Preliminary results on Self-modulation of PITZ Electron beam from HiPACE Simulations

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DESY

Outline

- Motivation
- Self-modulation
- HiPACE code – Input and Output
- Initial parameters
- Results
- Conclusion

Motivation

- A Proton driven plasma wakefield acceleration was proposed by A.Caldwell et. al. in 2009 .
- Generating short proton beams is challenging. The CERN SPS bunch has length ~12cm.

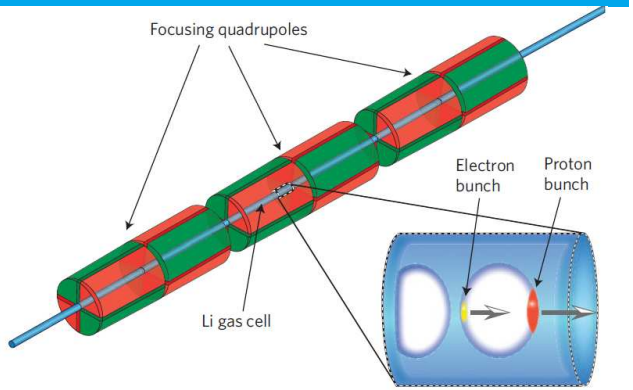
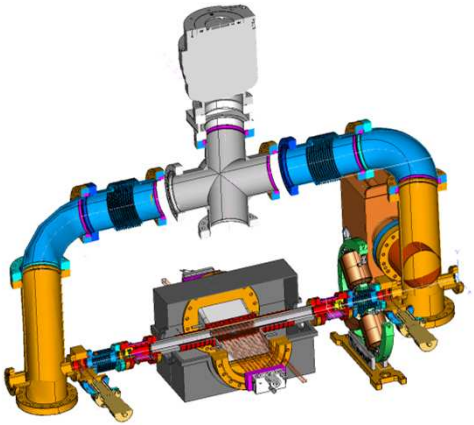


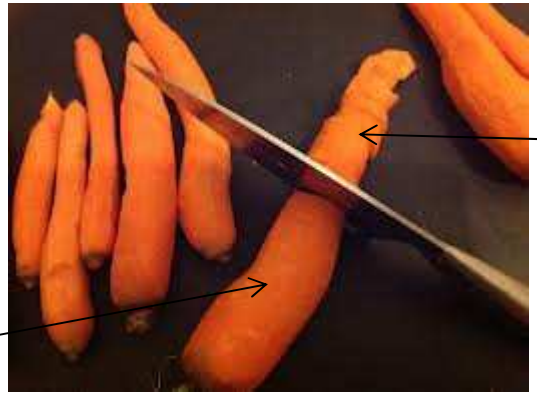
Figure 1 | A schematic description of a section of the plasma-wakefield-accelerating structure. A thin tube containing Li gas is surrounded by quadrupole magnets with alternating polarity. The magnification shows the plasma bubble created by the proton bunch (red). The electron bunch (yellow) undergoing acceleration is located at the back of the bubble. Note that the dimensions are not to scale.

- To generate a short proton bunches a technique viz. self modulation is proposed by N. Kumar and A. Pukhov in 2010.
- If a particle bunch travelling through plasma is long in comparison to the plasma wavelength then it can get self-modulated, splitting itself into short bunches.

- Before proceeding further with proton bunches a test bed experiment with electron bunches was proposed by Schroeder and Gruener in 2011.
- Because of its very favorable condition with electron beams an experiment is proposed to set up a plasma oven in the PITZ beam line to study the self-modulation of electron beams when they passes through laser generated Lithium plasma.



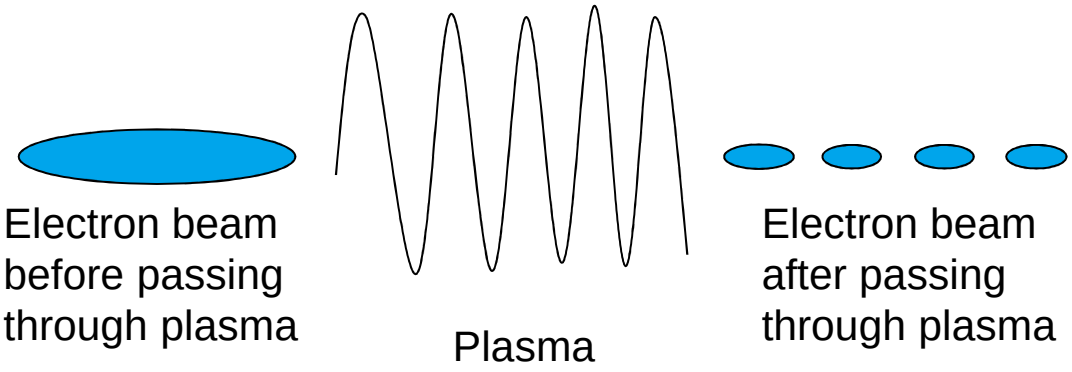
Self-modulation of electron beams



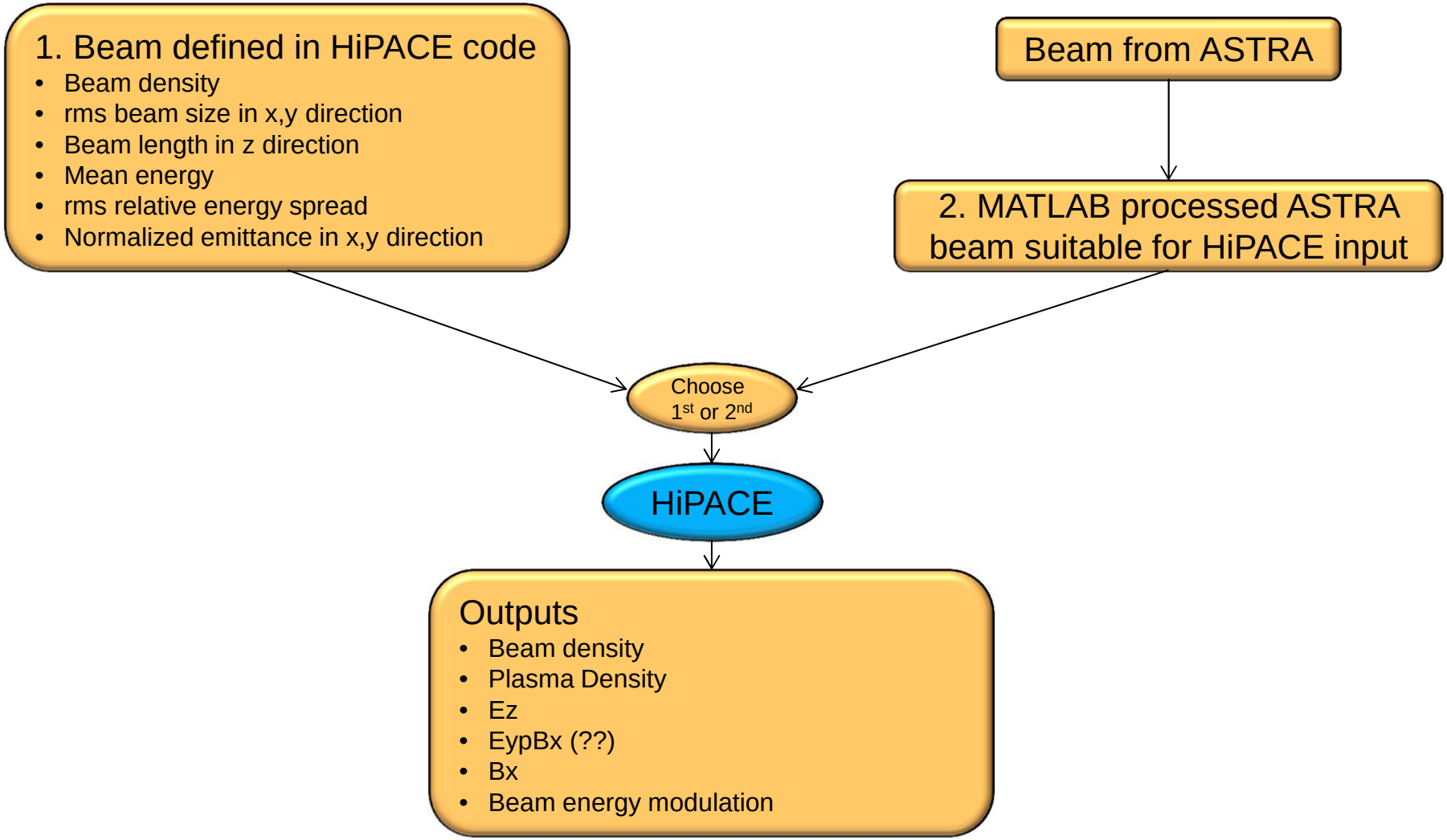
After passing through knife

Before passing through knife

If a particle bunch travelling through plasma is long in comparison to the plasma wavelength then it can get self-modulated, splitting itself into short bunches



HiPACE code – Input and Output



Initial parameters

- When loading the beam phase space from an ASTRA file to HiPACE, the aim usually is to have exactly the same 6D phase-space distribution as in the ASTRA simulation.
- However future simulation would be done for zero beam energy spread.

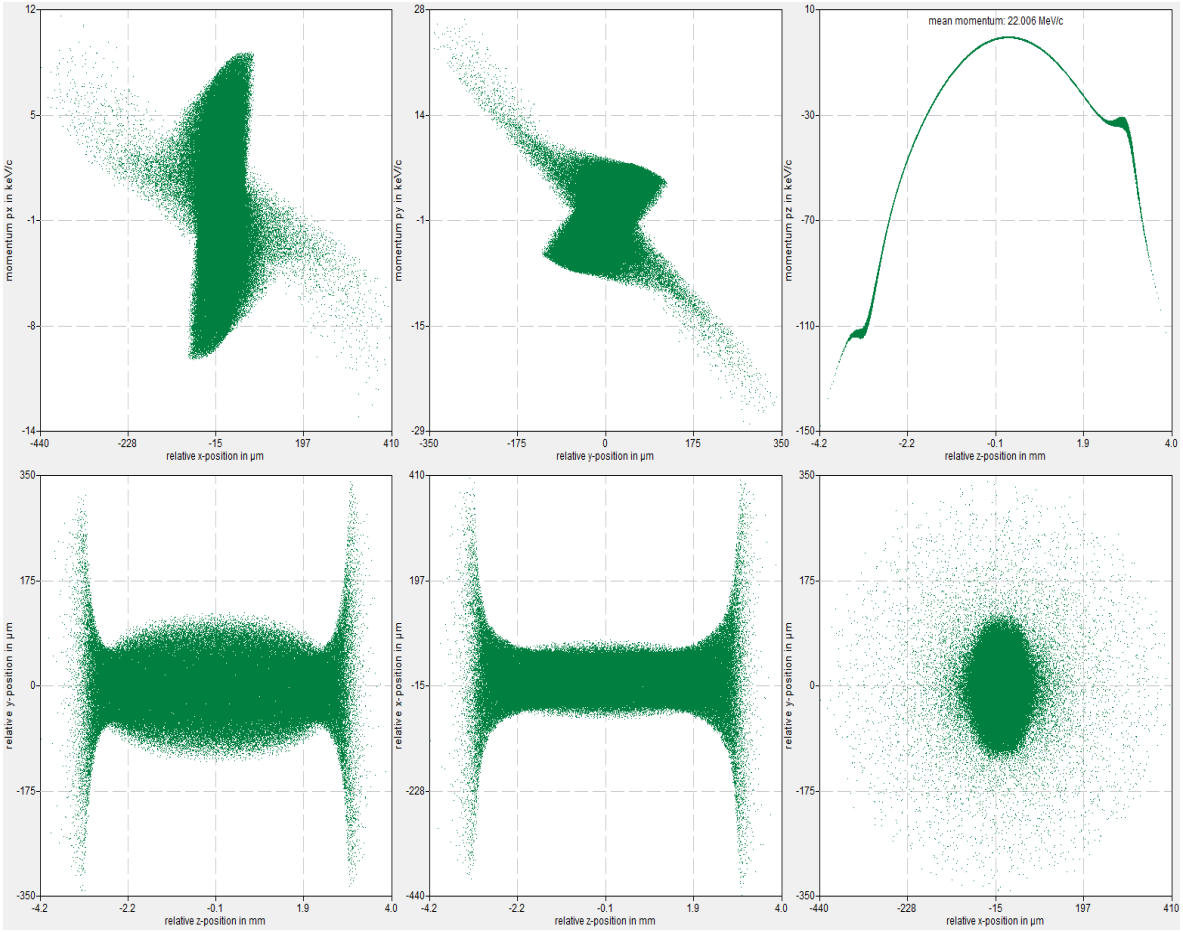
Parameter	Details
Plasma Density	$10^{16} cm^{-3}$
Plasma species	1=electron, 2 = positrons, 3 = ions
Order of particle shape of plasma	2 (??)
Beam charge	0.1 nC
Beam energy spread	Defined by ASTRA (24.96 KeV)
Beam length	~6mm

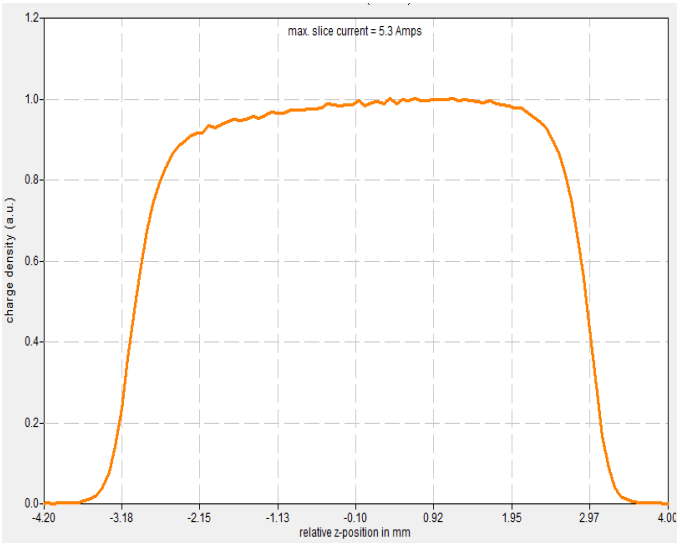
$\longrightarrow \quad \lambda_p = 0.3mm$

- The other parameters (like Beam density, rms beam size in x,y direction, beam length etc.) are imported from the ASTRA file.

Initial parameters

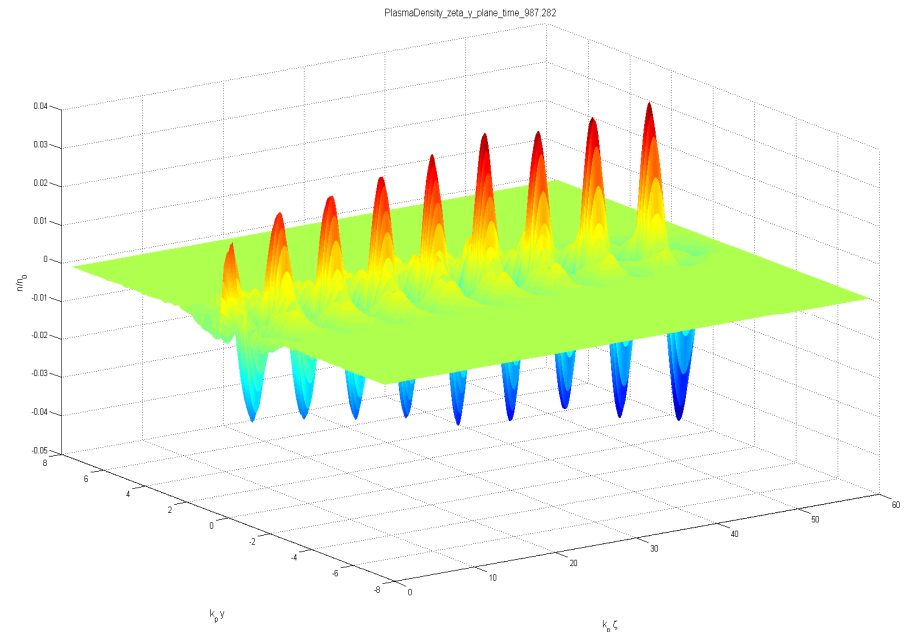
ASTRA Input



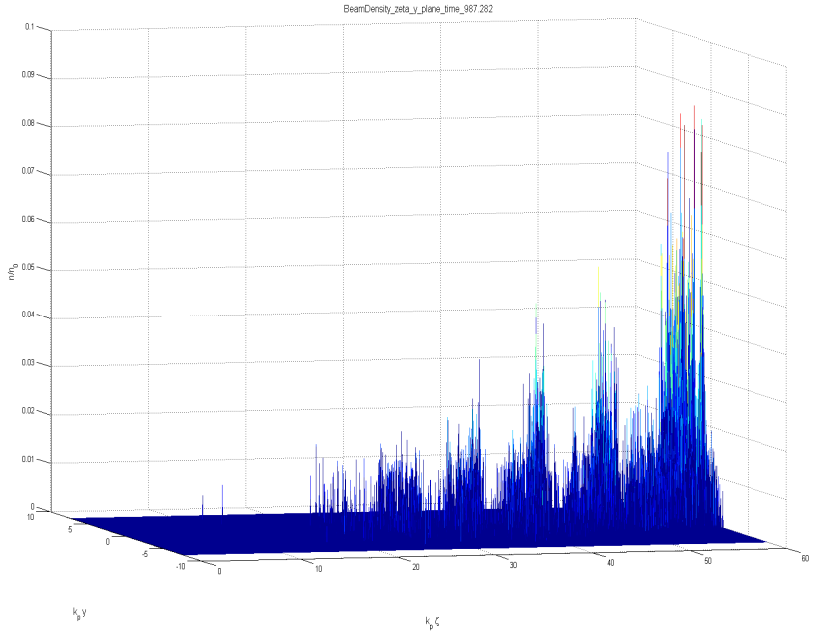


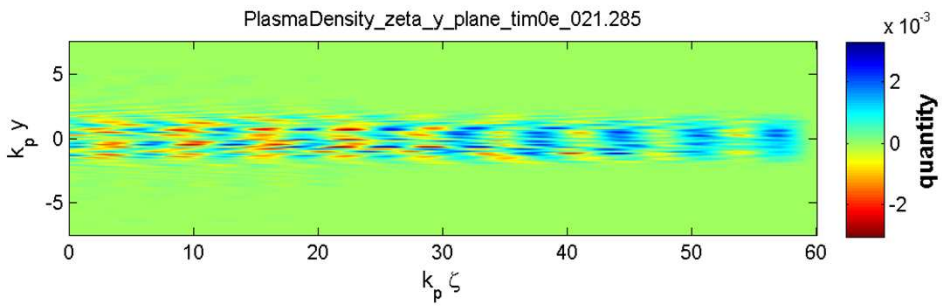
Results (plasma and beam density)

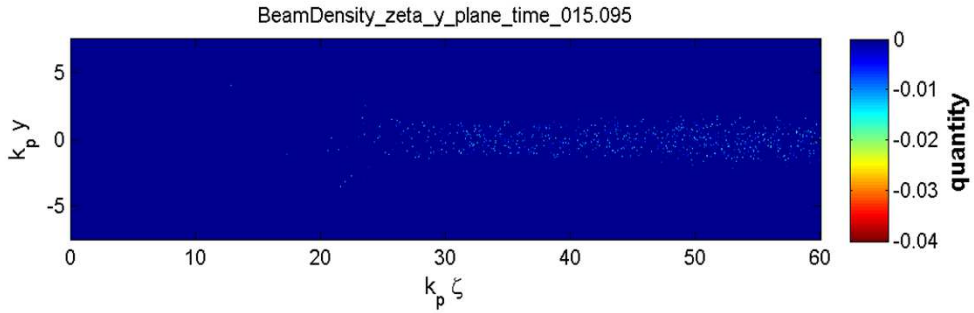
Plasma Density



Beam density

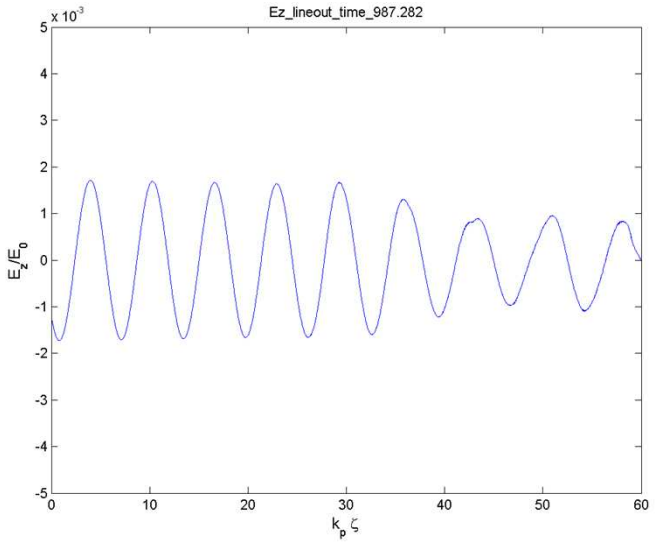




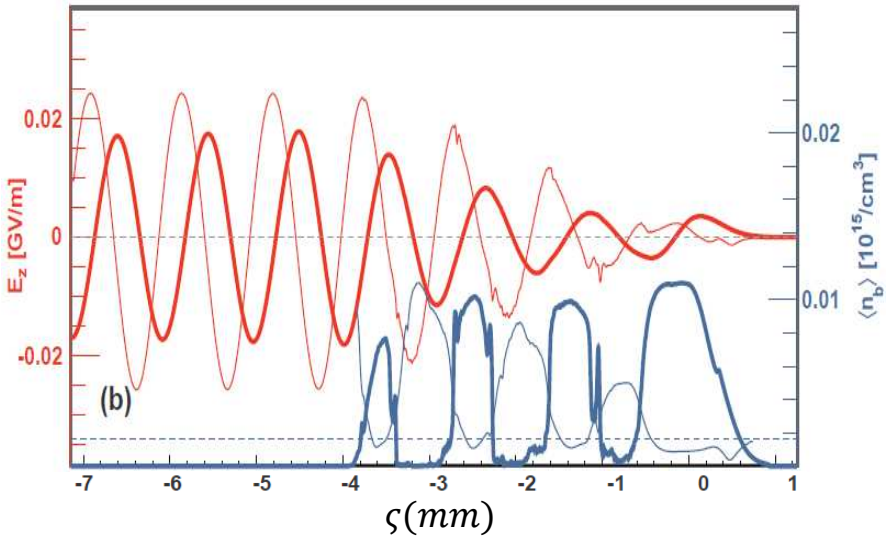


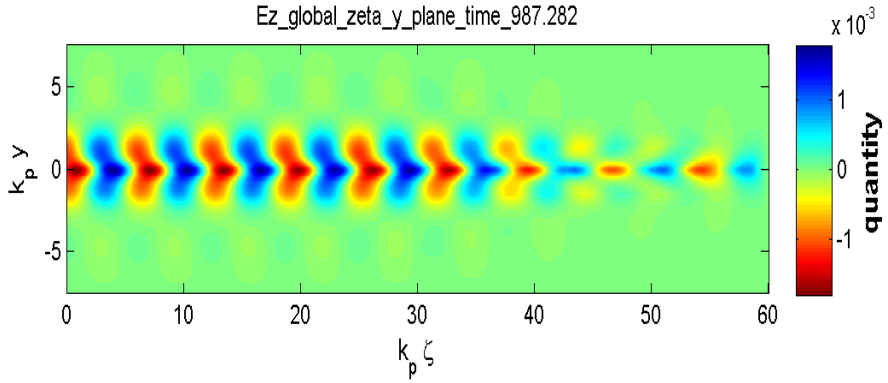
Results (longitudinal electric field)

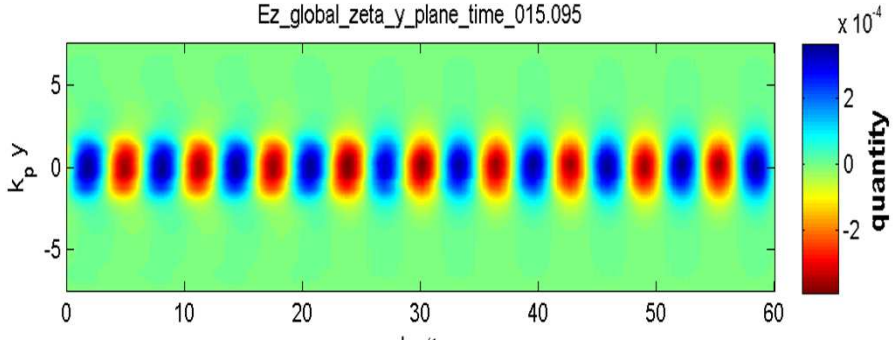
Longitudinal electric field



Alberto's simulation*



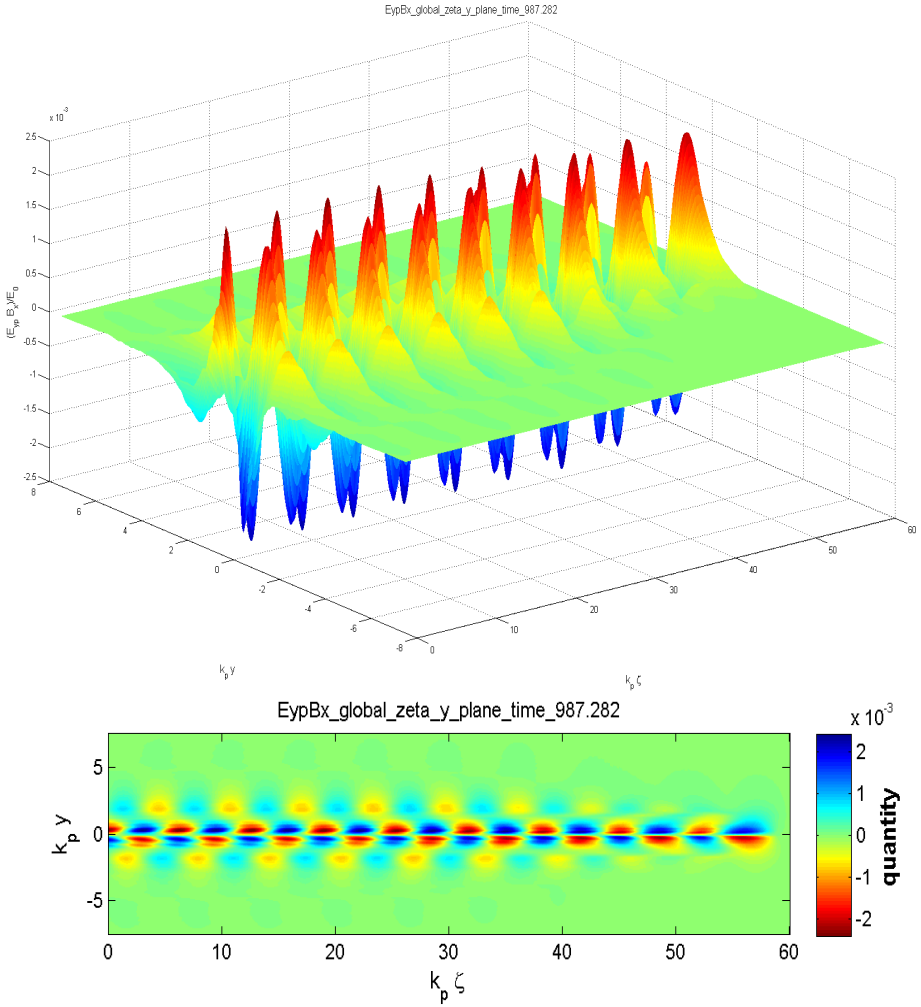




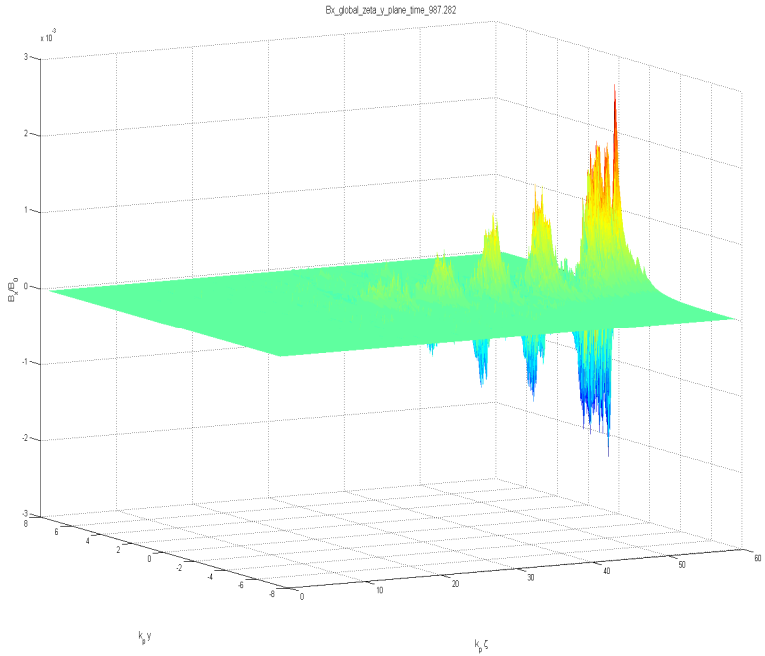
* Self-modulation of long electron beams in plasma at PITZ, A. Martinez de la Ossa et. al, AIP Conf. Proc. 1507, 588 (2012)

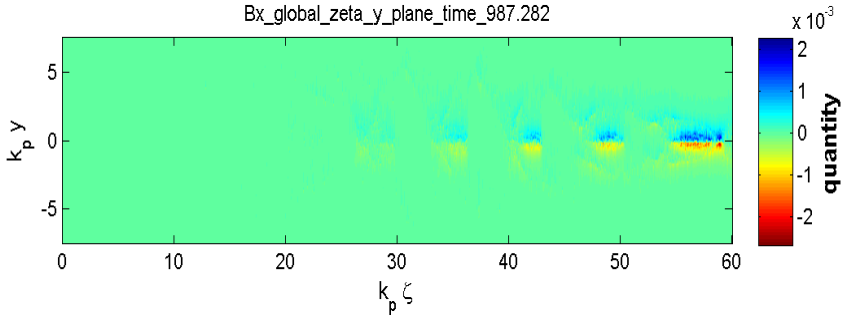
Results (Focusing fields)

$E_{yp}B_x$

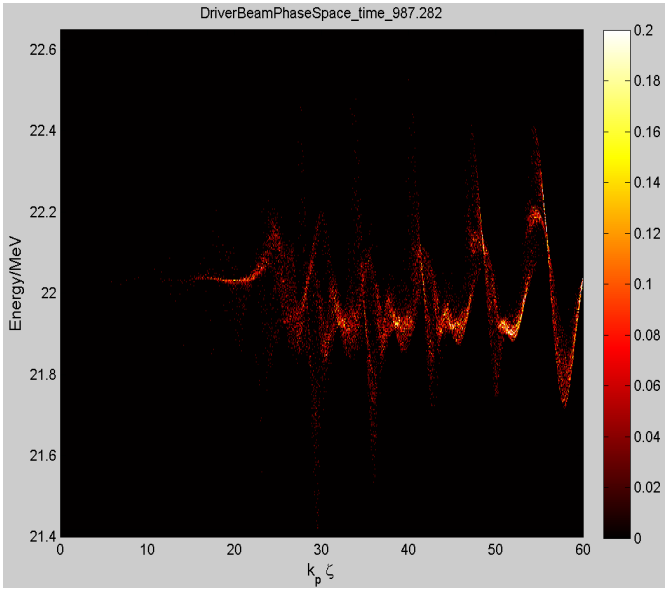


B_x

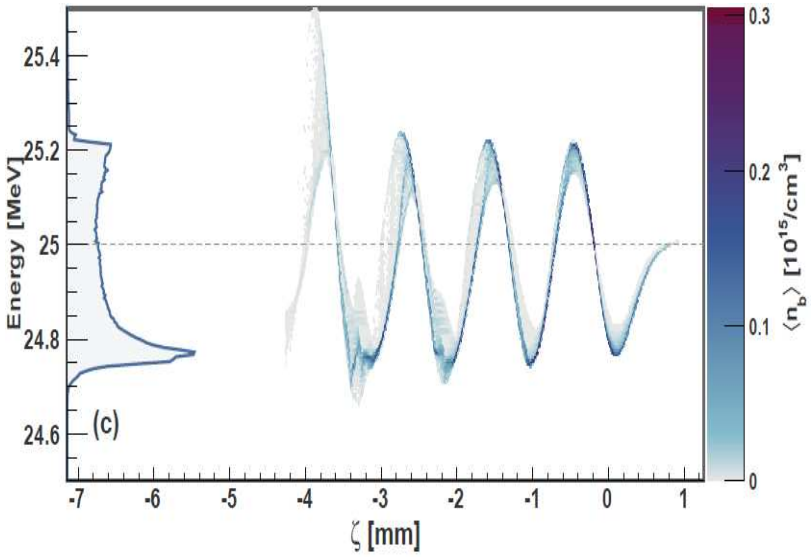


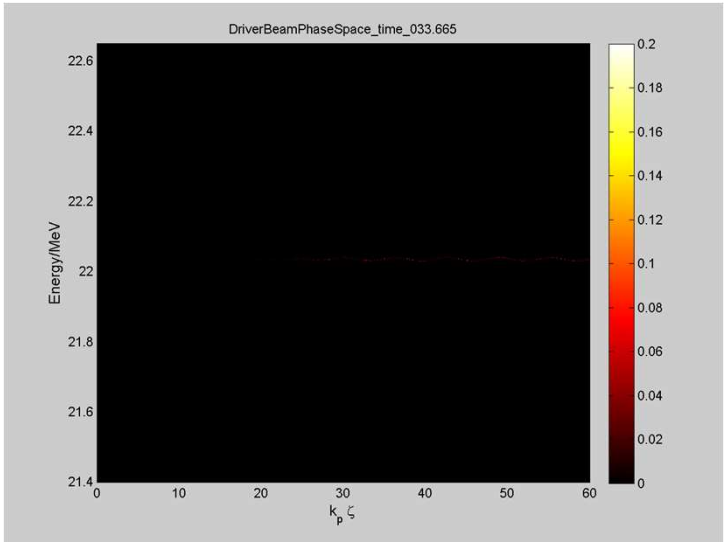


Results (Energy modulation)



Alberto's simulation





Conclusion

- HiPACE simulation works properly.
- The output from the HiPACE simulation looks similar to OSIRIS code. However further simulation with appropriate parameters should be done for exact matching of OSIRIS and HiPACE outputs.
- Number of particles used in this simulation is small (2×10^5) with charge of 0.1nC. Increment of charge and number of particles may increase the longitudinal electric field and energy modulation.
- The plasma density used in this simulation is $10^{16} cm^{-3}$. Decrease in plasma density “may” decrease the modulation in electron beam.

Initial parameters (beam emittance)