Phase 1- Upgrade Injector Model for KLF

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Outline

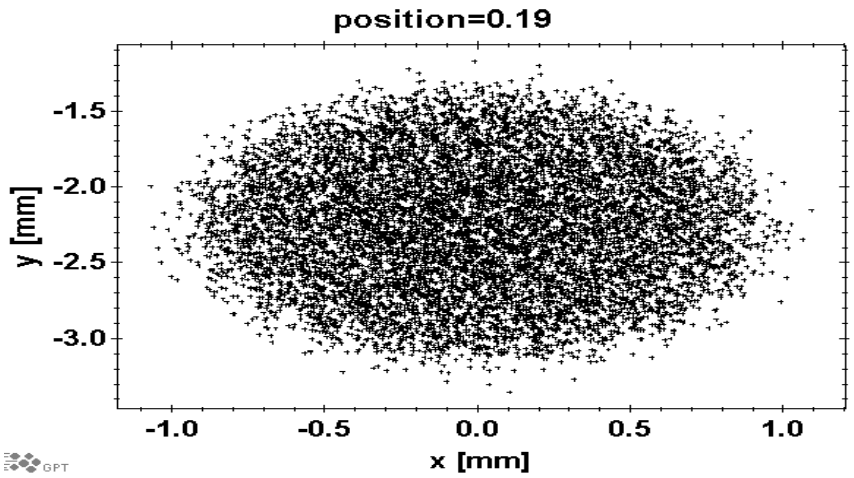
- Used the optimized parameter Phase 1 Upgrade Injector GPT Model (Courtesy- Alicia Hofler, 06/16/2021)
- Positions for elements from the gun through MFA0I03 are based on beamlinelayoutapril152020-gun-chopper.pdf and is noted as beamlinelayoutapril15.pdf in the GPT files.
- Downstream of MFA0I03, the positions are based on measurements Y. Wang and A. Hofler made in 2011, information from mechanical drawings, and even extracted from the old CEBAF PARMELA deck.
- Reference the quick reference drawing injector-quick-reference-rev6-20210607.pdf
- Initial distributions
- Energy gain
- Beam Characteristics
- End distribution

Initial distribution

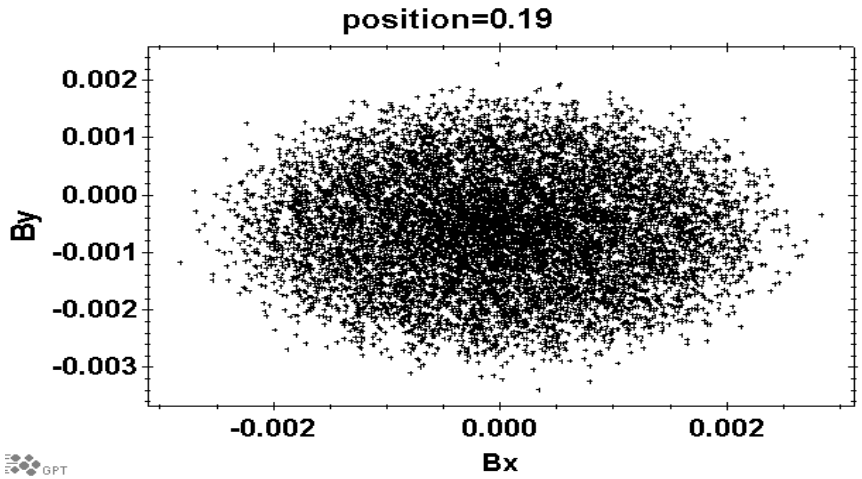
- 130 kV D.C. gun
- 1 Prebuncher, 1Buncher, 5 Captures, Old 5-5 1/4 Cryomodule Booster (2 Cornell-style 5-cell cavities)
- 320 μA (0.64 pC, 128 ns) and 160 μA (0.32 pC, 64 ns) beam current at laser rf frequency=499 MHz (with space charge3Dmesh)
- The are equivalent to 5 μA, 7.80 MHz and 15.59 repetition rates
- GaAsMTE = 0.030691;
- Thermal emittance 0.061 mm-mrad, FWHM=45 ps; 19.10 ps bunch length, 0.25 mm beam size, Gaussian Beam
- 10k macro-particles

Initial distribution, 128ns

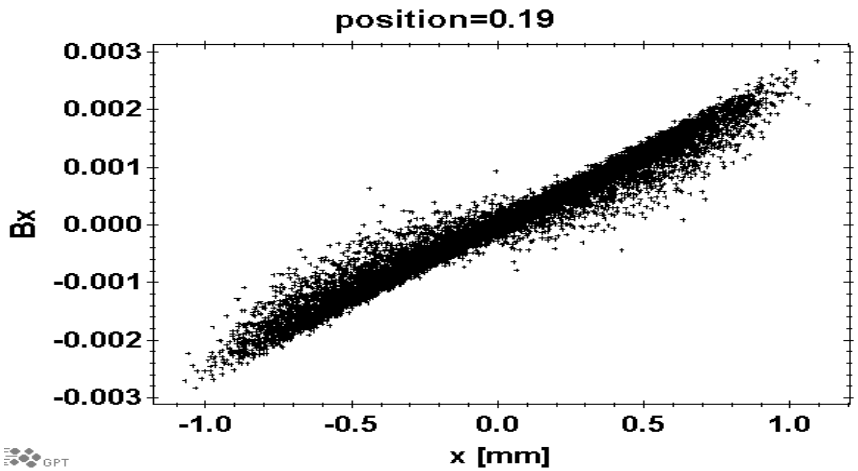
spatial distribution



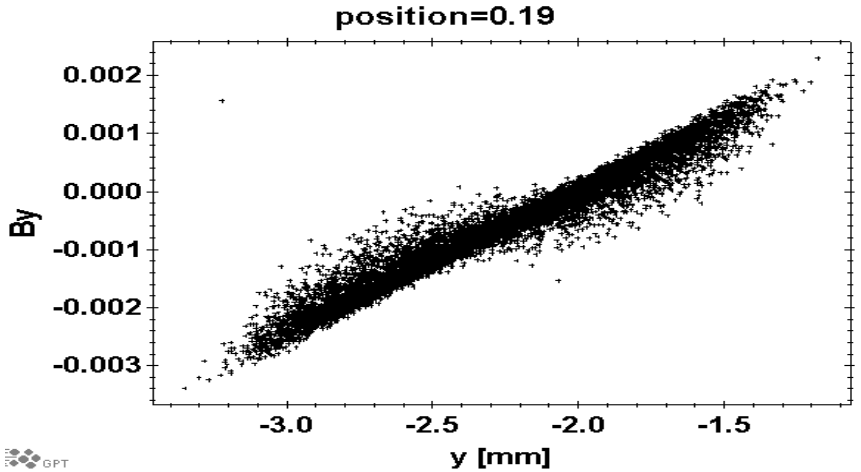
momentum distribution



horizontal phase space

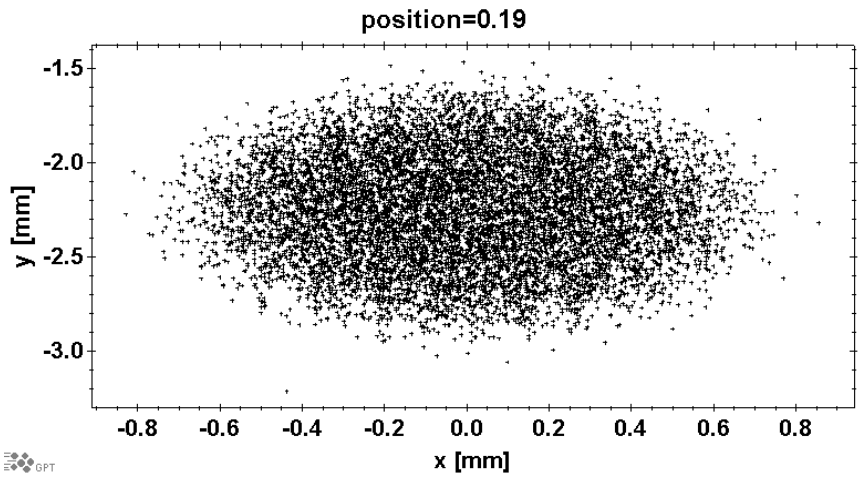


vertical phase space

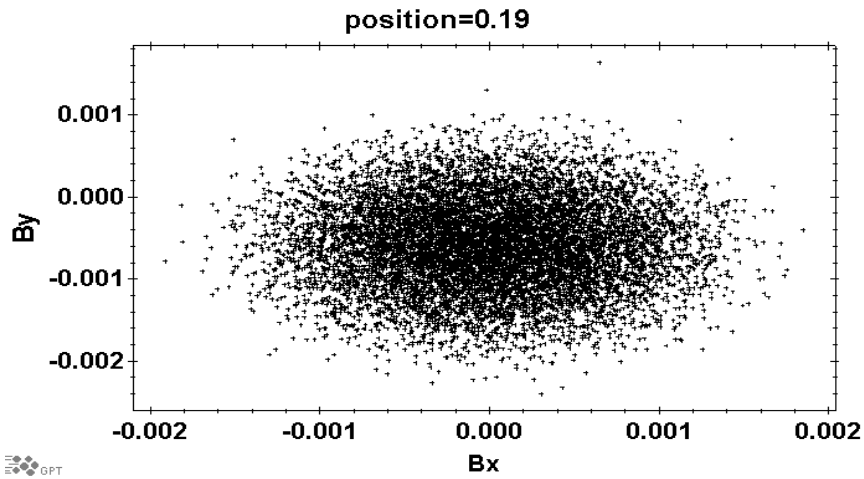


Initial distribution, 64ns

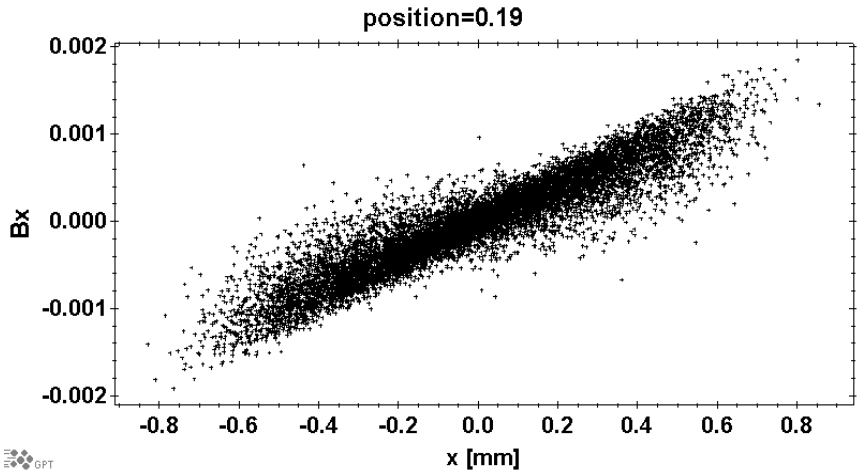
spatial distribution



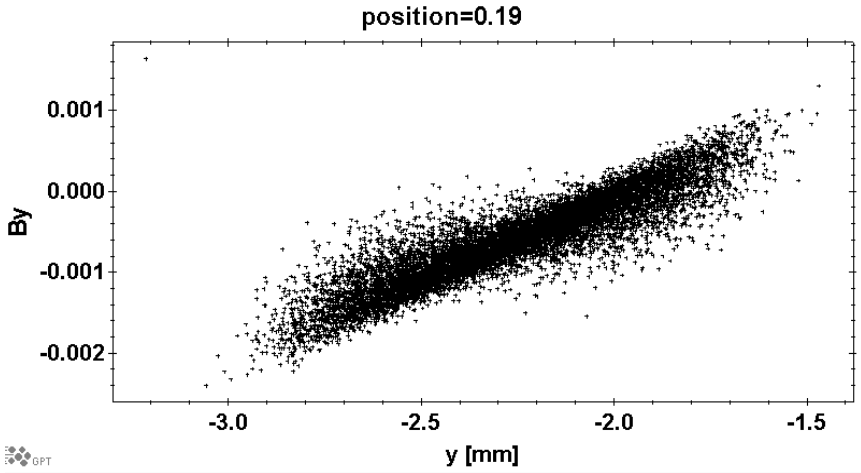
momentum distribution



horizontal phase space

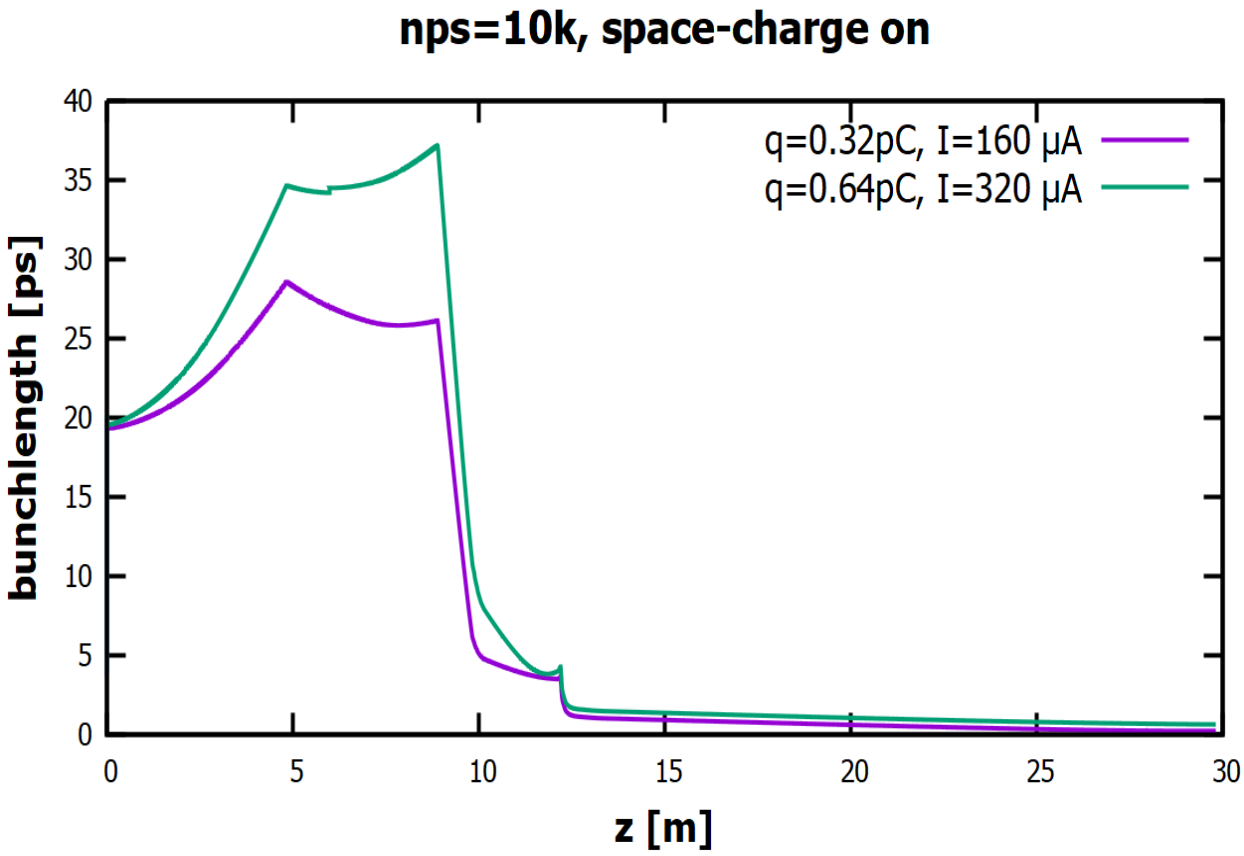


vertical phase space



Simulated Beam Characteristics

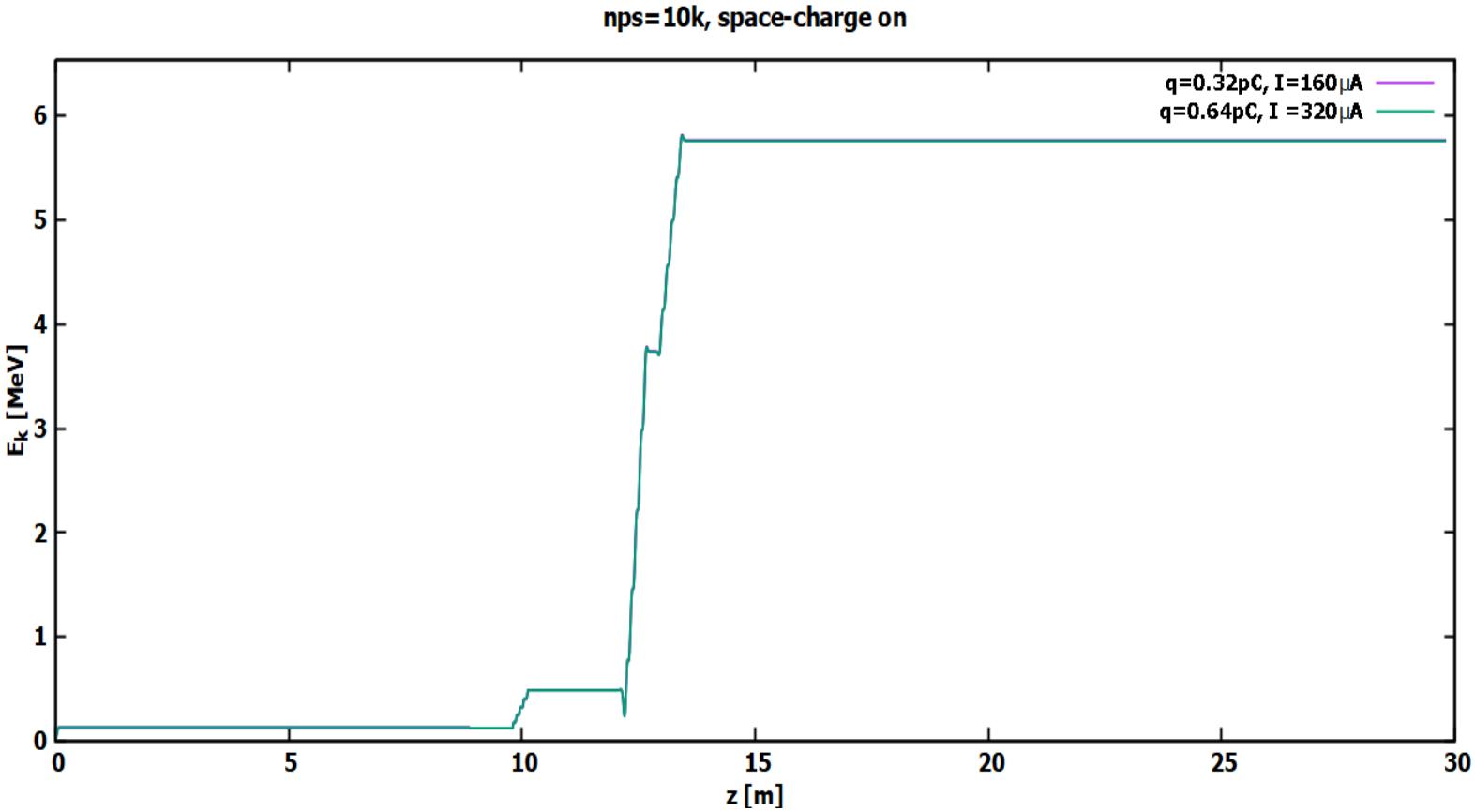
Bunchlength(σ_t)



Bunchlength upstream of the full module are 0.64 ps for 128ns and 0.23 ps for 64ns beam

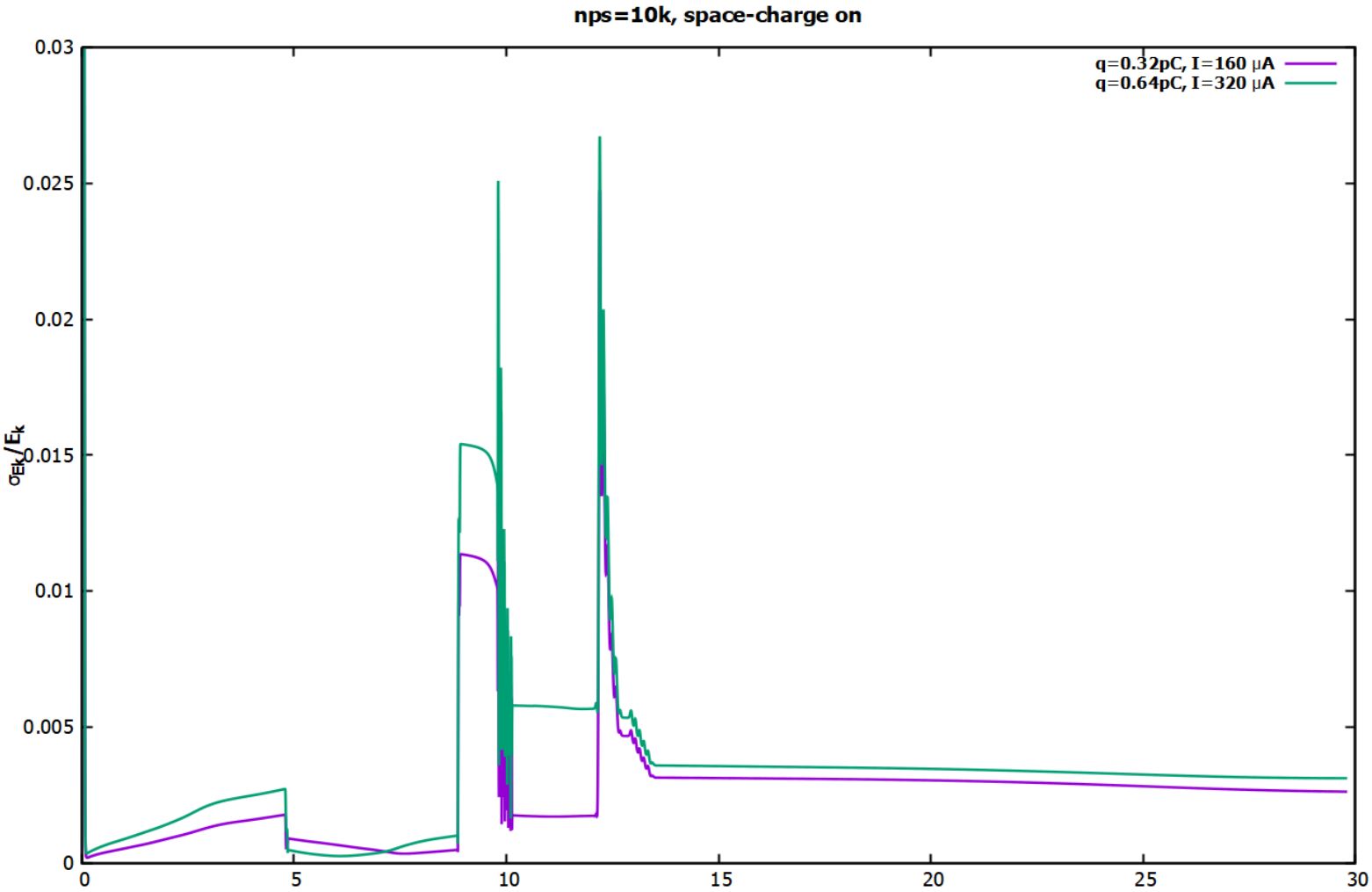
Simulated Beam Characteristics

Kinetic Energy (E_k)



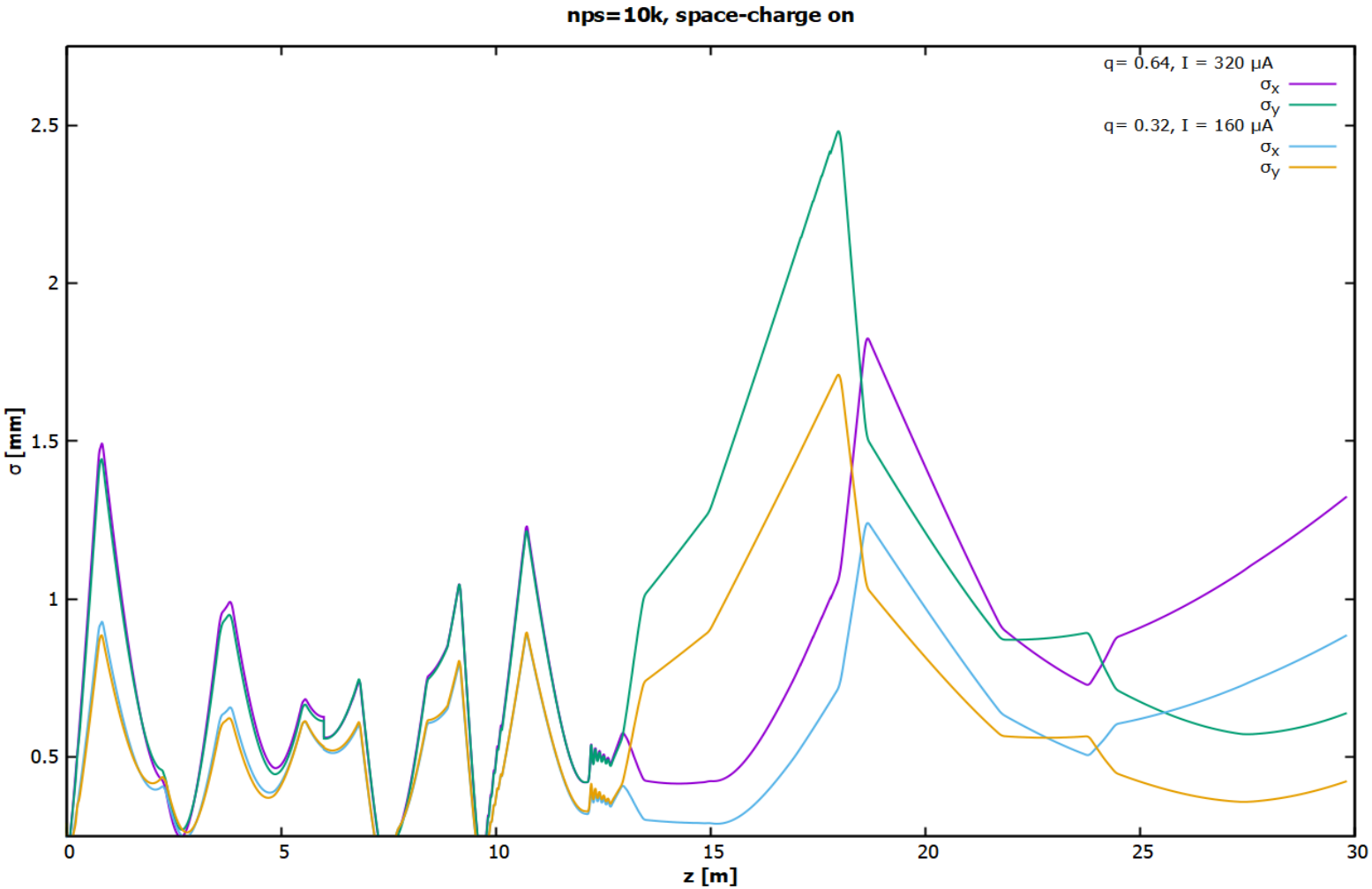
The average KE is 5.76 MeV

Simulated Beam Characteristics



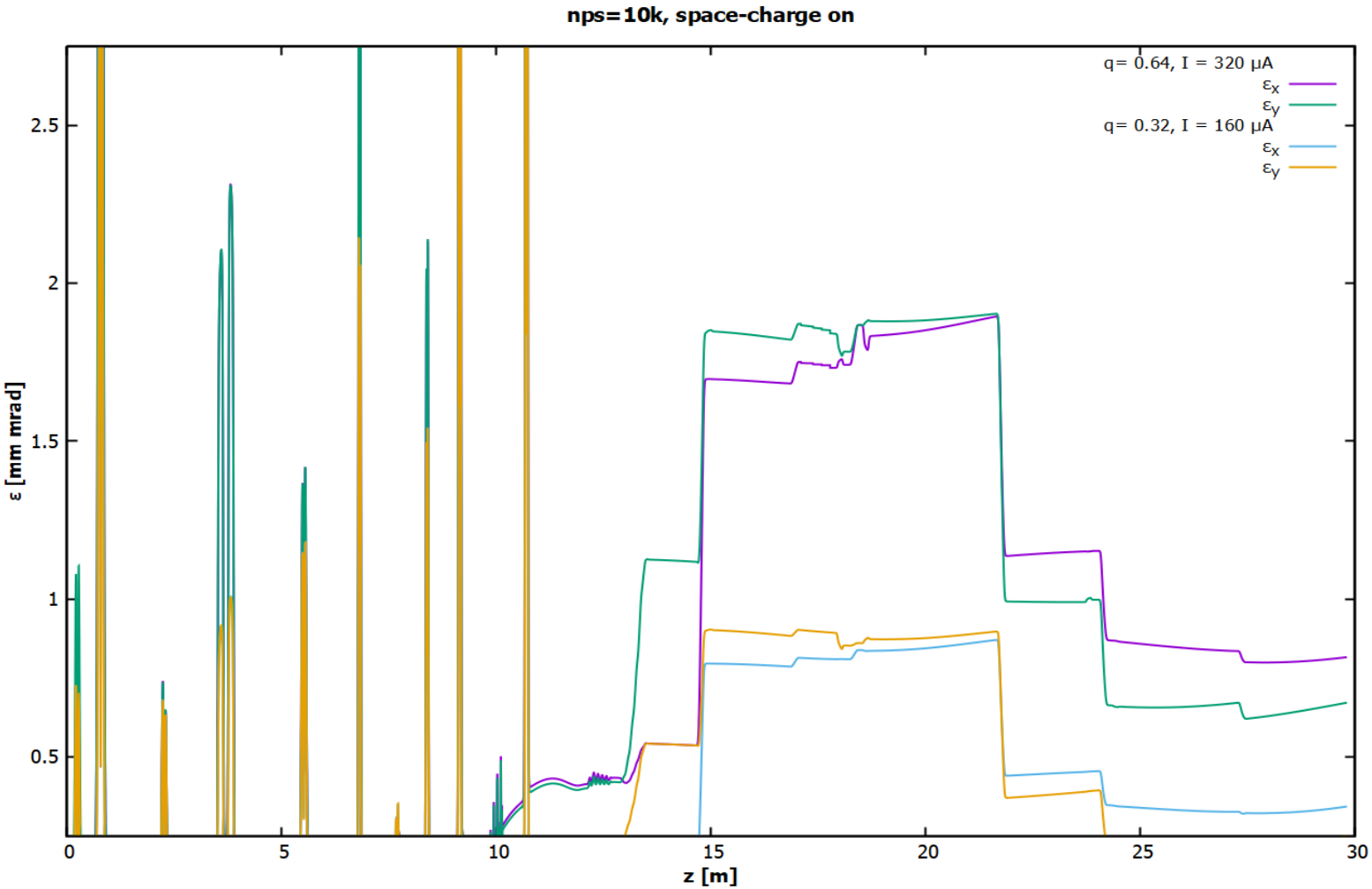
Fractional energy spread < 0.004

Simulated Beam Characteristics



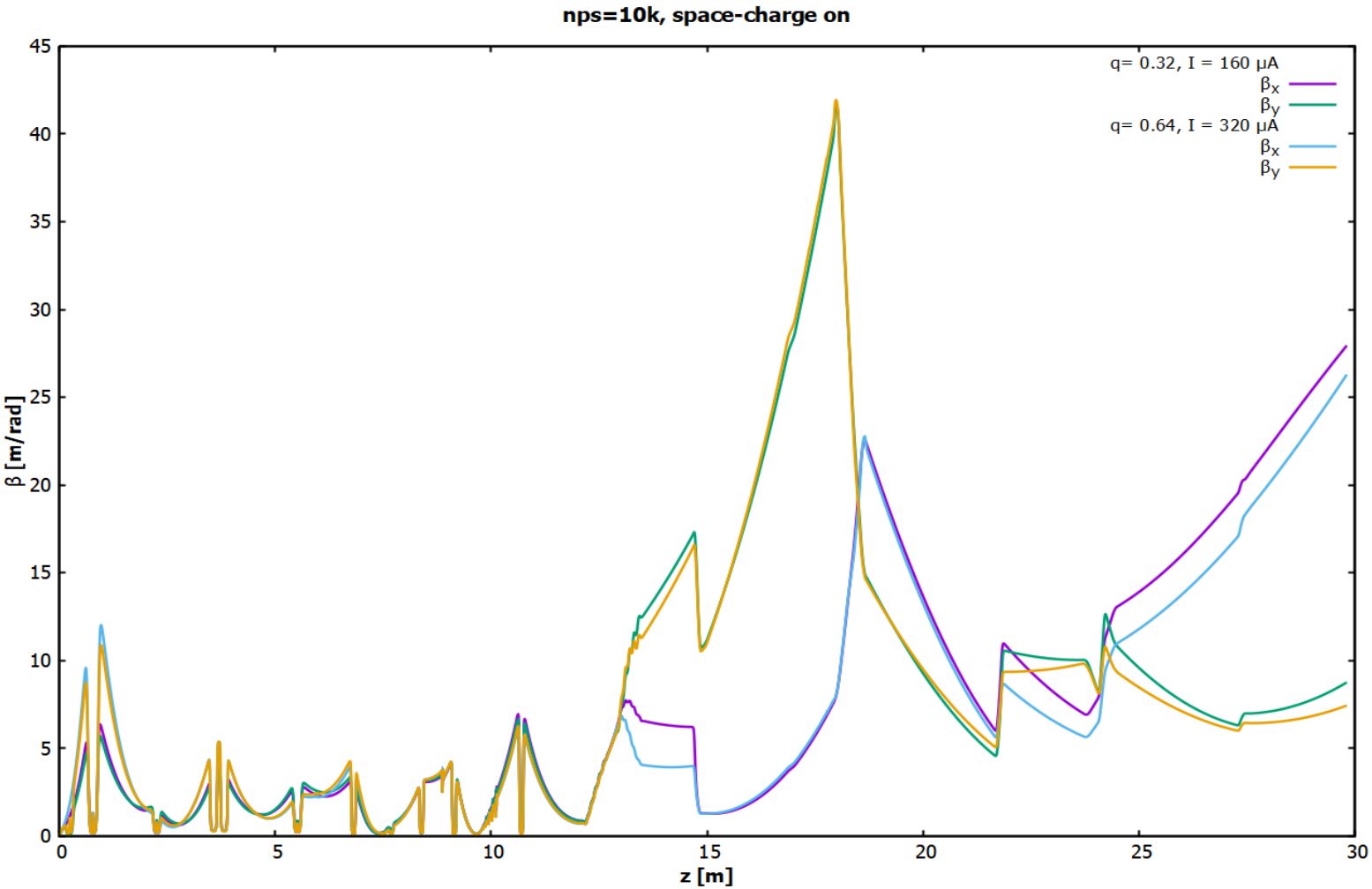
Beam Sizes σ_x, σ_y

Simulated Beam Characteristics



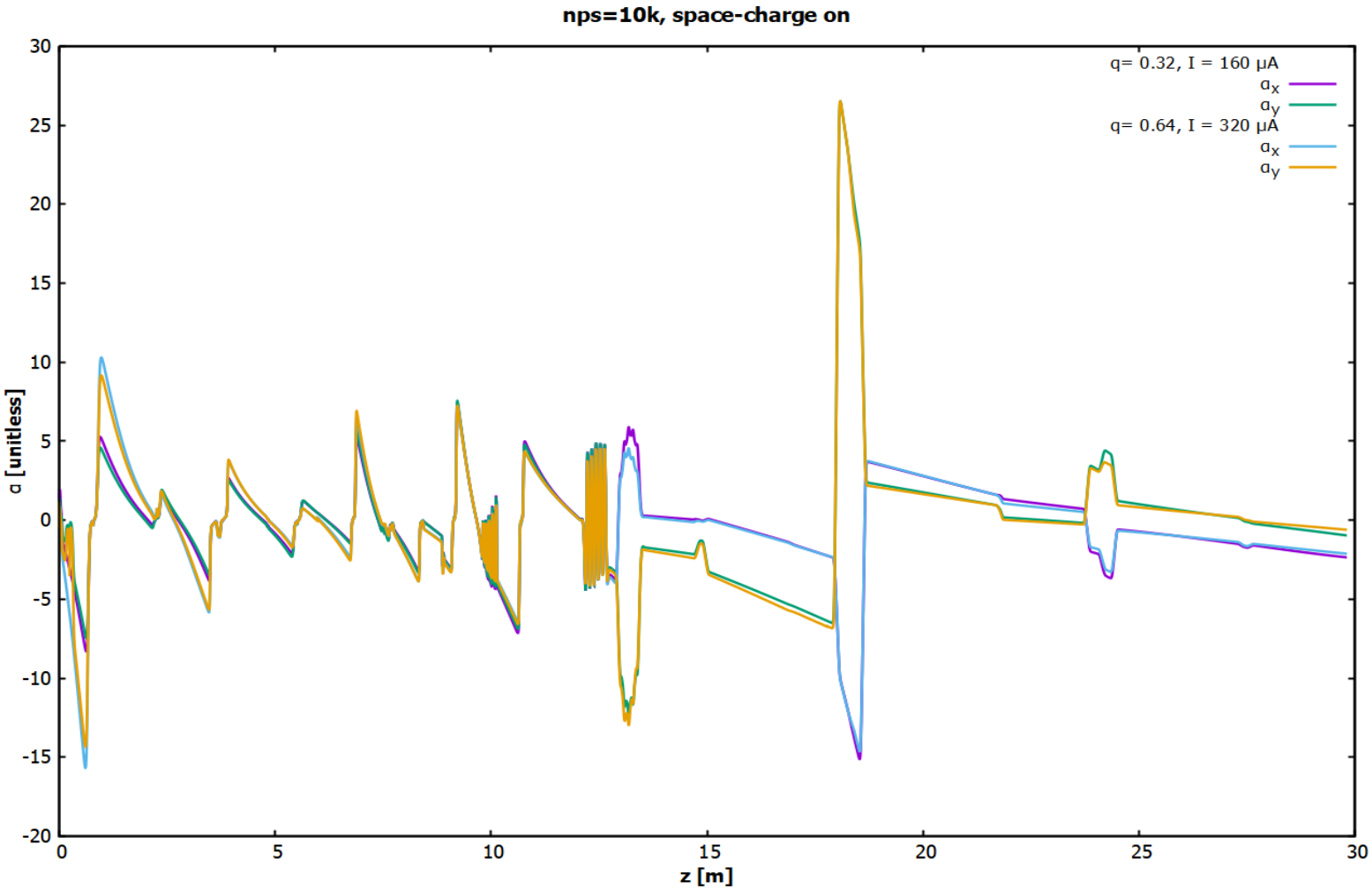
Normalized Emittances ϵ_{n_x}, ϵ_{n_y}

Simulated Beam Characteristics



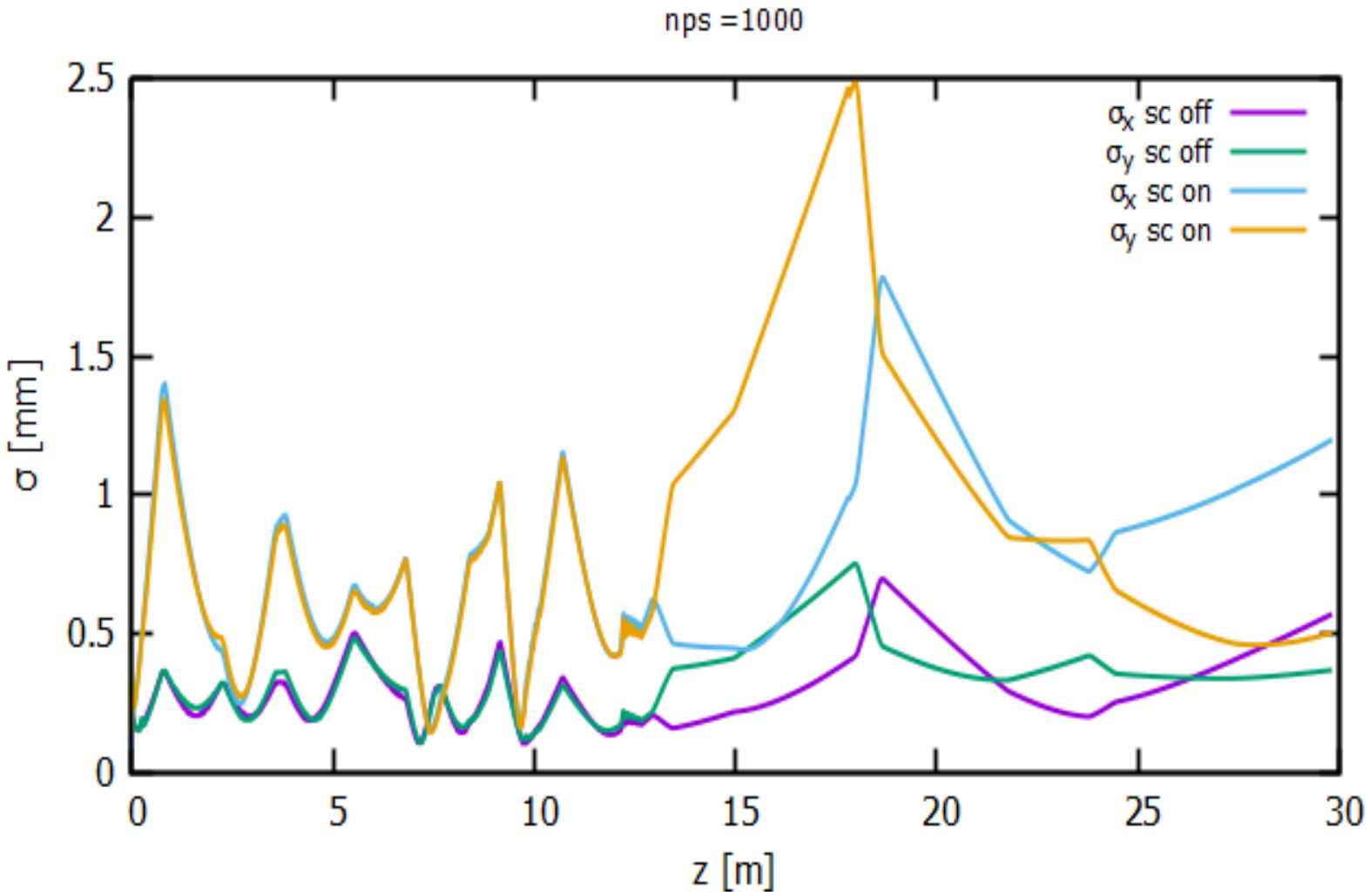
Courant-Snyder β_x, β_y

Simulated Beam Characteristics



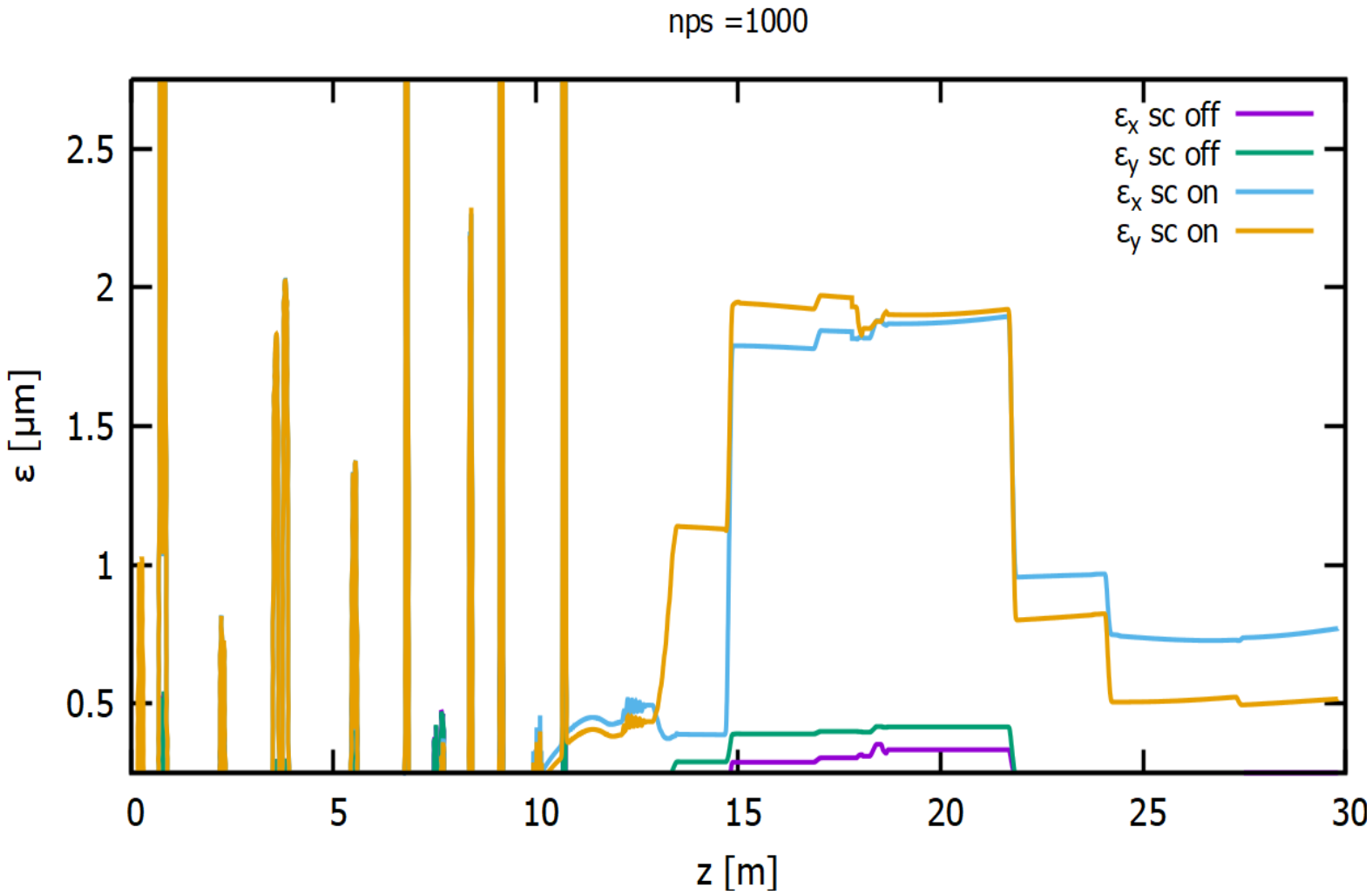
Courant-Snyder α_x, α_y

Simulated Beam Characteristics



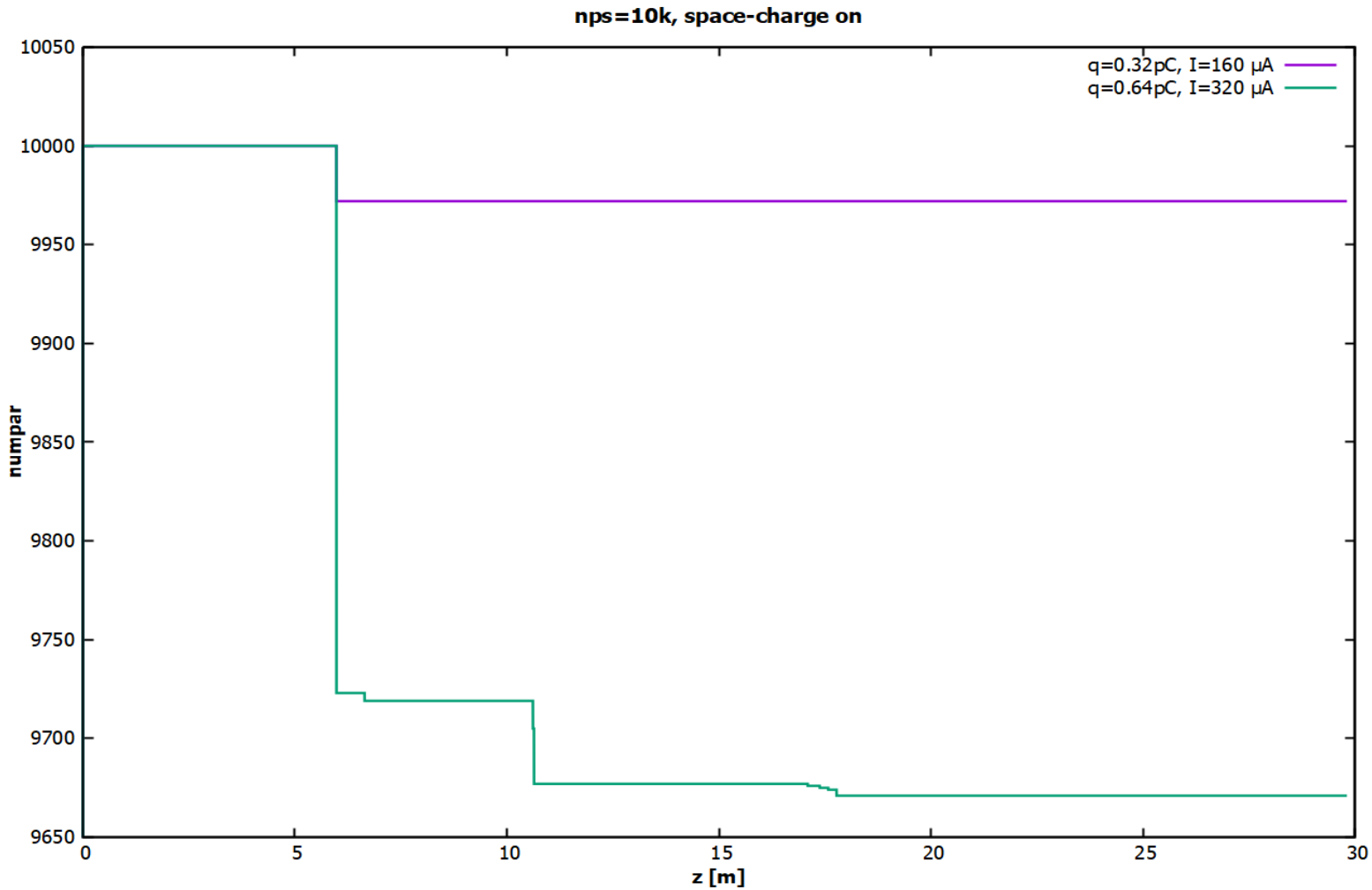
Space-charge effect

Simulated Beam Characteristics



Space-charge effect

Beam Transmission



Beam transmission decreases with increase in bunch charge

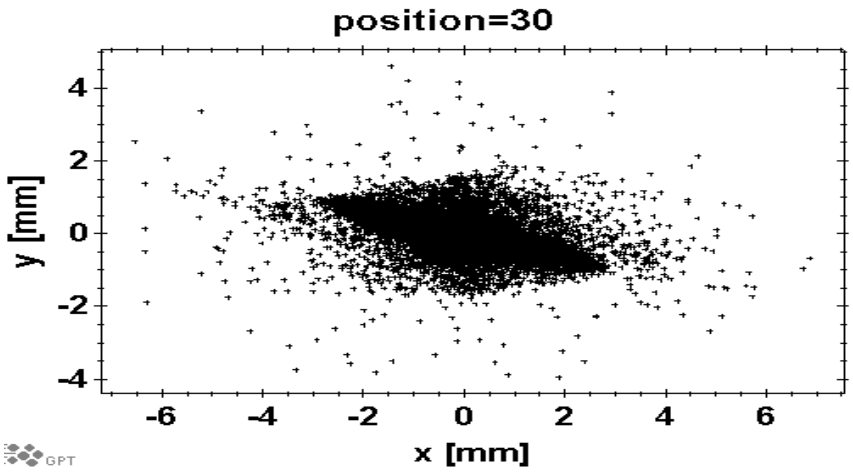
Acceptable beam characteristics

Beam Characteristic	Sensitivity Limit	Optimization Goal
beam transmission	$\geq 99.9\%$	$\geq 99.9\%$
transverse emittance	≤ 1 mm mrad	≤ 0.25 mm mrad
bunchlength	≤ 1 ps	≤ 0.5 ps
$\bar{E}_k$	not considered	5.5 to 7.5 MeV
σ_{E_k}	see $\sigma_{E_k}/\bar{E}_k$	≤ 50 keV
σ_{E_k}/E_k	comparable to optimal case	not specified since use σ_{E_k}

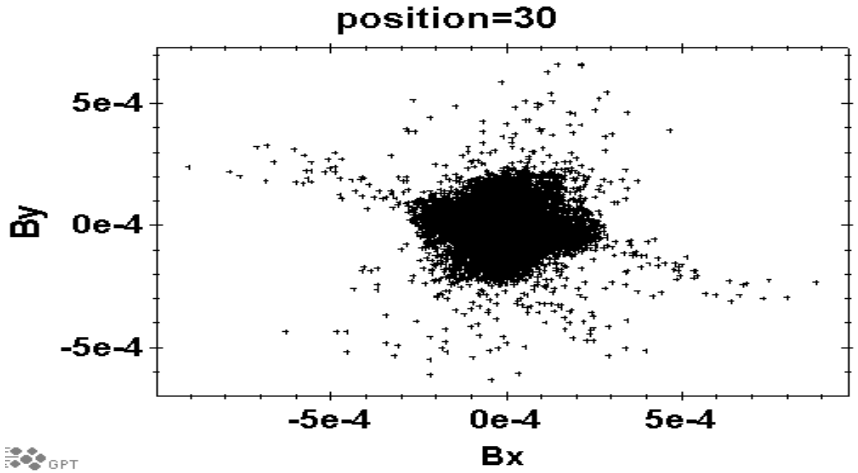
Criteria for acceptable beam characteristics upstream of the first full cryomodule in the Injector

Final distribution, 128ns

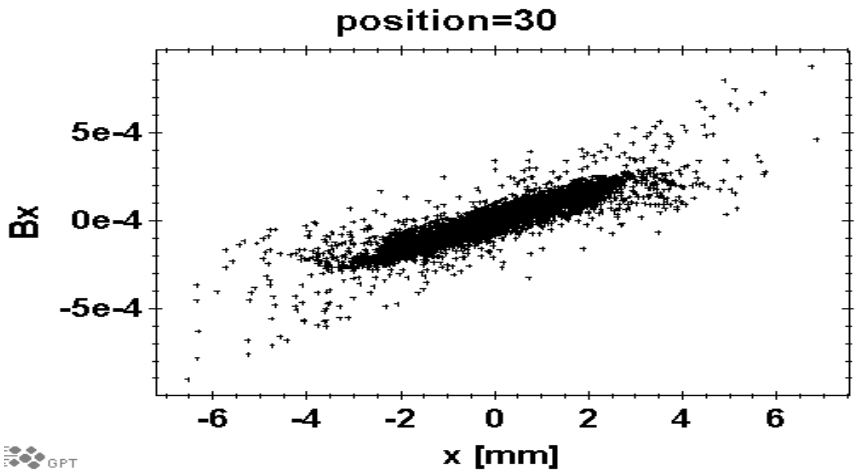
spatial distribution



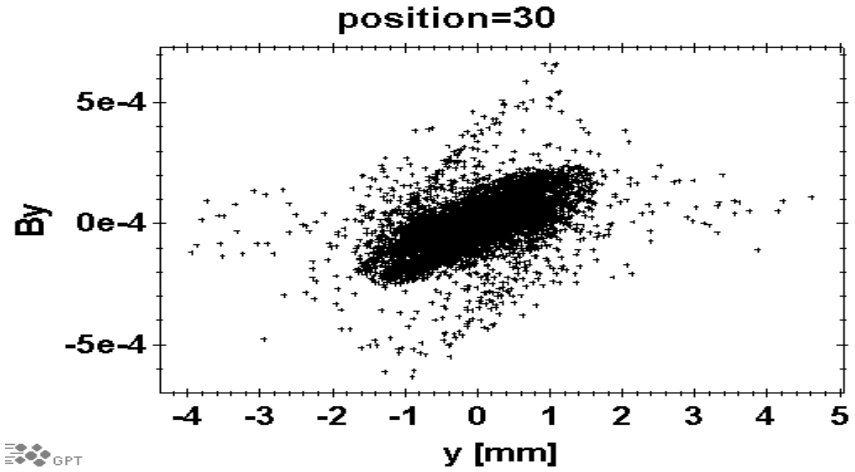
momentum distribution



horizontal phase space

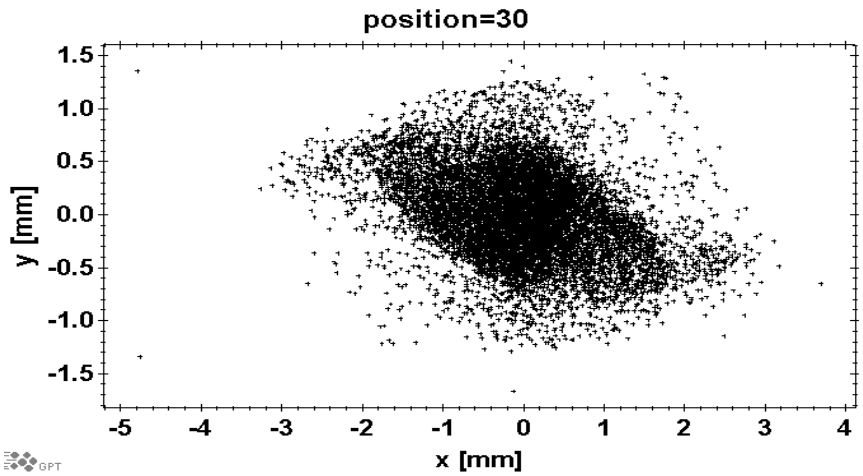


vertical phase space

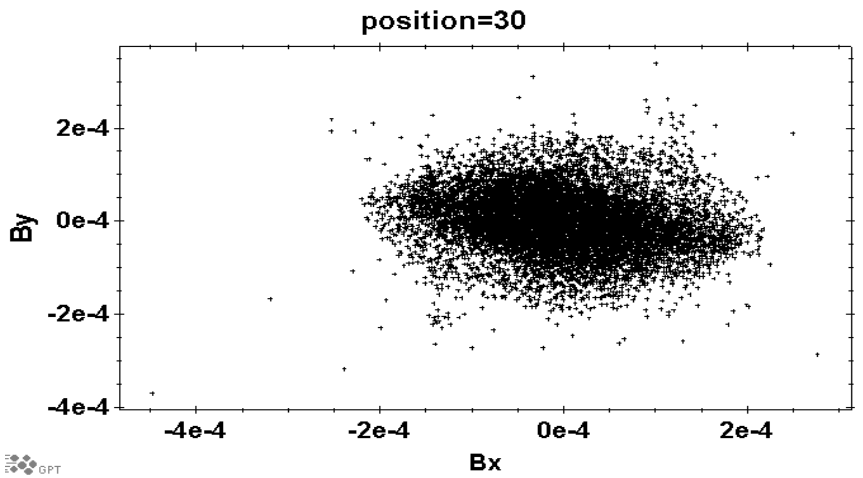


Final distribution, 64ns

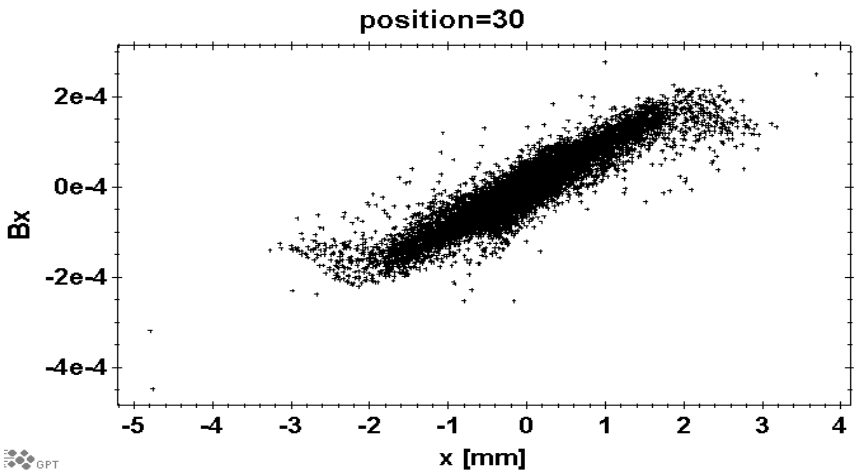
spatial distribution



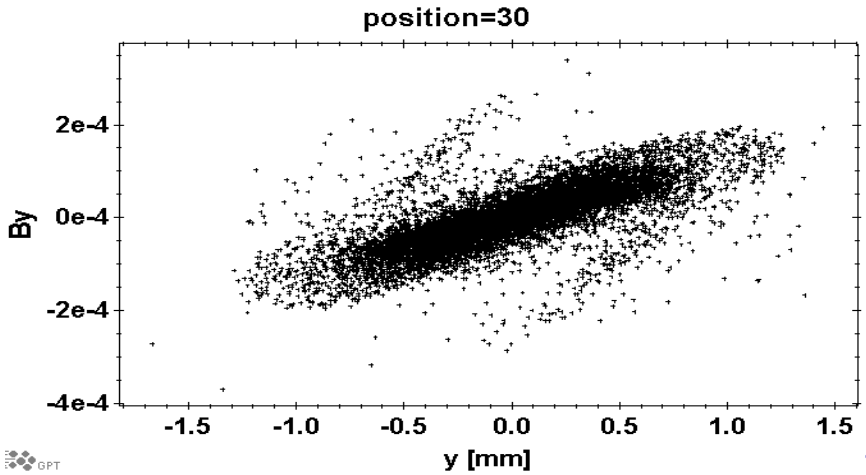
momentum distribution



horizontal phase space



vertical phase space



Summary

1. Phase 1- Upgrade Injector Model for KLF 128 ns and 64 ns is simulated using GPT
2. For 130 keV beam, the results are produced using GPTwin.
3. The average electron beam kinetic energy is 5.76 MeV with sigma energy spread around 18 keV for 128 ns and 15 keV for 64 ns. The average beam energy is 6.27 MeV upstream at 30 m.
4. For 128 ns beam, $\sigma_x = 1.32$ mm, $\sigma_y = 0.64$ mm and $\sigma_z = 0.64$ ps, normalized emittances $\epsilon_{n_x} = 0.816$ mm-mrad and $\epsilon_{n_y} = 0.672$ mm-mrad respectively
5. For 64 ns beam, $\sigma_x = 0.88$ mm, $\sigma_y = 0.42$ mm and $\sigma_z = 0.23$ ps, normalized emittances $\epsilon_{n_x} = 0.344$ mm-mrad and $\epsilon_{n_y} = 0.251$ mm-mrad respectively
6. For 128 ns beam transmission is 96.71% while for 64 ns it is 99.72 %

Thank You !