Virtual National Laboratory for Heavy Ion Fusion

April 2003

HIF News

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Two new diagnostics for absolute beam energy measurements on HCX

The High Current Experiment (HCX) at LBNL is primarily designed to study the transport of high current beams at the low energy end of a Heavy Ion Fusion (HIF) driver. Two new diagnostics, an electrostatic Energy Analyzer (EA) and a Time of Flight pulser (TOF) were installed to more precisely determine the beam energy and to make longitudinal phase-space measurements.

The EA, a 90° spectrometer with a radius of 46 cm, and a gap of 2.5 cm was operated up to ΔV = 110 kV. The relative accuracy is ± 0.2%, allowing us to follow variations in the beam energy as a function of time during the beam pulse. The EA calibration depends on the geometry and fringe fields of the analyzer. By changing the beam energy by a known absolute amount, we provide an independent calibration. The beam passed through a 28%-transparent hole-plate, and the gas cloud created at the hole-plate stripped singly-charged K^+ beam ions to doubly-charged K^{2+}. The absolute calibration was determined by varying the electric potential at the plate, and thus the energy of the K^{2+} ions entering the EA.

TOF measurements were made by inducing short-duration (0.3 μs FWHM), small-amplitude (~10 keV) energy perturbations in the matching section using a specially designed fast pulser. These energy pulses were manifest as current perturbations measured ~5 m downstream. Figure 1 shows a close-up of the beam current waveform measured downstream along with a theoretical calculation of the expected perturbation based on a 1-D cold-fluid model. Comparing the measured and expected delay time of the perturbation determines the absolute energy of the beam.

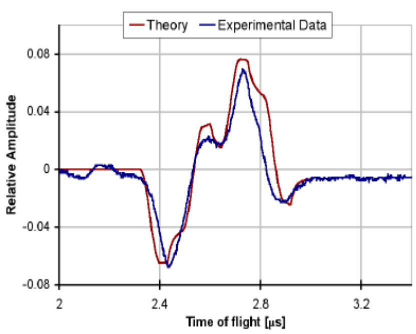

Figure 1 – Cold fluid model vs TOF perturbation on the beam current waveform. Perturbation applied @ t = 0.

Both the TOF and EA diagnostics determine the absolute beam energy to ±2%, with both measurements agreeing within these uncertainties (Figure 2). The precise determination of the energy is essential for agreement between simulations and experimental data.

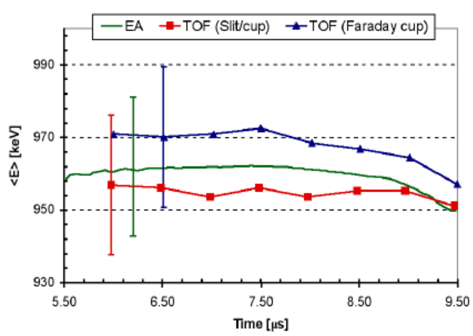

Figure 2 – TOF and EA measurements comparison. The error bars represent the systematic error (± 2%).

Figure 3 shows the longitudinal energy distribution obtained with the EA. The high-energy head and low-energy tail are understood to be from the beam longitudinal space charge, which accelerates particles at the front end of the bunch and decelerates particles at the rear of the pulse. These data also show that in the middle of the pulse, the mean beam energy is constant to within 0.5% for 3.1 μs.

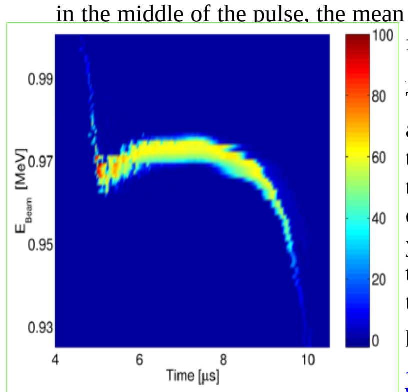

Figure 3 – Longitudinal Energy Distribution measured with the electrostatic energy analyzer.

This information (particularly the head and tail energy variations with respect to the core of the beam pulse) will be used to help complete the design of a bunch end control module to be installed next year in between the matching section and the periodic transport lattice; a first step towards conducting more longitudinal physics experiments. *- L. Prost, F. Bieniosek, A. Faltens, P. Seidl, W. Waldron*

Study of mismatch oscillations in beam envelope

Mismatch oscillations, in the envelope of beam particles, play a role in transport limits by generating halo. This induces beam loss, resulting in gas desorption and secondary electron production, so understanding mismatch oscillations are important in the transport of intense ion beams. We performed an extensive analytical and numerical study on the transverse envelope oscillations of intense ion beams in continuous focusing, periodic solenoidal, and periodic quadrupole transport channels. This study significantly extends earlier work by Struckmeier and Reiser [Part. Accel. 14, 227 (1984)] and is being submitted for publication. We map regions of parametric instability, find new classes of envelope instabilities, explore parametric sensitivities, describe launching conditions for pure normal mode oscillations, and calculate analytically accessible limits. We also analyze driving sources of mismatch oscillations resulting from focusing errors, particle loss, and beam emittance growth. The figure shows bands of parametric instability for breathing and elliptical envelope distortions for a periodic solenoidal focusing lattice with solenoids filling 75% of the lattice. If higher order instabilities can also be suppressed, broad parameter regions with σ_0> 90° outside of the envelope instability bands can be exploited to allow transport of higher current density beams.

- Steven M. Lund and Boris Bukh

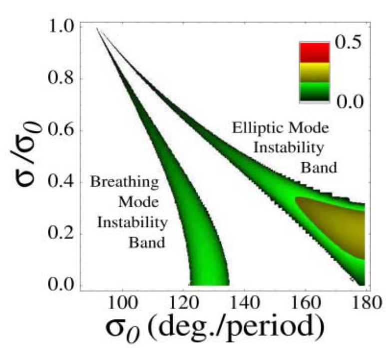

Figure 1 – Contours of the log of the growth in envelope oscillation amplitude per lattice period for periodic solenoid focusing as a function of the single particle phase advance σ_0 and the space-charge depression σ/σ_0.

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