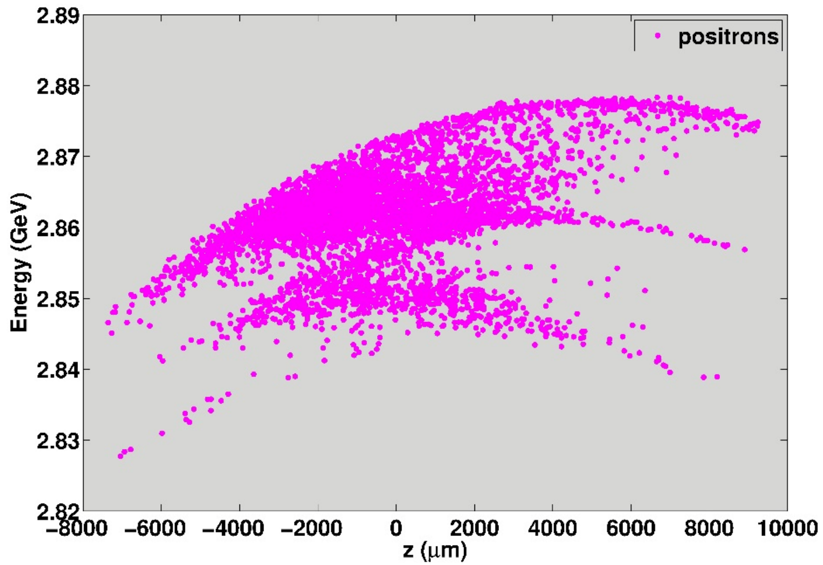
Table 21 – Positron yield for different values of the energy acceptance of the Pre-Damping Ring.

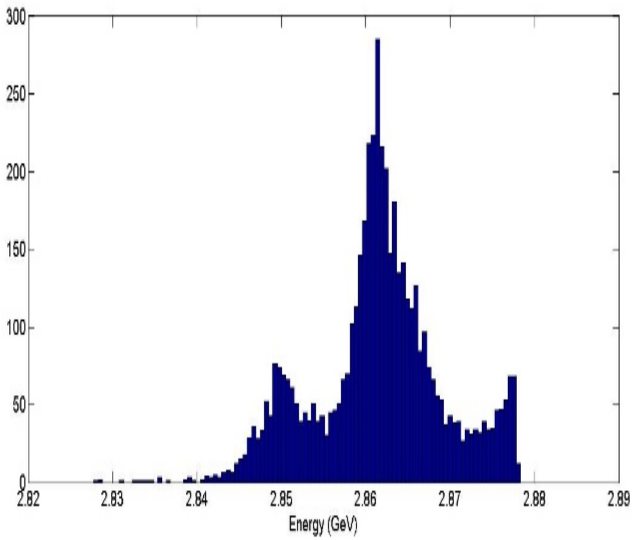
Energy Acceptance %	Yield (e^+/e^-)
1.2	0.453
2	0.561
3	0.619

http://cds.cern.ch/record/1277226/files/CERN-OPEN-2010-020.pdf

New Results

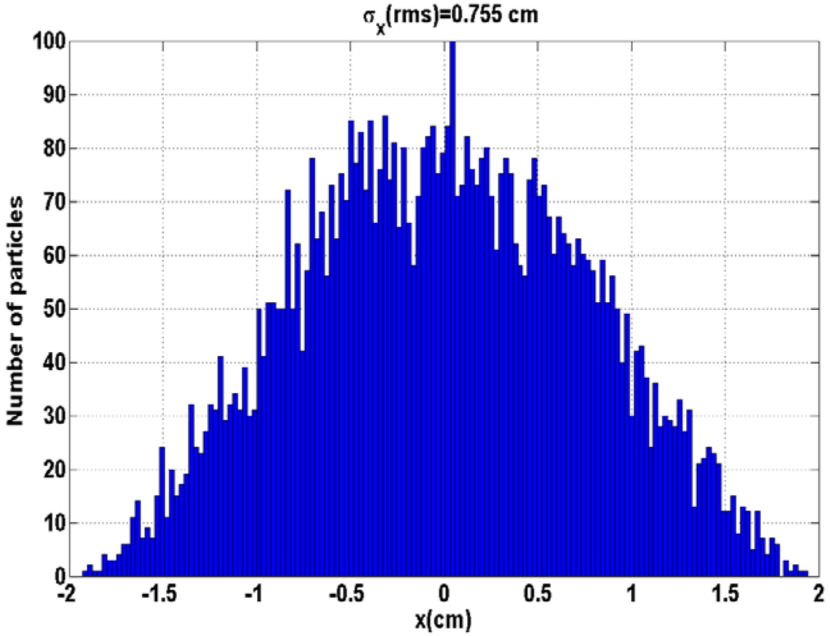
Positron yield, 0.97 e^+/e^-, is increased by a factor of 2.5.

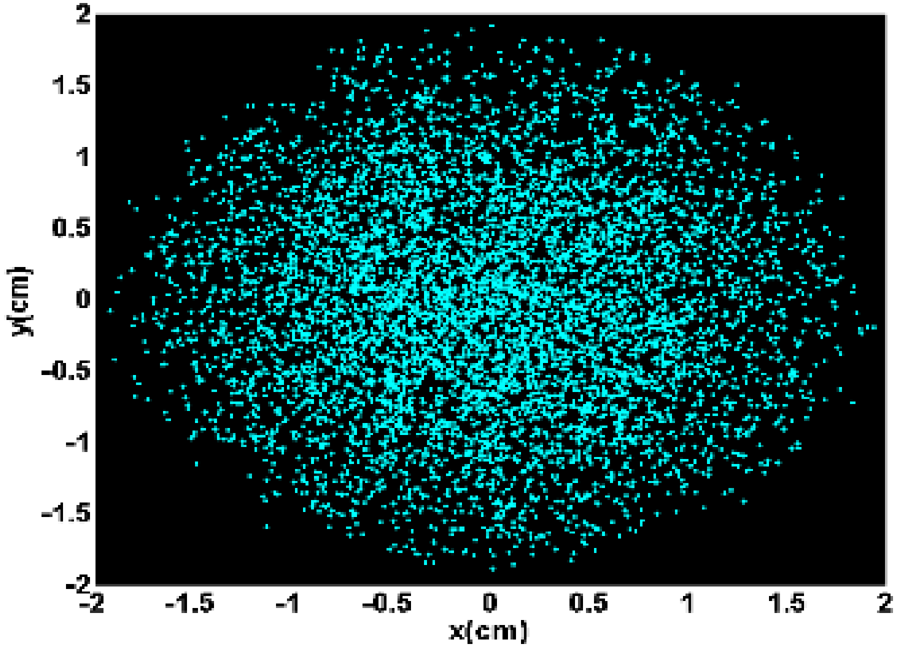


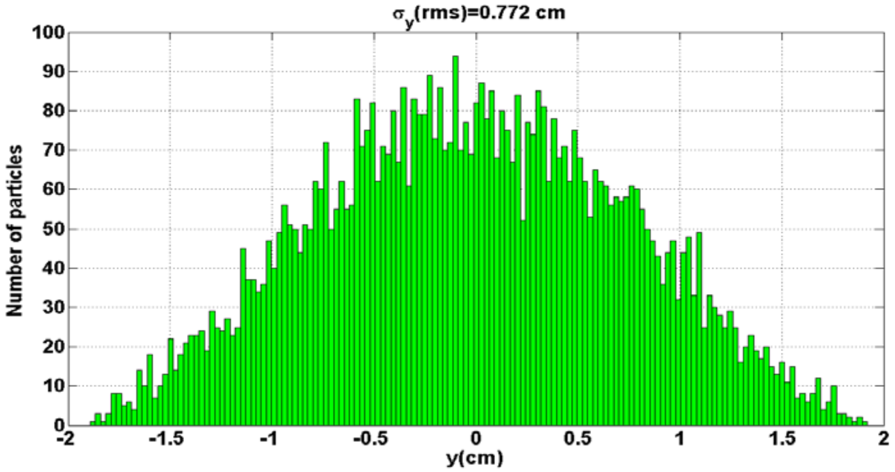


- It was necessary to increase the aperture of the beam pipe in the quadrupoles to 4 cm along the beam line.
- All positrons by 99 % are transported.
- All positrons are within 1% acceptance window of the pre-damping ring.
- An aperture of 2 cm all along the beam line would have resulted in a 10 % loss of positrons.

INJECTOR LINAC: BEAM OFFSET ERROR

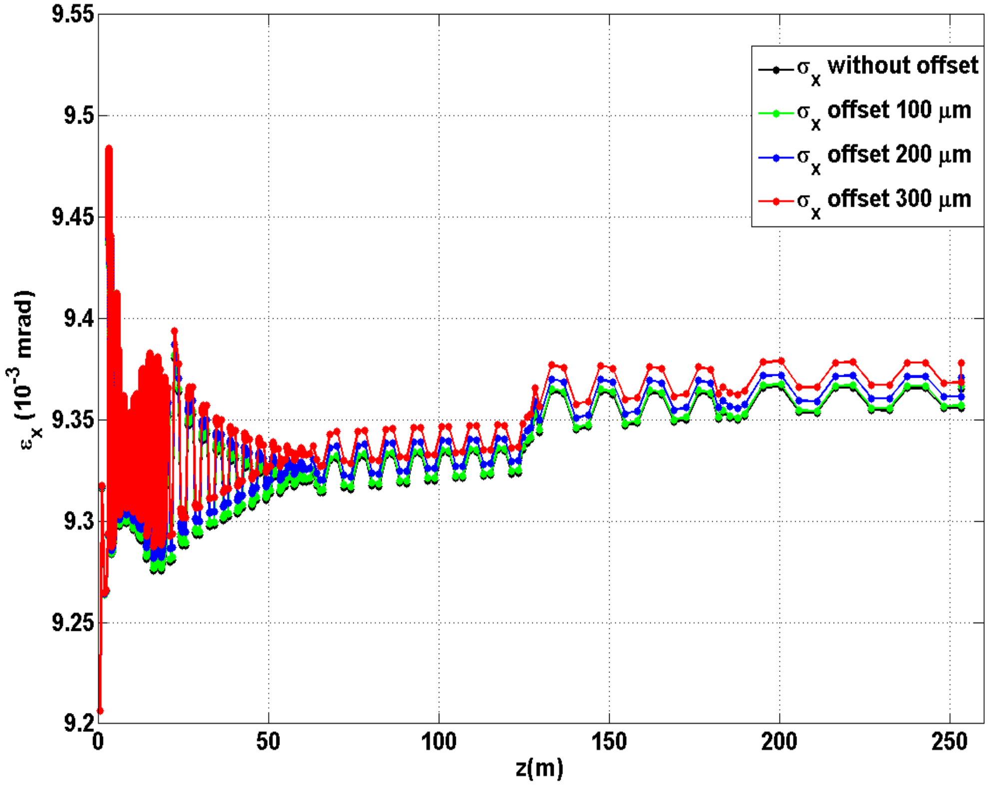


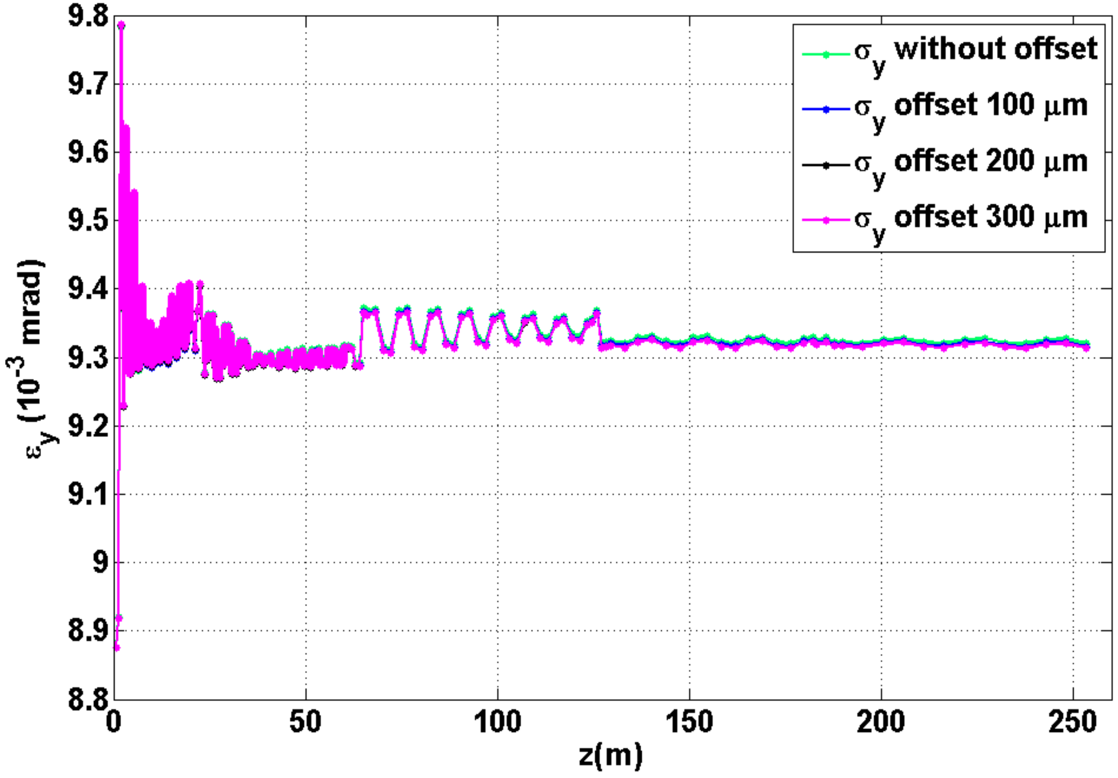




- For positrons, the beam size (rms) is bigger than 700 micrometres at the entrance of the injector linac.

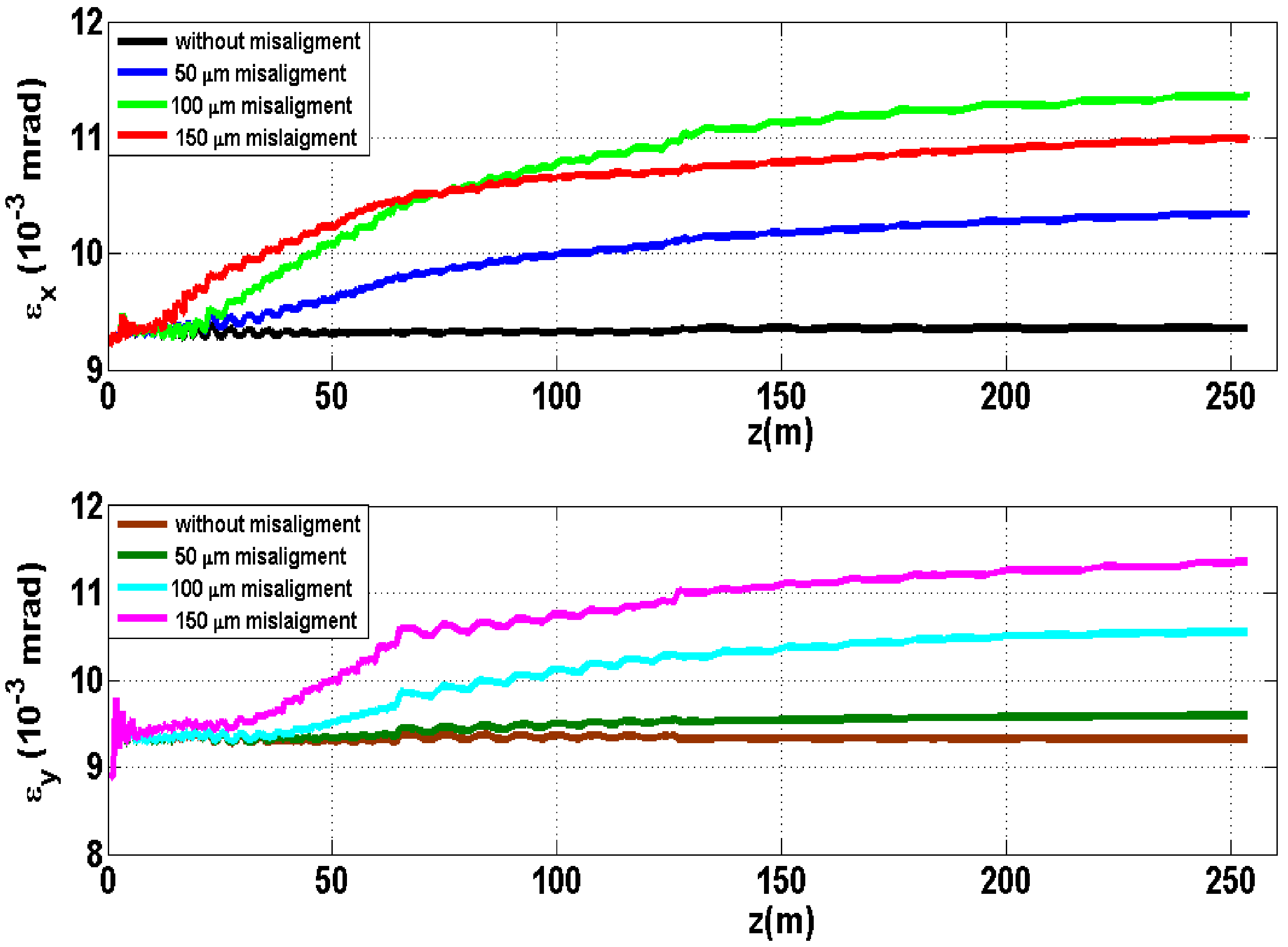
INJECTOR LINAC: BEAM OFFSET ERROR





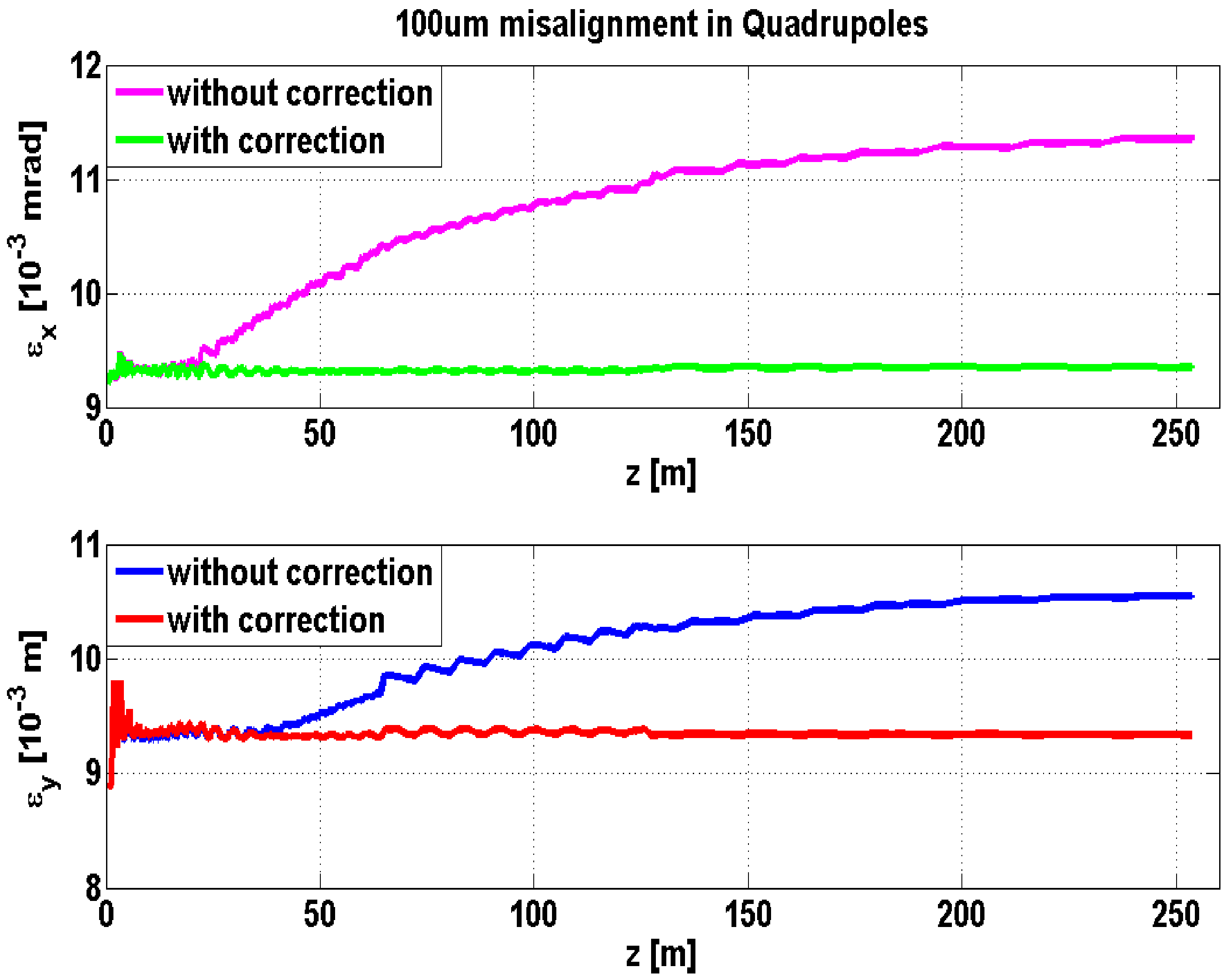
The beam offsets do not affect the emittance growth much for positrons at x and y axes due to the large rms beam size.

INJECTOR LINAC: MISALIGNMENT IN QUADRUPOLES



- Misalignment errors: 50 μm, 100 μm and 150 μm for each quadrupole randomly.
- Beam position monitor (BPM) with zero length before each quadrupole
- BPM resolution: 1 μm.

INJECTOR LINAC: MISALIGNMENT CORRECTION



- The correction is applied just for a misalignment error of 100 µm
- BPM resolution: 1 µm.
- Dipole (corrector) magnet with zero length after each quadrupole.
- “One to one” correction by correctors.
- The emittance growth is mitigated.

CONCLUSION

CDR:

- ➢ The number of quadrupoles: 192
- ➢ Used long accelerating structures (4 or 5 meters TW)
- ➢ Used the quadrupoles and TW structures separately by increasing the average accelerating gradient
- ➢ Used triplet structures along the injector linac
- ➢ Needed a bunch compressor
- ➢ Total yield: 0.70 e-/e+
- ➢ Positron yield: 0.39 e-/e+ within 1% acceptance window
- ➢ Assumed two targets in parallel for the first stage of CLIC

NEW DESIGN:

- ✓ The number of quadrupoles: 141 (Reduced by 26 %)
- ✓ Used technologically feasible accelerating structures (1.5 m TW)
- ✓ Used together quadrupoles and TW structures by using thin length approximation
- ✓ Used F0D0 structures along the injector linac
- ✓ Do not need a bunch compressor
- ✓ Total yield: 0.97 e-/e+
- ✓ Positron yield: 0.97 e-/e+ within 1% acceptance window (increased by a factor of 2.5)
- ✓ Assumed a single target for the first stage of CLIC at 380 GeV

THANK YOU
FOR YOUR ATTENTION