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Long-path-length experimental studies of longitudinal phenomena in intense beams

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Intense charged particle beams are nonneutral plasmas and they can support a host of plasma waves and instabilities. For a long beam bunch, the longitudinal physics can often be reasonably described by a 1-D cold-fluid model, with a geometry factor to account for the transverse effects. The plasma physics of such beams has been extensively studied theoretically and computationally for decades, but until recently, the only experimental measurements were carried out on relatively short linacs. This work reviews experimental studies over the past 5 years on the U. Maryland Electron Ring, investigating longitudinal phenomena, for the first time, over time scales of hundreds and thousands of plasma periods. These results are in good agreement with theory and simulation. Topics that will be discussed are:

- Longitudinal confinement of a long bunch using barrier fields [1].
- The generation of space charge waves from barrier field mismatches, their propagation along the bunch and reflection at the beam ends, as well as their long-term dissipation [1].
- The characterization of solitary waves from density/velocity perturbations in the center of the bunch [2-3].
- Compression of solitary wave trains with velocity "tilts" (head-to-tail gradient).
- Observation of a multi-stream instability driven by the longitudinal merging of bunches and the characterization of the onset of the instability with a PIC code [4].
- The shock-wave compression of a bunch using rapidly-moving barrier fields [5].

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[5] B.L. Beaudoin, *et al., "Barrier Shock Compression with Longitudinal Space-Charge,"* Proc. 2015 IPAC, to appear (2015).