Longitudinal Physics

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Longitudinal Space-Charge in a Ring

Changes in line-charge density induce axial electric fields at the edges of the beam:

\[ E_z \propto -\frac{d\lambda}{dz} \]

\( \sim 100 \text{ turns} \)

0.6 mA beam

\( \eta = 0.5 \)

Initially injected 100 ns long bunch elongates as the beam propagates over multiple turns.
Observation of a Multi-stream instability

No longitudinal focusing – Beam expands and wraps around ring

Experimental

6 mA beam
\[ \eta = 0.5 \]

Beam becomes “DC”

Onset of instability
\[ t_{onset} = 16.5 \, \mu s \]

Phase Space
\[ \frac{c_s}{v_o} = 0.013 \]

Comparison between Theory, Simulation and Experiment

\[ t_{onset} = \frac{C}{4c_s} \left( \frac{2}{\eta} - \eta \right) \]

\( \eta = \text{fill factor} = \text{injected pulse length / ring lap-time} \)

Onset of Instability

\[ c_s = \left( \frac{q g \Lambda_0}{4 \pi \varepsilon_0 \gamma_0^5 m} \right)^{1/2} \]
Periodically Applied Non-Linear Containment Fields

Induction cavity allows us to apply voltage waveforms with high harmonic content. Revolution frequency of 5.066 MHz.
Containment of Long Bunches

Minimization of waves
1.013 MHz, 60 v

Overcorrecting Inducing Multiple waves
1.013 MHz, 130 v