

# Emittance preservation of an electron bunch in a loaded quasi-linear plasma wakefield

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We investigate beam loading and emittance preservation for a high-charge electron beam being accelerated in quasi-linear plasma wakefield driven by a short proton beam. The structure of the wakefield is similar to that of a long, modulated proton beam. By selecting transverse and longitudinal electron beam parameters in order to appropriately load the wake, we show that the bulk of the electron beam can be accelerated without significant emittance growth.

## I. INTRODUCTION

The preliminary design of AWAKE Run 2 proposes to use two plasma sections. The first section of 4m is the SMI stage. The electron beam will be injected into the modulated proton beam before stage two, where acceleration will occur. As the  $e_z$  field will decrease due to the gap between the two cells, it is desirable to keep this as short as possible [1].

## II. METHOD

The main focus of this study has been on the beam loading of the electron beam. In order to eliminate other factors that may affect this, we have tried several approaches to create a stable drive beam structure based on previous SMI studies [citations].

Our first approach was to use a premodulated, short proton beam with the same structure as a section of the full AWAKE proton drive beam. These studies were done using the full PIC code Osiris [2] using 2D cylindrical-symmetric simulations. The proton beam was pre-modulated by a clipped cosine function to the longitudinal density profile, with a period matching the wavelength,  $\lambda_p$ , of the plasma. The length was limited to  $26 \cdot \lambda_p$ , and the electron beam injected after the 20th micro-bunch [3]. We performed several parameter scans with this setup, testing for optimal charge as well as beam length [1, 4].

[Add something about the optimal results]

In order to evaluate the quality of the beam, we also needed to study its emittance. Full PIC codes like Osiris are vulnerable to numerical growth of emittance caused by the “numerical Cherenkov effect” [5]. This is a known issue with the Yee EMF solver, which causes the phase

velocity of electromagnetic fields to be lower than  $c$ , while the beam moves very close to  $c$ . The effect can be mitigated somewhat by the Lehe solver [6], but the effect is still prominent in the high density regions of the electron beam.

In order to study the emittance evolution of the beam we used QuickPIC, a fully relativistic 3D PIC code [7, 8].

### A. Simulation Setup

In these simulations we use a single proton drive bunch that sets up a wakefield comparable to that which we expect to see from the self-modulated SPS beam. This was done both to reduce simulation time, as we run 3D simulations, and to create a stable environment for the witness beam.

## III. BEAM LOADING

The structure of the single drive beam set-up behaves similarly to the self-modulated case. However, since the drive beam is prevented from significant evolution in this simulation set-up, we are presented with an idealised case where the electron witness beam sees consistent fields.

## IV. PARAMETER OPTIMISATION

## V. DISCUSSION

## VI. CONCLUSION

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