Beam Dynamics and Tolerance Studies of the THz-driven Electron Linac for the AXSIS Experiment.

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1. INTRODUCTION

- The **AXSIS** experiment (**A**ttosecond **X**-ray **S**cience, **I**maging and **S**pectroscopy) is foreseen to provide a fully coherent attosecond X-ray radiation for 3D imaging and spectroscopy.
- The fully coherent attosecond X-ray will be provided by inverse Compton scattering of a laser beam on an electron bunch accelerated in the AXSIS linac.
- The experiment will use a dielectric loaded waveguide to accelerate e-bunches up to 20 MeV

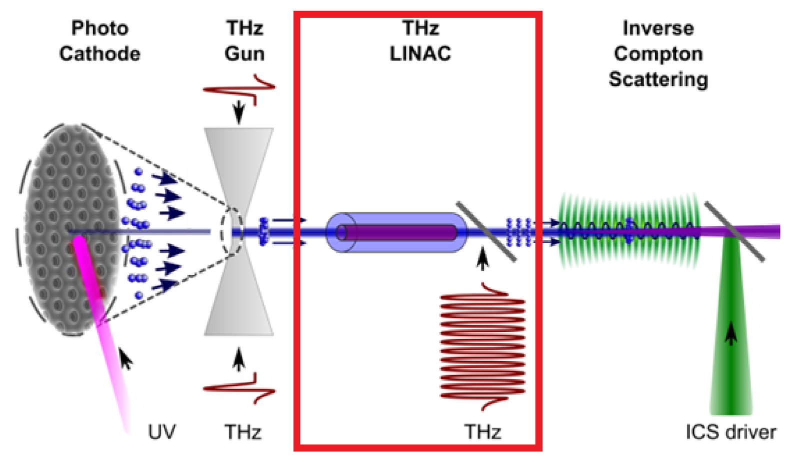

Figure 1: *AXSIS experiment layout*

2. STATEMENT OF THE PROBLEM

- THz-pulse is focused on the open end of the dielectric-loaded waveguide **(a)**, propagates along the linac **(b)** and after reflection **(c)** co-propagates with the injected electron bunch **(d)**.

We want to know how the accelerator fabrication errors and inaccuracy of the beam injection affect the acceleration process

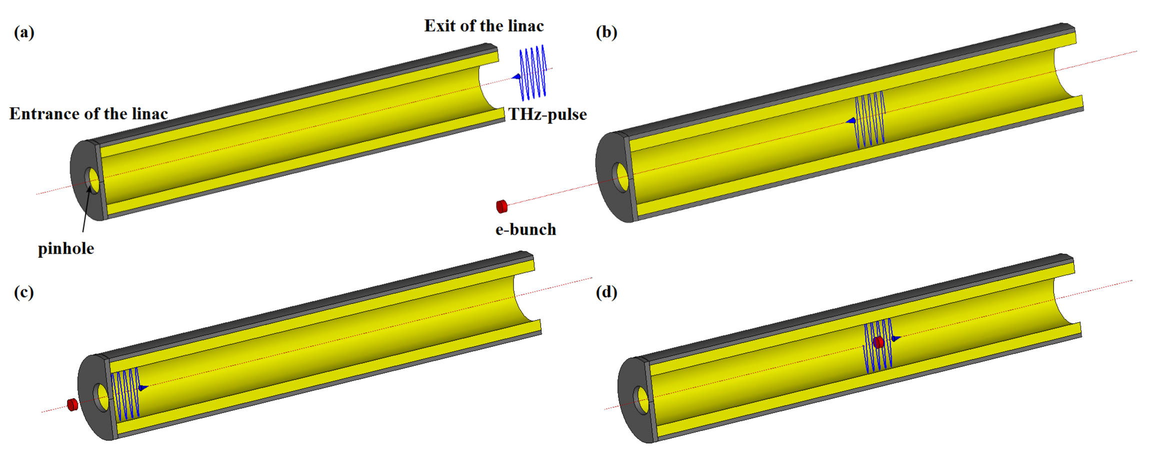

Figure 2: *Schematic of a dielectric (yellow) loaded metal waveguide (gray) with an electron bunch (red) and the metal plate with a pinhole aperture at the entrance of waveguide. Electron bunch moves from left to right.*

3. PARAMETERS and TOOLS

- ECHO (developed by Igor Zagorodnov)

Table 1: *Parameters of the linac, e-bunch and THz-pulse.*

Parameter	Value	Unit
Linac		
Dielectric inner radius	625.0	μm
Dielectric thickness	77	μm
Rel. permittivity of the dielectric	4.41	a.u.
Pinhole radius	300.0	μm
Length of the linac	100.0	mm
β_{ph}(300 GHz)	1.0	a.u.
β_{gr}(300 GHz)	0.62	a.u.
Electron bunch		
Beam charge	-0.99	pC
Average kinetic energy	4.77	MeV
Energy spread	10.21	keV
Horizontal (x) beam size	98.50	μm
Vertical (y) beam size	98.47	μm
Longitudinal (z) beam size	11.16	μm
Horizontal beam emittance	0.38	π mm mrad
Vertical beam emittance	0.38	π mm mrad
Longitudinal beam emittance	$5.36 \cdot 10^{-2}$	π keV mrad
THz-pulse		
Temporal shape of the pulse	flat top	a.u.
Frequency of the pulse	300.0	GHz
Duration of the pulse	133.3	ps
Peak E_z (on-axis)	240.0	MV/m

4. RESULTS OF SIMULATIONS

- How much should we correct the central frequency of the THz-pulse in order to take into account the outer dielectric radius fabrication error ?

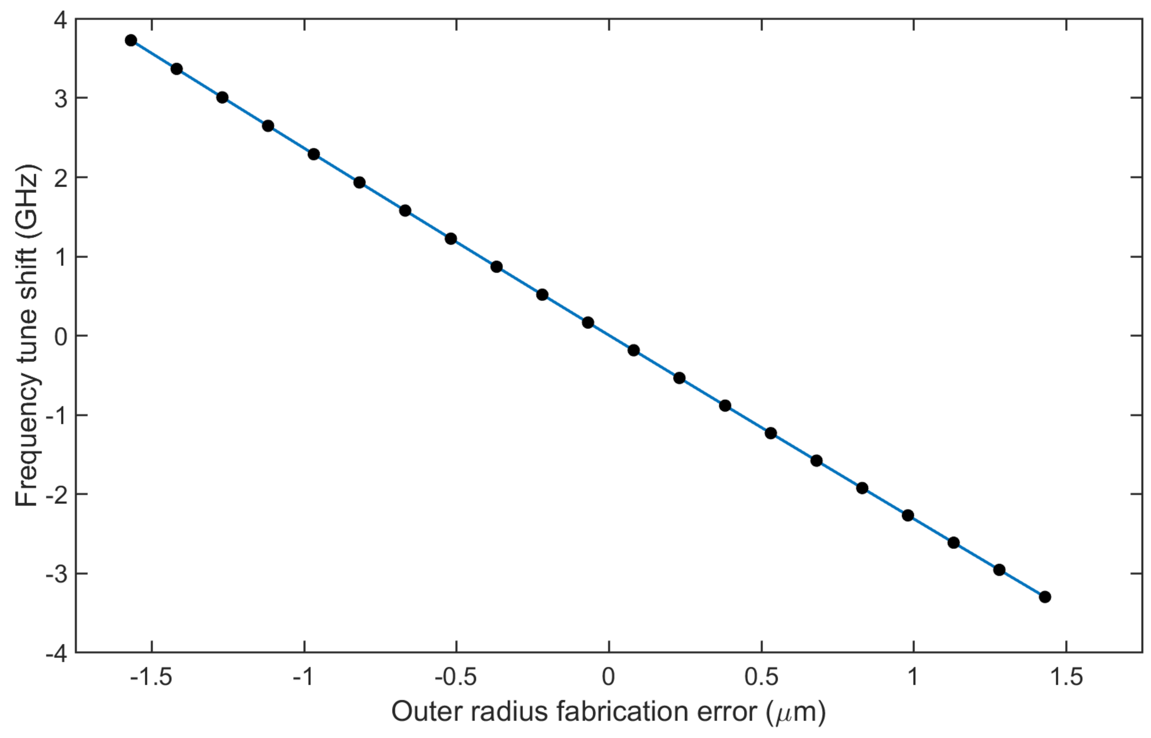

Figure 3: *Dependence of the frequency correction on the outer dielectric radius fabrication error. The phase velocity equals the speed of light along the line. A thickness of the dielectric is constant along the linac*

- **The THz-pulse frequency correction will require the frequency tuning precision ~1 MHz**

- How strong the fabrication errors affect the maximal achievable output bunch kinetic energy ?

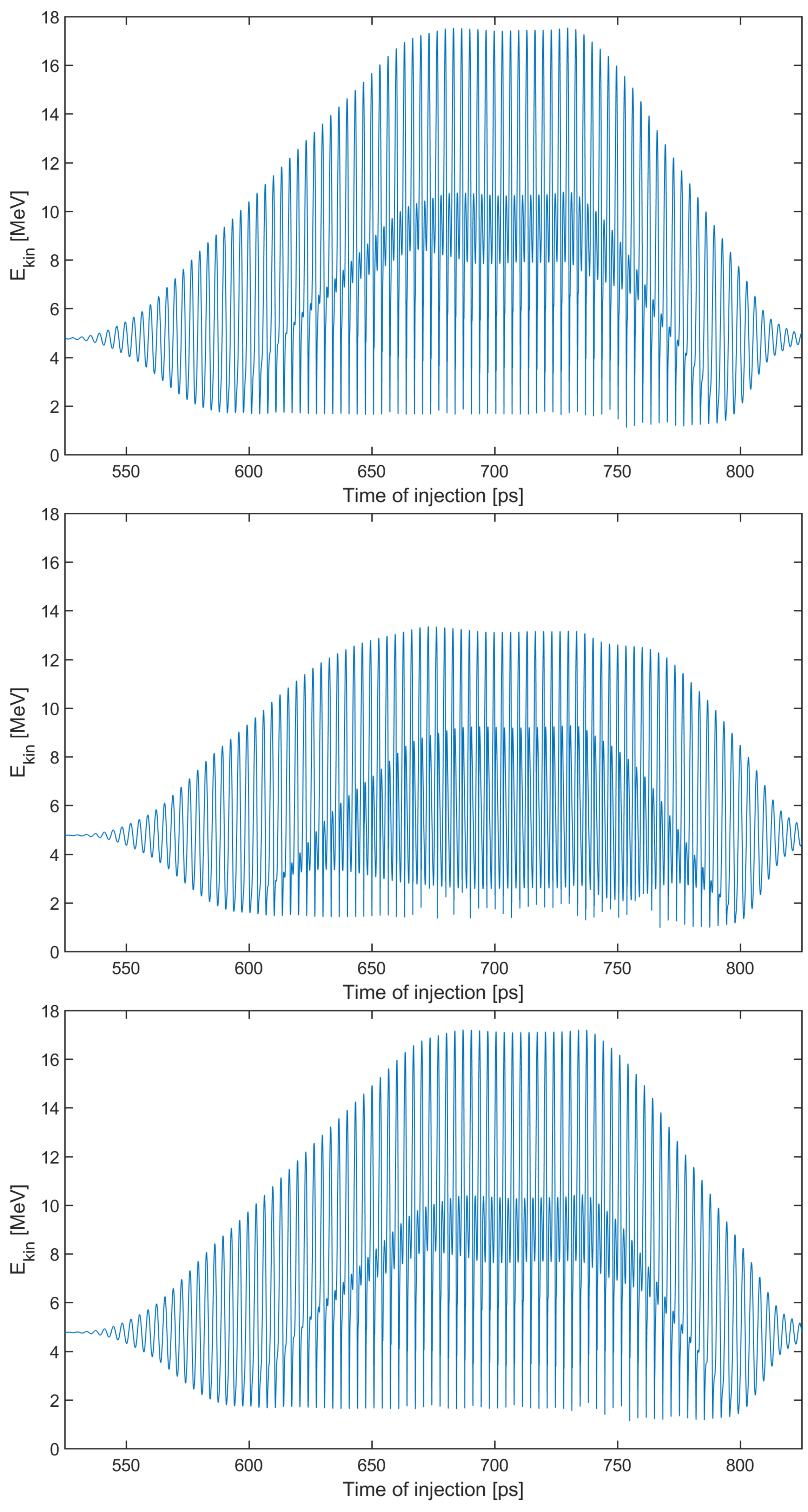

Figure 4: *The output kinetic energy as a function of the injection time for the optimized linac (top), detuned linac with 1.5 μm outer dielectric radius fabrication error without the frequency correction (middle) and detuned linac with 1.5 μm outer dielectric radius fabrication error with the frequency correction (bottom).*

- **With the frequency tune shift it is almost possible to compensate the linac detuning**

- Phase space reconstruction by the frequency tune

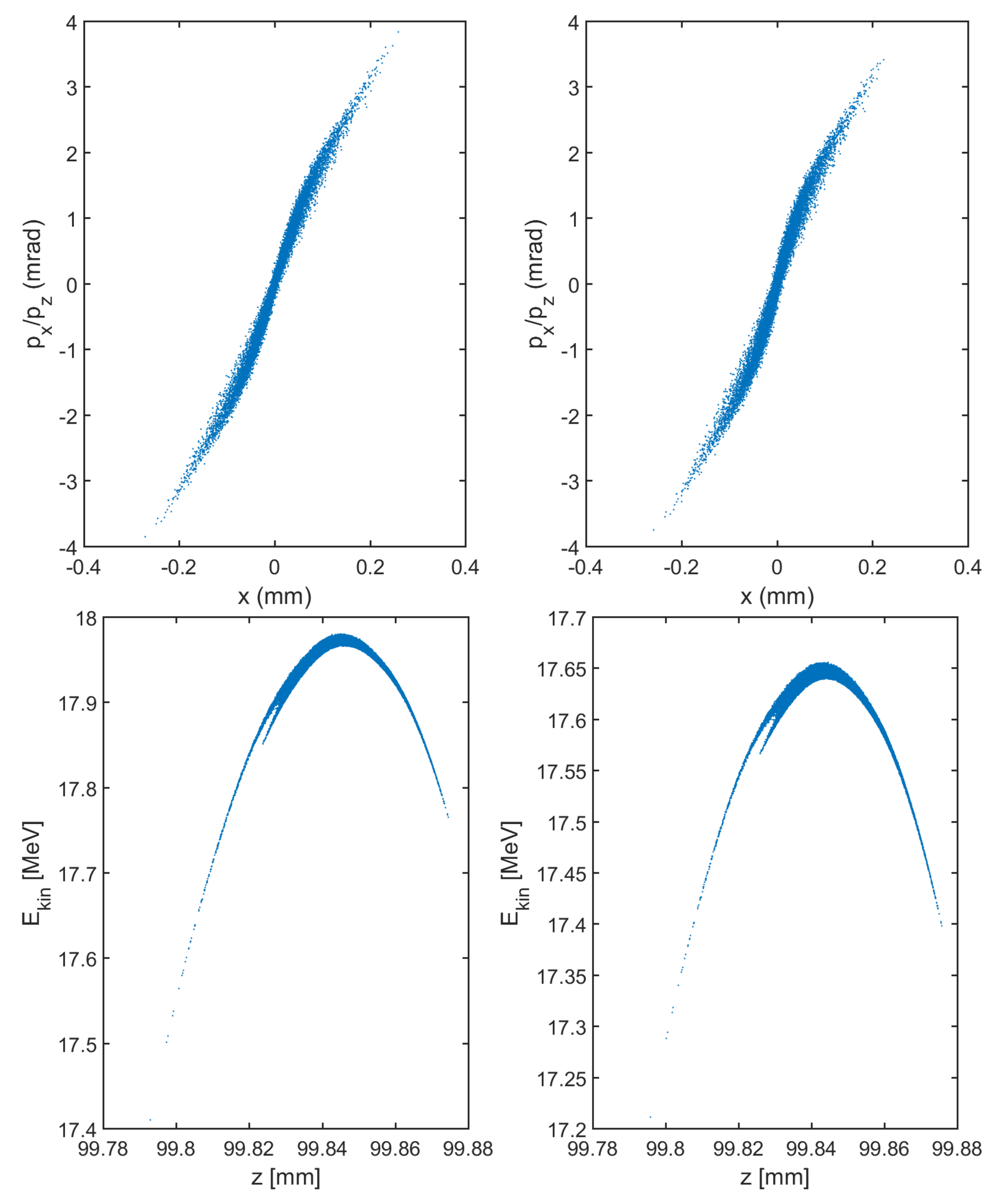

Figure 5: *Transversal and longitudinal phase space of the bunch at the output for the tuned linac (left) and for the detuned linac with corrected frequency of the THz-pulse (right).*

- **From beam point of view the tuned linac and detuned linac with corrected THz-pulse frequency are almost the same**

- Beam injection misalignment. Offset of the bunch

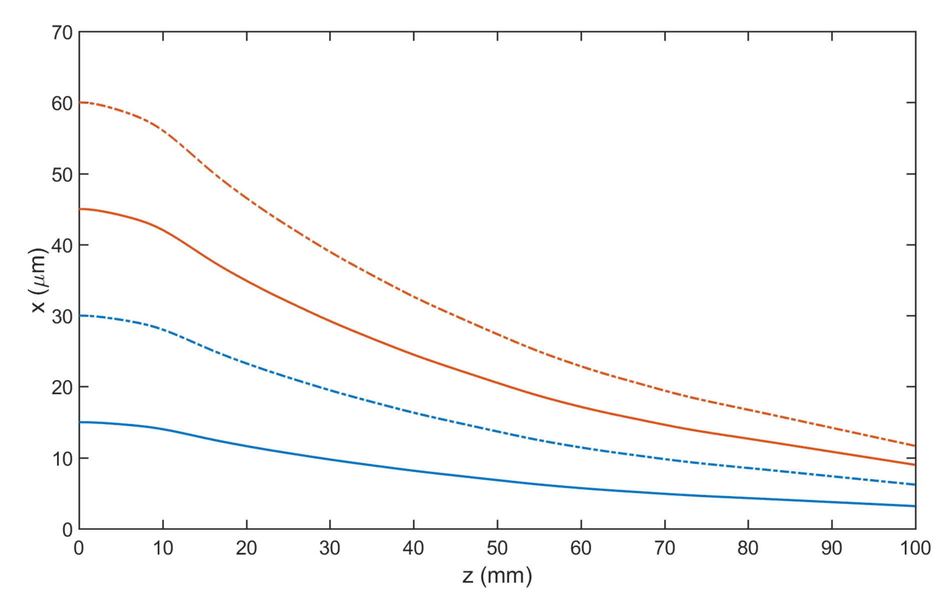

Figure 6: *Evolution of the beam position for the different values of the initial offsets: 15 μm (blue solid line), 30 μm (blue dot-dash line), 45 μm (orange solid line), 60 μm (orange dot-dash line).*

- **For initial ~5 MeV beam and for the maximal energy gain regime correction of the radial beam position takes place during acceleration**

- Beam injection misalignment. Non-zero axial angle injection

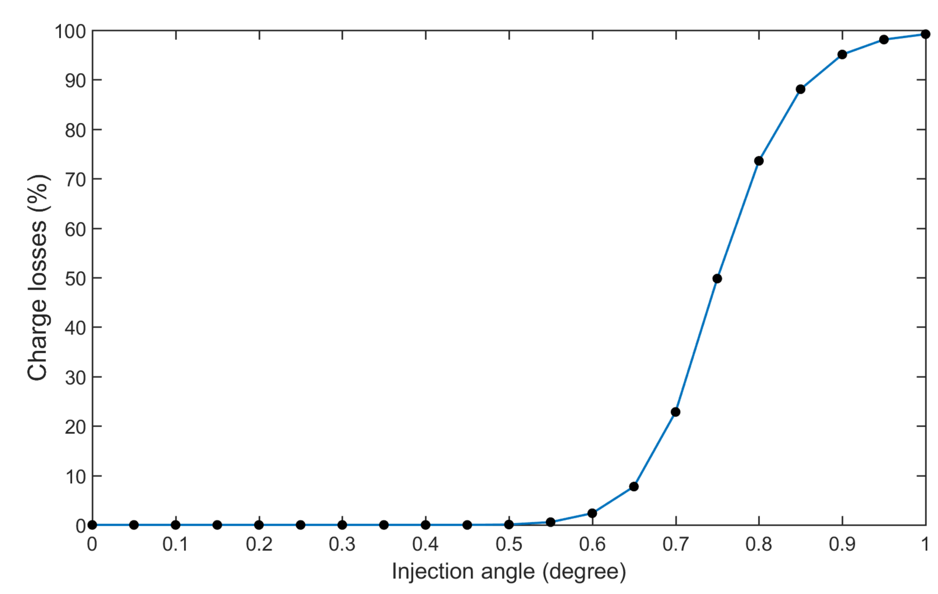

Figure 7: *Charge losses as a function of the angle of injection with respect to the longitudinal direction.*

- **For the beam injection angle < 0.5 degree there is no charge losses at all and ~10% of the charge is lost for the angle of ~0.65 degree**

5. ACKNOWLEDGMENTS

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