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Absolute measurement of electron cloud density in positively-charged particle beam

Clouds of stray electrons are ubiquitous in particle accelerators and frequently limit the performance of storage rings. Earlier measurements of the electron energy distribution and flux to the walls provided only a relative electron cloud density. We have made the first detailed absolute and time-dependent measurements of electron cloud densities in a positively charged beam. We measured electron accumulation from the energy of ions expelled by the beam, using a retarding field analyzer (RFA). The peak ion energy varies in time with the electron-depressed beam potential. From this and the radial profile of electrons, we compute the cloud density. Clearing electrode currents reveal the static background cloud density and corroborate RFA measurements of the dynamic electron cloud density, allowing the first absolute measurement of the time dependent electron cloud density during the beam pulse. Results from these two techniques are summarized in the table, which is color-coded to Fig. 1. These results were published in Phys. Rev. Letters (2006). Future experiments will exploit these techniques, in conjunction with phase space measurements, to quantify the degradation of the beam with increasing electron density, and compare with simulations.

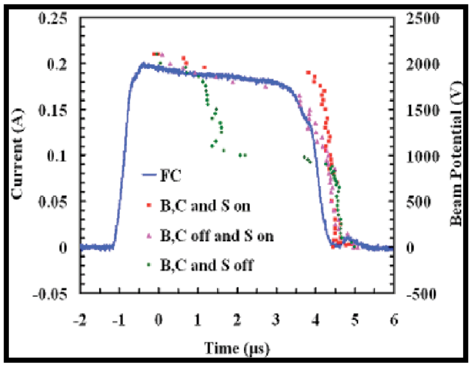

Figure 1. Dynamic beam potential for 3 electron densities.

Beam Neutralization	B, C, & S on	B, C off S on	B, C, S off
Clear. Electr. A	~ 7%	~ 25%	~ 89%
RFA	(~ 7%)	~ 27%	~ 79%

– Michel KireeffCovo

Simultaneous transverse and longitudinal neutralized focusing

The primary challenge in using heavy-ion beams to heat targets to warm dense matter (WDM) conditions is to achieve a high power density by simultaneously compressing the pulse duration to less than the target disassembly time and focusing the beam to a small spot size. Previously, each of these has been demonstrated individually by means of a neutralizing plasma background to prevent space-charge forces from limiting the compression and focusing.

For new simultaneous focusing, Fig. 1, the compressed beam pulse has a peak current of ≈1.9 A, implying a compression ratio (or current amplification) of ≈ 50. The FWHM is 4 ns. The red blocks of Fig. 1 denote the image intensified CCD gate widths and gate delays that were used to measure the transverse beam distributions from the alumina scintillator located at the same axial location as the fast faraday cup. At the time of the peak compression (5.12 µs), the gate width was 10 ns. For the "early" and "late" images the gate width was increased to 100 ns to compensate for the reduced beam intensity and keep a satisfactory signal-to-noise ratio.

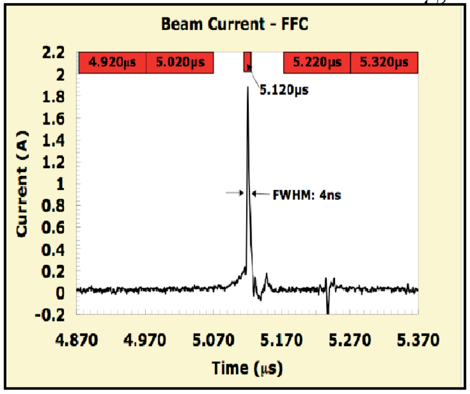

Figure 1: Beam current at the focal plane measured with the fast Faraday cup shows a compressed current pulse with FWHM = 4 ns.

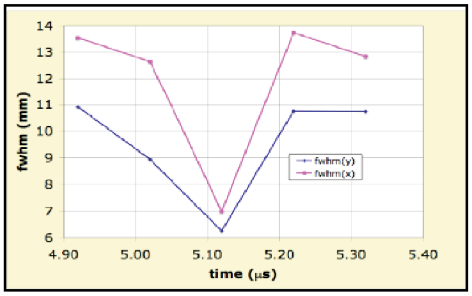

Figure 2: The radial spot size (FWHM) in the vertical and horizontal direction for diagnostic gate times in Fig. 2.

The reduction in the spot size by a factor of 2 for the compressed pulse is shown in Fig. 2, where the horizontal and radial profile widths (FWHM) have been extracted from the scintillator images. Low-intensity tails of the spatial profile that extend to relatively large radii limit the spot size.

The observed 2X reduction in the spot size corresponds to a 4X increase in beam intensity, and brings the peak beam density to the range ~10^{11} cm^{-3}. The experiments and PIC modeling are continuing. Higher Solenoidal fields are predicted to reduce the spot size further.

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