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Experimental Generation of PWFA-suitable Bunch Current Profiles by Arc-like Bunch Compressors

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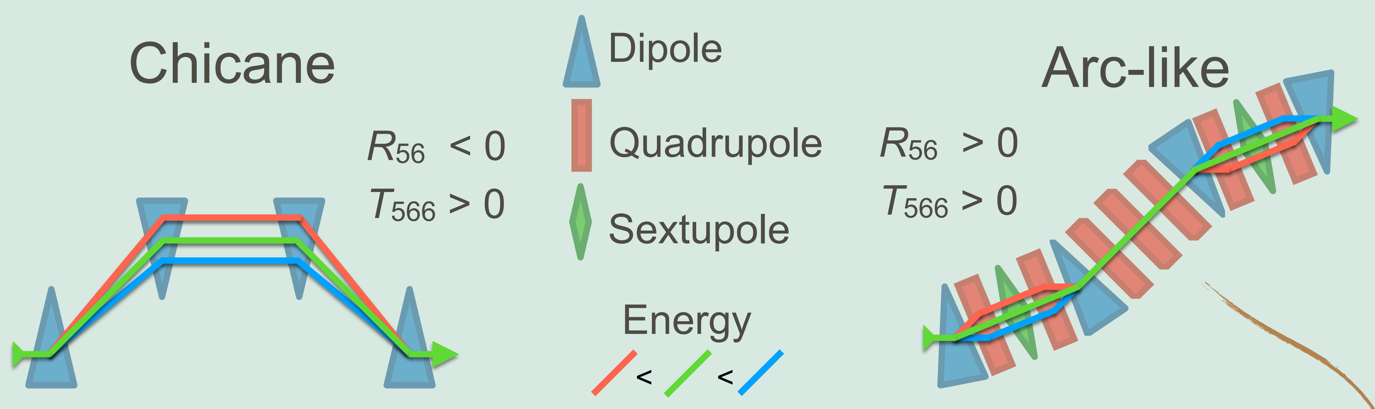
Introduction

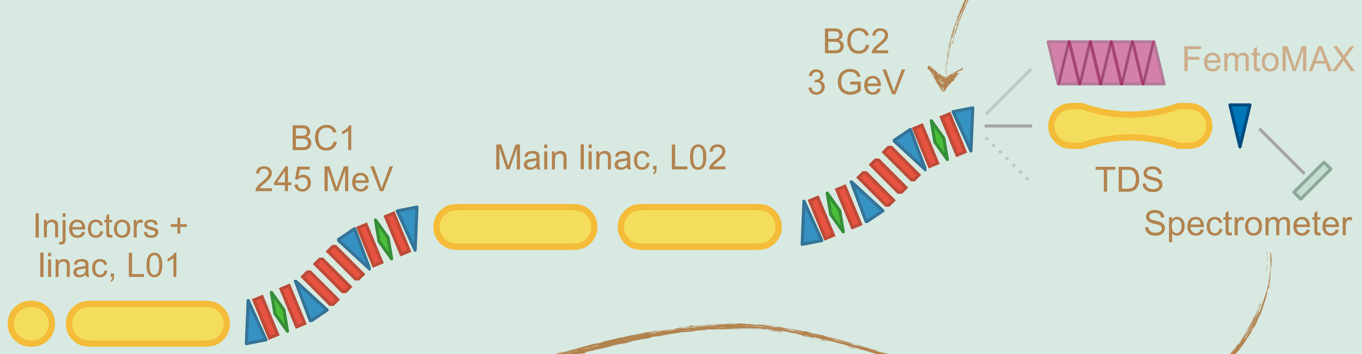
Linear accelerators often use *chicane* bunch compressors and higher-harmonic radio-frequency cavities to tune bunch current profiles. In this work, we demonstrate the generation of linearly ramped bunch current profiles using *arc-like* bunch compressors in the MAX IV linear accelerator by tuning the compressor sextupoles. Wakefield accelerators benefit from ramped bunch current profiles, which increase energy efficiency and minimize energy spread. Generating such current profiles with chicane compressors is possible but not trivial. These results suggest high suitability of arc-like bunch compressors for linacs supplying wakefield accelerators. This compression scheme can also passively mitigate bunch compression jitter by appropriately setting the sextupoles.

Bunch compressor types



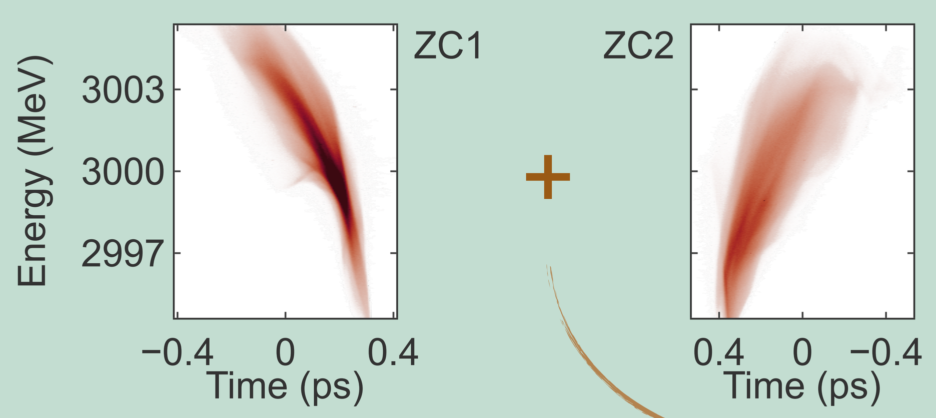
Schematics of different bunch compressor geometries. Chicanes are simple but longitudinal dispersions of different orders (R_{56}, T_{566}, …) are intrinsically linked. Arc-like compressors [1,2,3] are more complex, but do not require harmonic cavities and dispersions are independent.

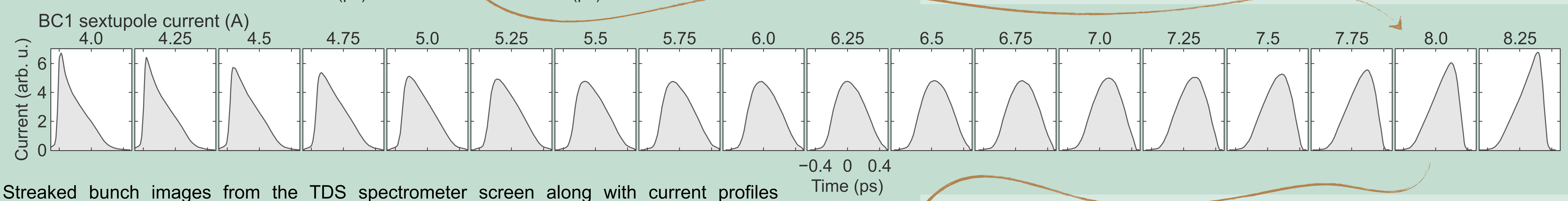
The MAX IV linac



Schematic of the MAX IV linac [4], including the diagnostics beamline with the transverse deflecting structure (TDS) and spectrometer where the bunch current measurements were performed.

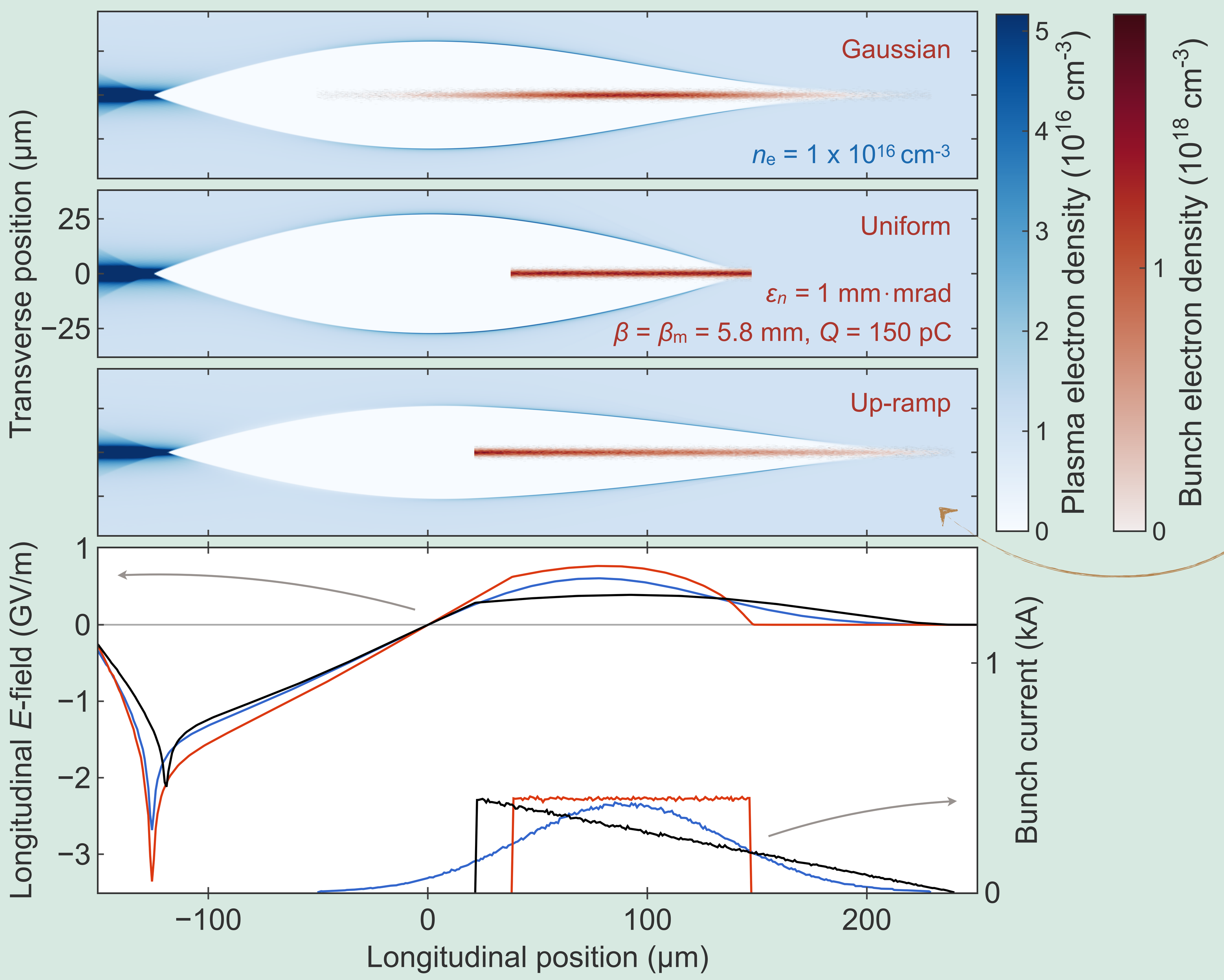
Measured bunch current profiles





Streaked bunch images from the TDS spectrometer screen along with current profiles reconstructed from measurements of a BC1 sextupole scan using the "two-point tomography" method [5]. The majority of the compression was done in BC1. A narrow range of sextupole strengths yielded a smooth transition from down-ramped to up-ramped bunch currents.

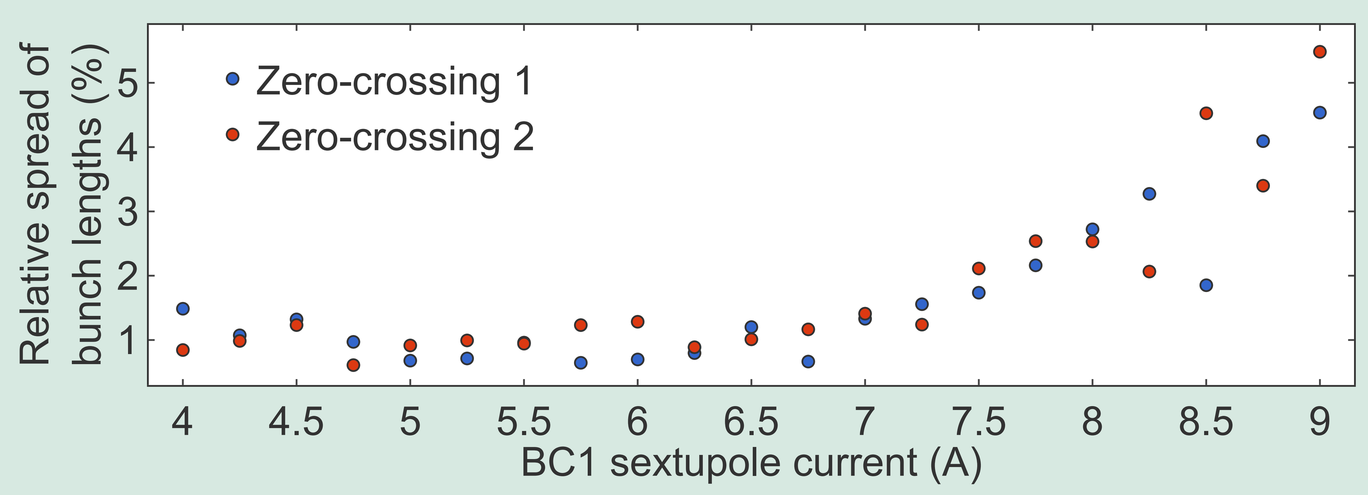
Application to PWFA



Wake-T [6] simulation snapshots. The plasmas are identical as are the bunches, apart from their current profiles (equal duration, 368 fs FWHM, like the 8.0-A setting above). The decelerating field along the up-ramped bunch is lowest and flattest, the accelerating fields are similar.

Bunch length stability

Unlike chicane-based systems [7], the phase sensitivity of the linear compression factor, $C_0 = 1/\left(1 + hR_{56}\right)$, in arc-like systems can be canceled. The proper choice of T_{566} changes R_{56}'s energy dependence by the reciprocal factor of the chirp, h. For a single RF accelerator + compressor system, the compression sensitivity is $\frac{1}{C_0}\frac{dC}{d\phi} = a\left(C_0 R_{56} k\cos(\phi) - 2(C_0 - 1)\frac{T_{566}}{R_{56}}\sin(\phi)\right)$, where k is the RF wave number.



Relative standard error of shot-to-shot bunch lengths as a function of sextupole current (T_{566}). For sextupole currents below 7 A, the measured bunch length jitter was constant and finite, determined by the full accelerator system and measurement precision.

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MAX IV