2011 Particle Accelerator Conference, New York

Space-Charge Effects in Bunched and Debunched Beams

Monday-MOODS1

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Outline

1. The University of Maryland Electron Ring (UMER)

2. Longitudinal expansion as a result of space-charge

3. Using induction focusing to apply pulsed waveforms, keeping a long beam bunched

4. Diagnostic method that uses induced space-charge waves in bunched beams to predict beam size

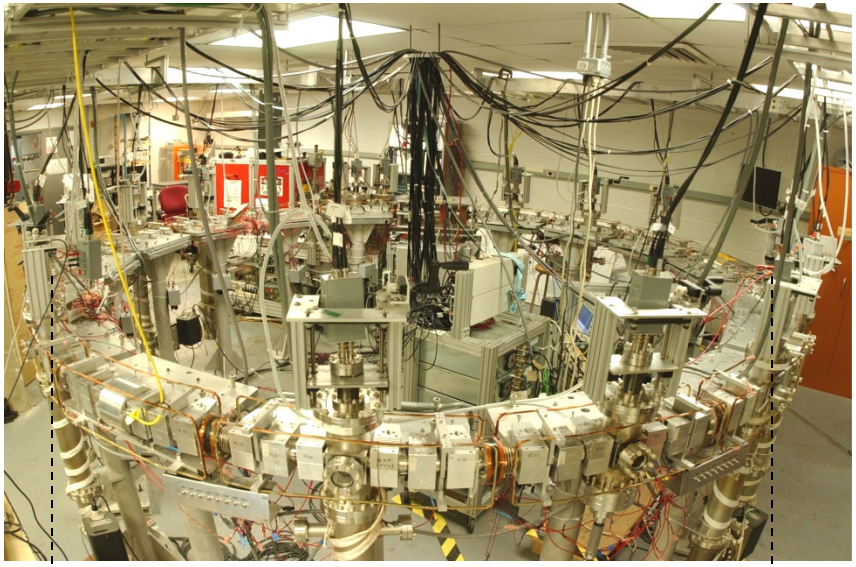
Motivation

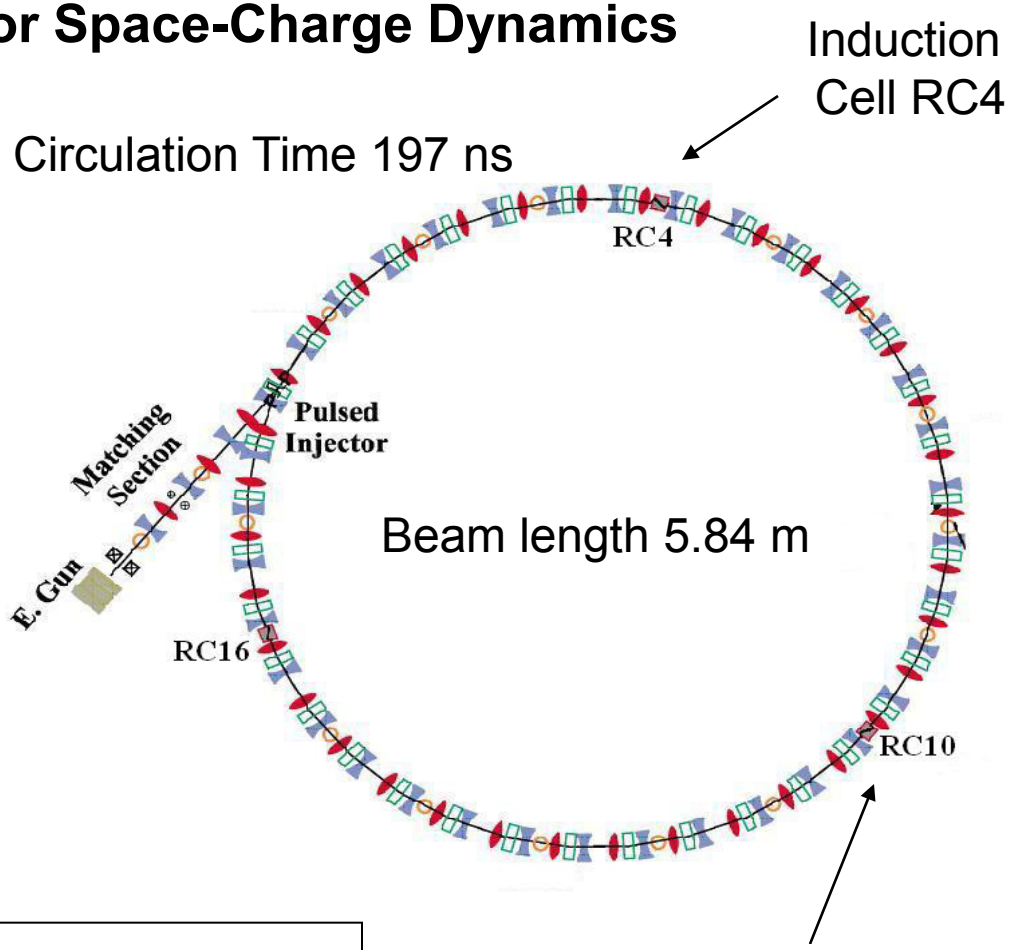
- Goal: Understanding extreme space-charge in a ring over long propagation lengths (tune shifts > ½)

- Approach: Development longitudinal bunch-end only longitudinal focusing system to maintain bunch shape
  - Implemented on the University of Maryland Electron Ring, a research machine for space-charge physics

University of Maryland Electron Ring

Research Machine for Space-Charge Dynamics

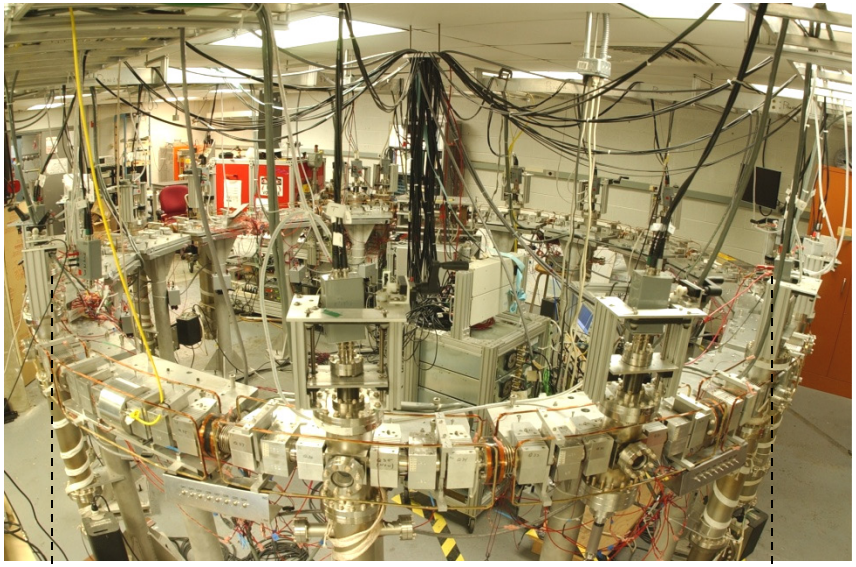


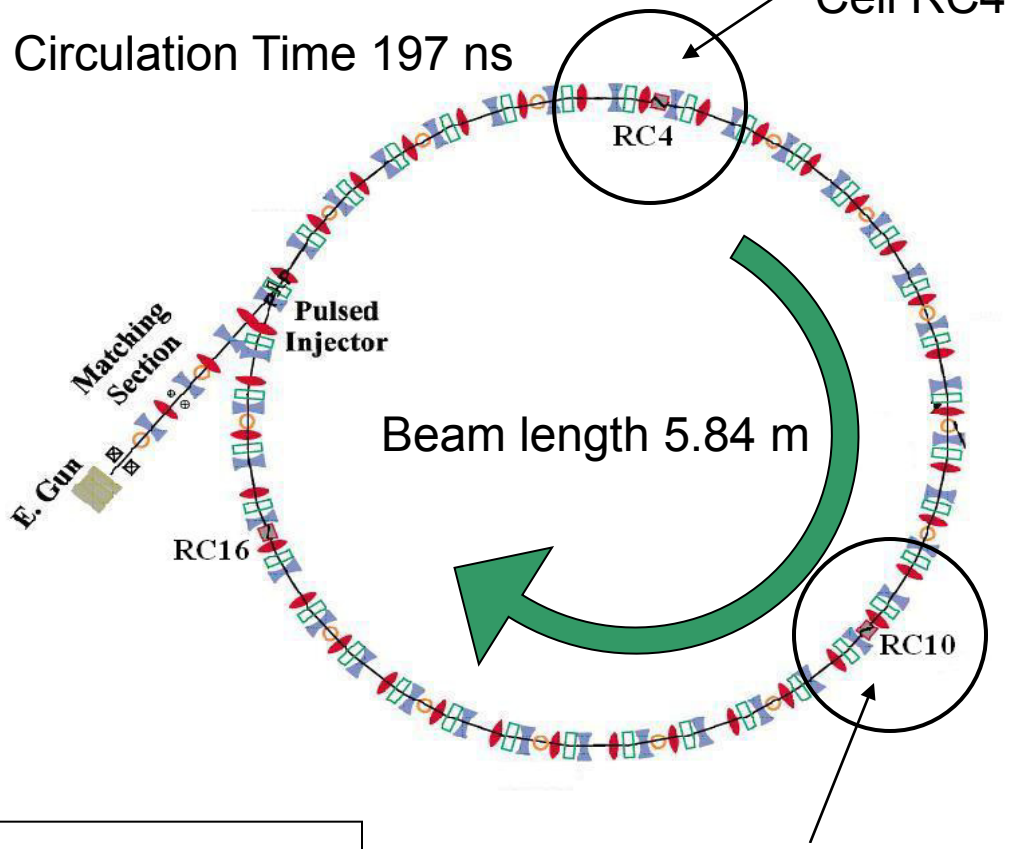


Beam Current: 0.6 – 100 mA
ν/ν_o = 0.84 – 0.17, $\Delta\nu$ = 1.0-6.4
Beam Energy: 10 keV

University of Maryland Electron Ring

Research Machine for Space-Charge Dynamics





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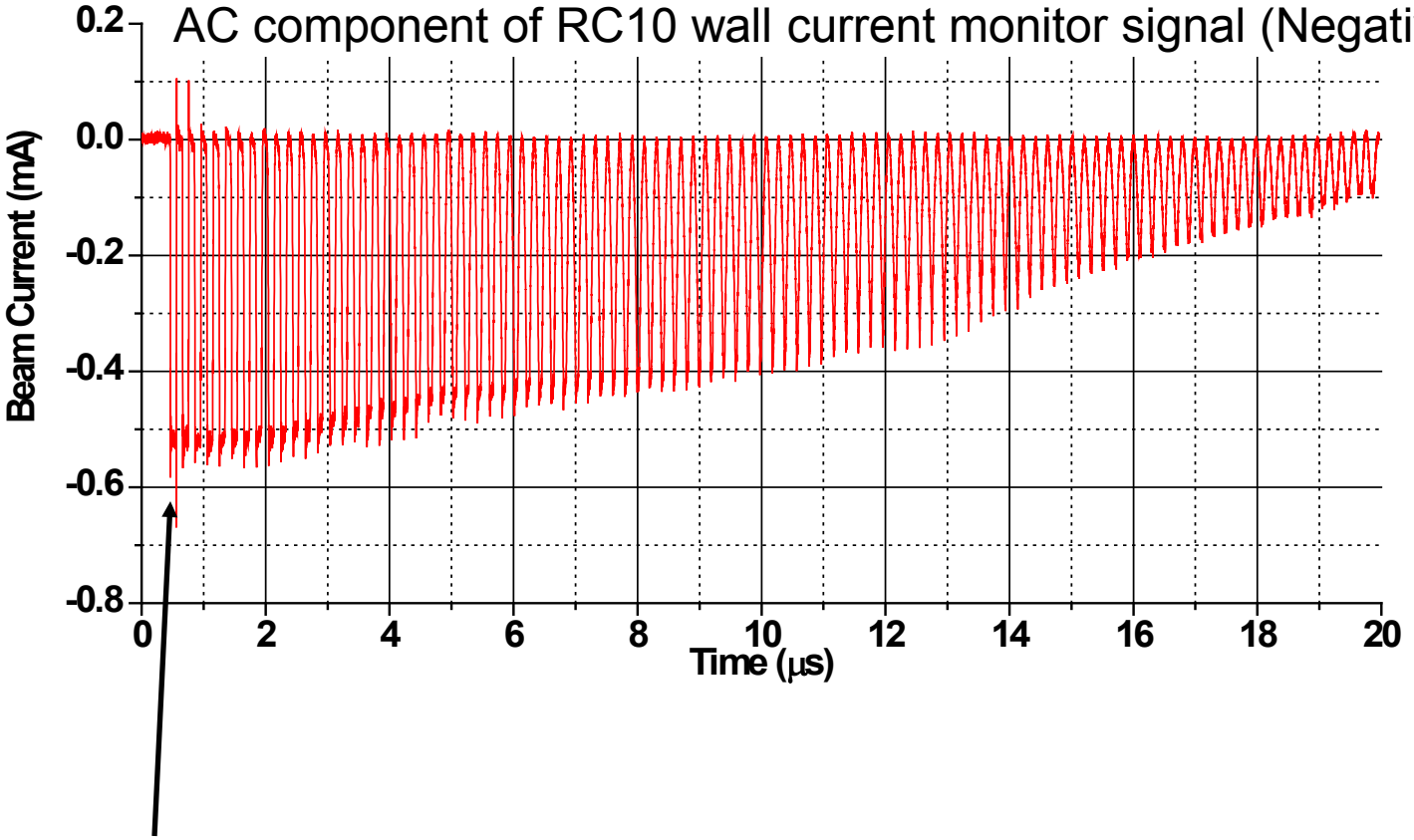
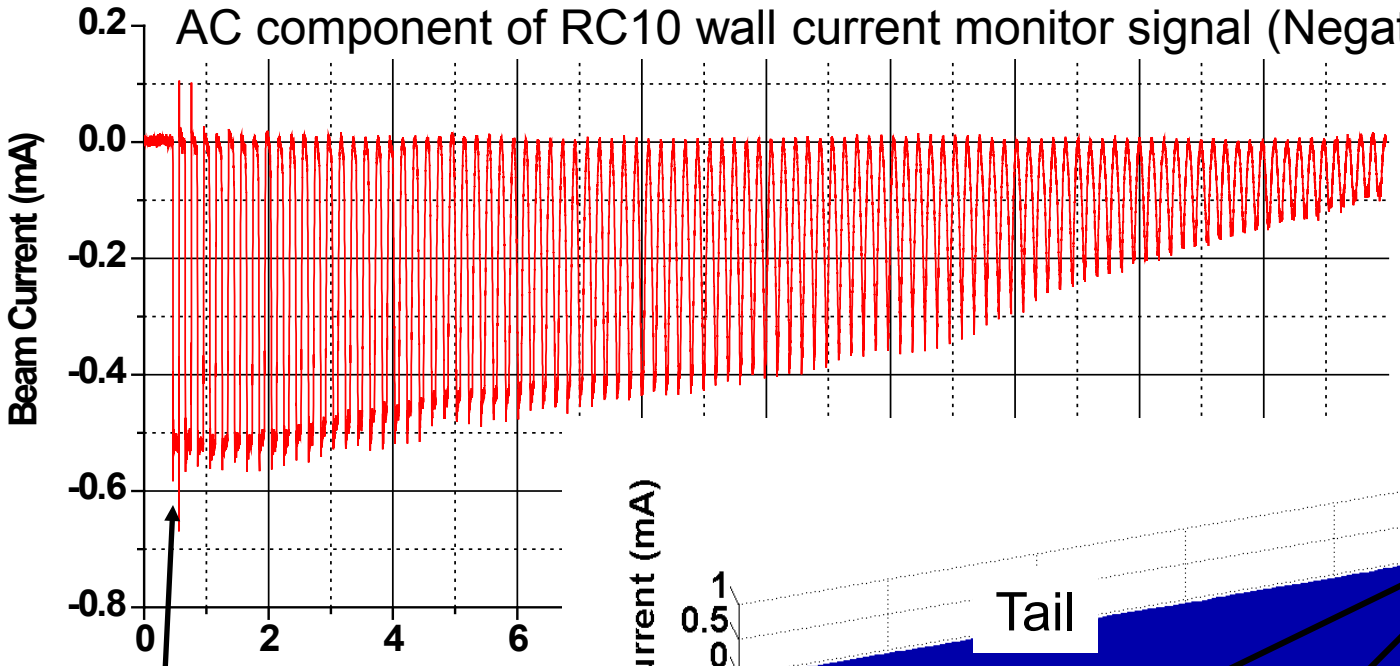
Longitudinal Space-Charge Forces Erodes Bunch Length



$$C_s = \sqrt{\frac{qg\lambda}{4\pi\varepsilon_o\gamma_o^5 m}}$$

Injected Turn
0.52 mA

Longitudinal Space-Charge Forces Erodes Bunch Length



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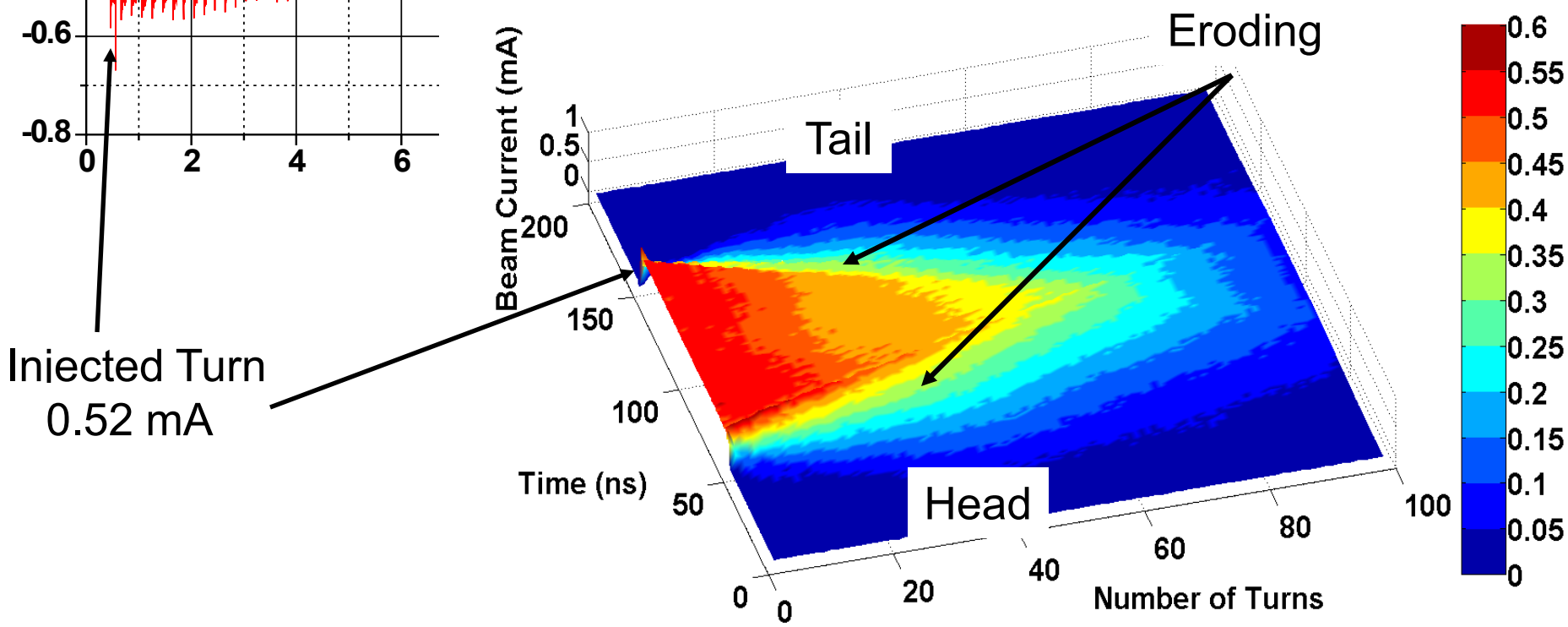
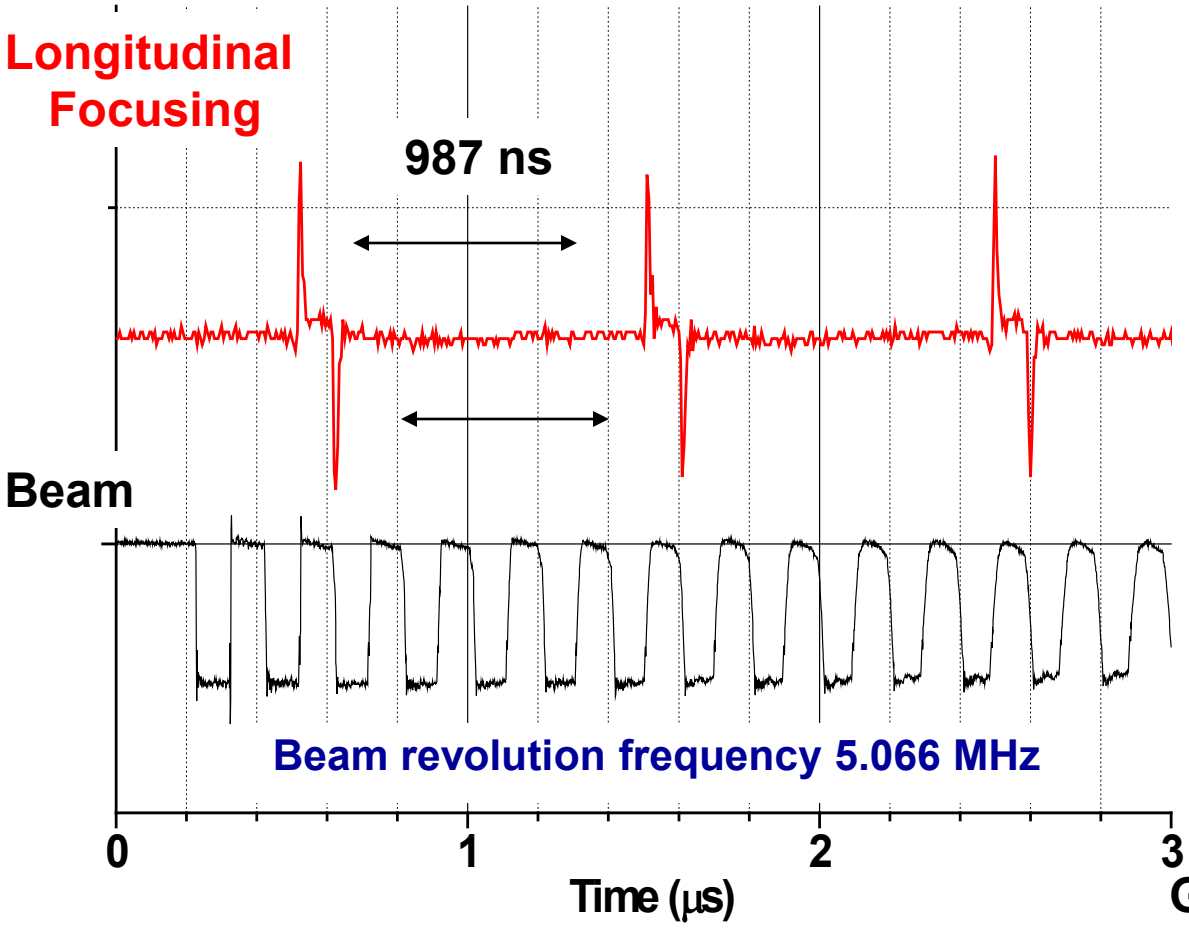
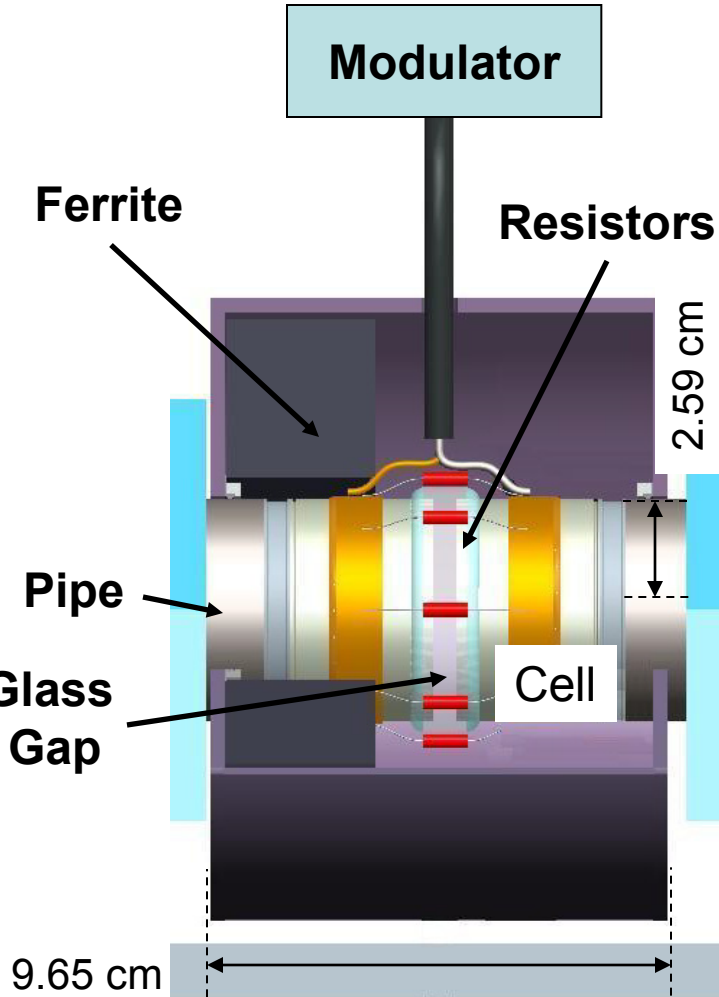


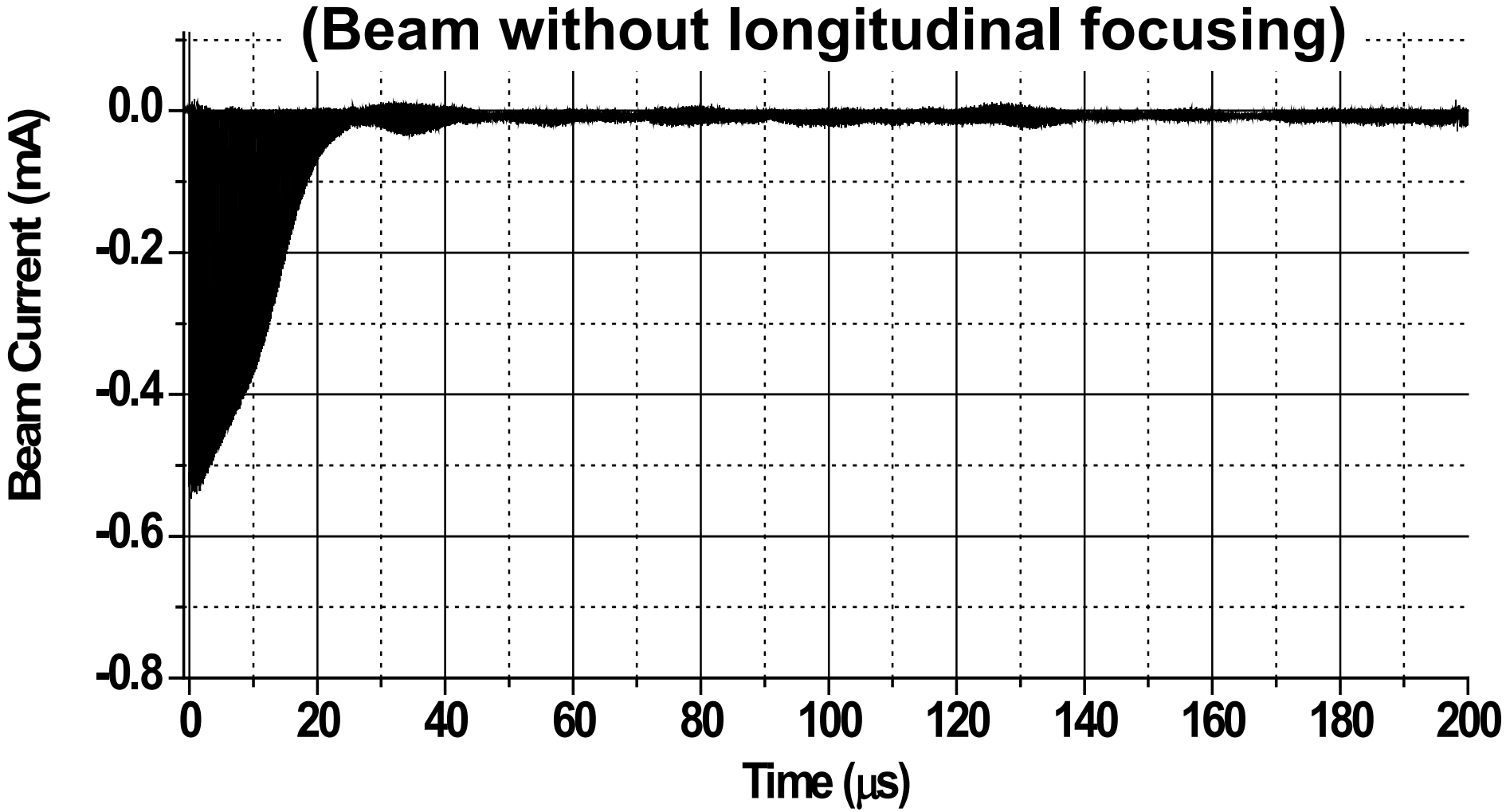
Longitudinal Containment using an Induction Cell



Ferrite Material (CMD 5005)
Maximum Volt-seconds
0.36 mV-s

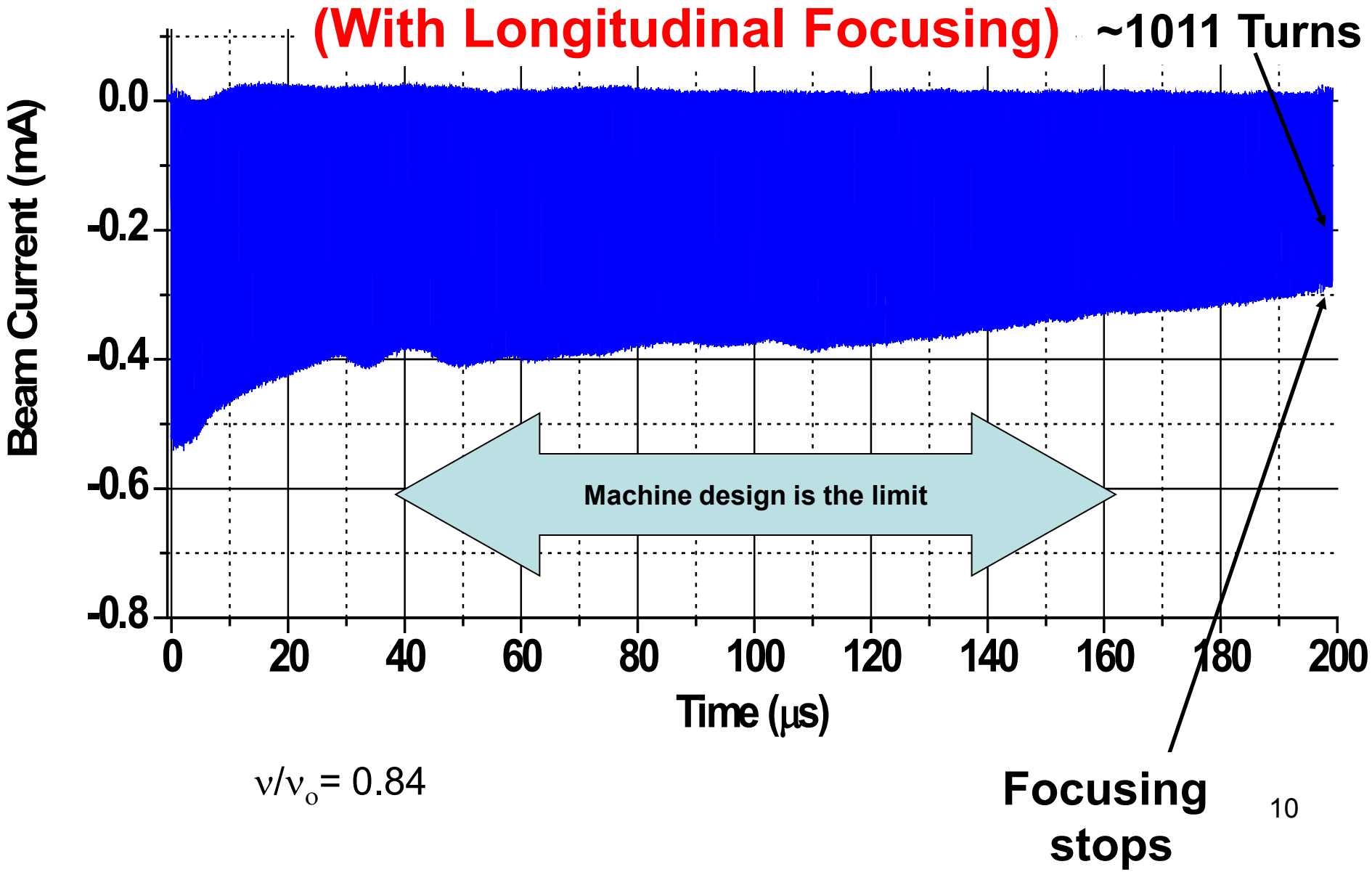


Bunch Shape Erodes as a Result of Longitudinal Space-Charge Forces



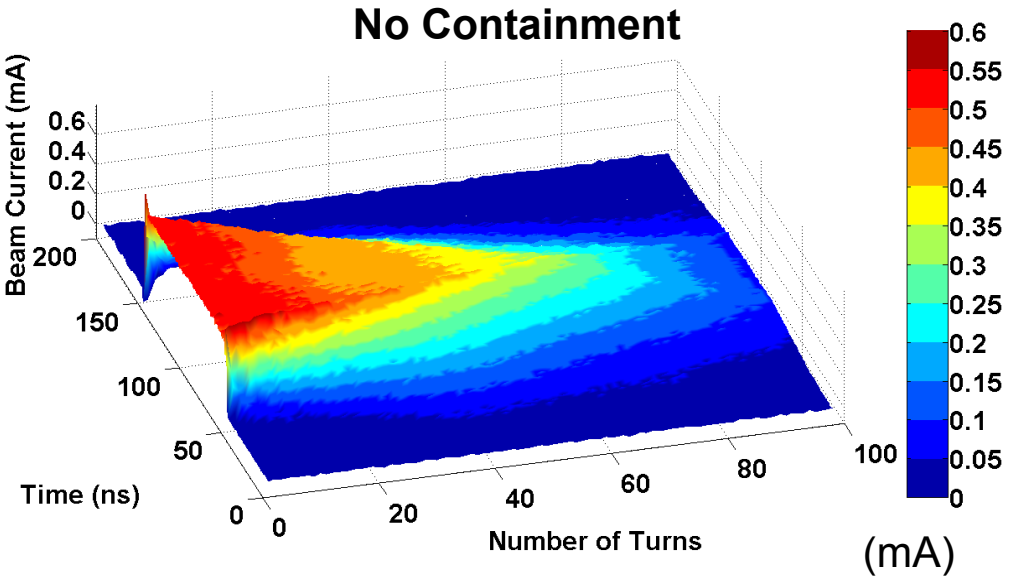
$\nu/\nu_o = 0.84$

Bunch Lifetime is Extended with Longitudinal Control



$\nu/\nu_o = 0.84$

Variation of Focusing Gradient and Frequency on Bunch Charge



(mA)

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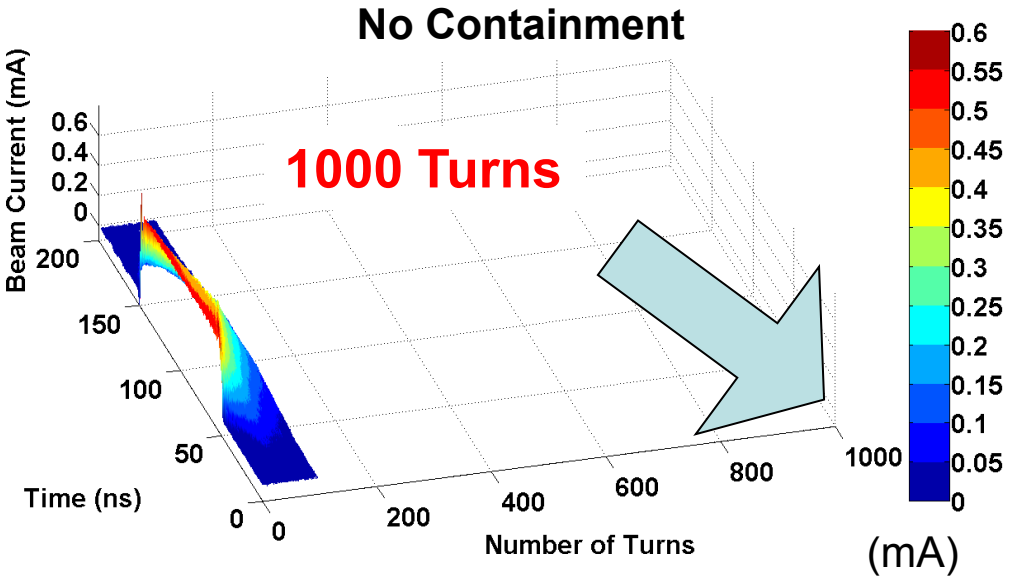

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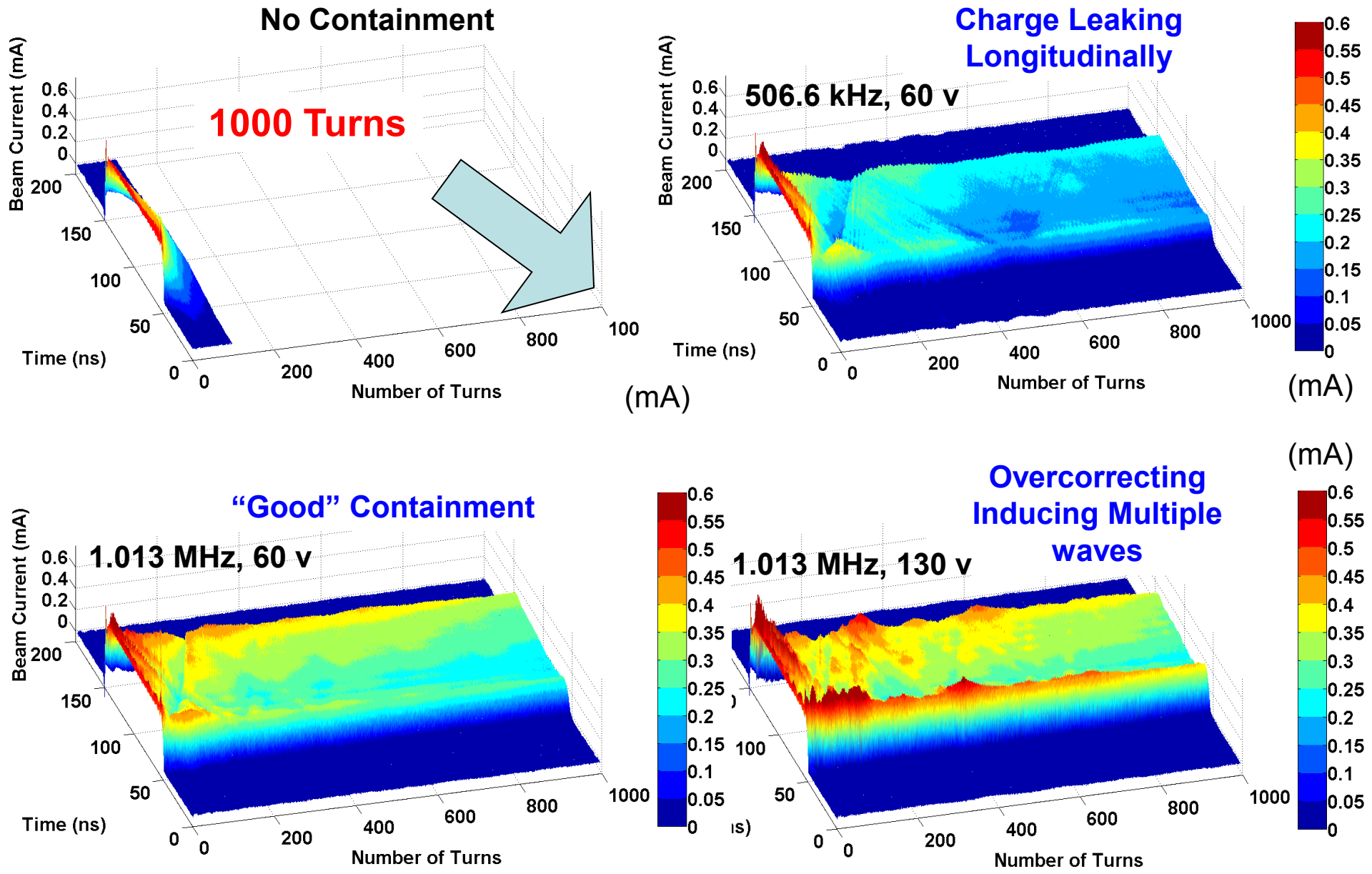
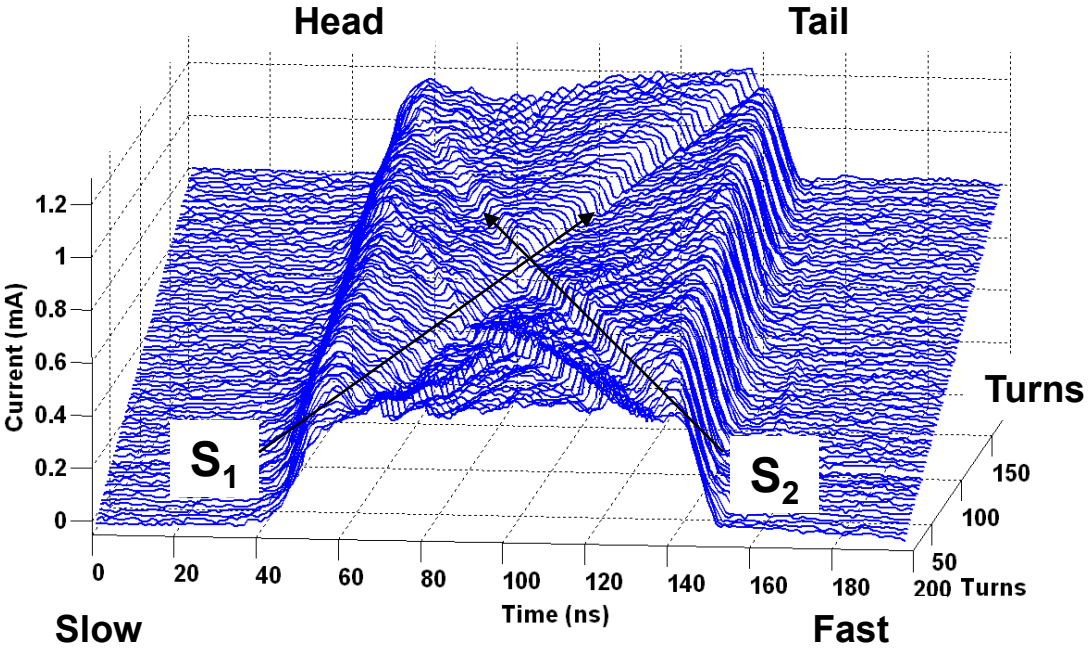


Discrepancy between Simple Calculations and Measurements to Predict Transverse Growth



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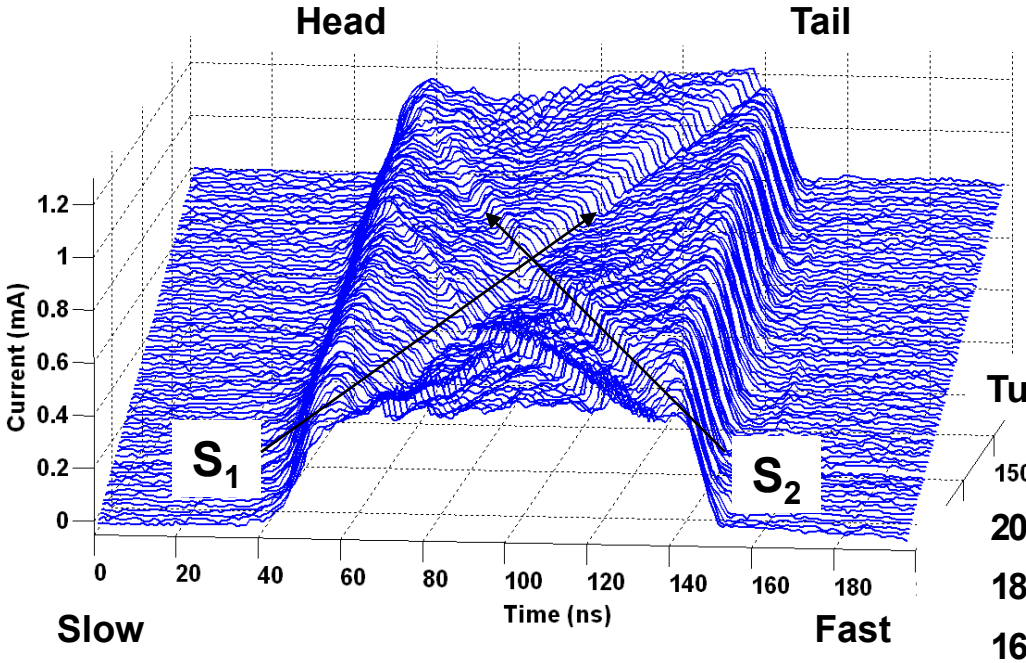

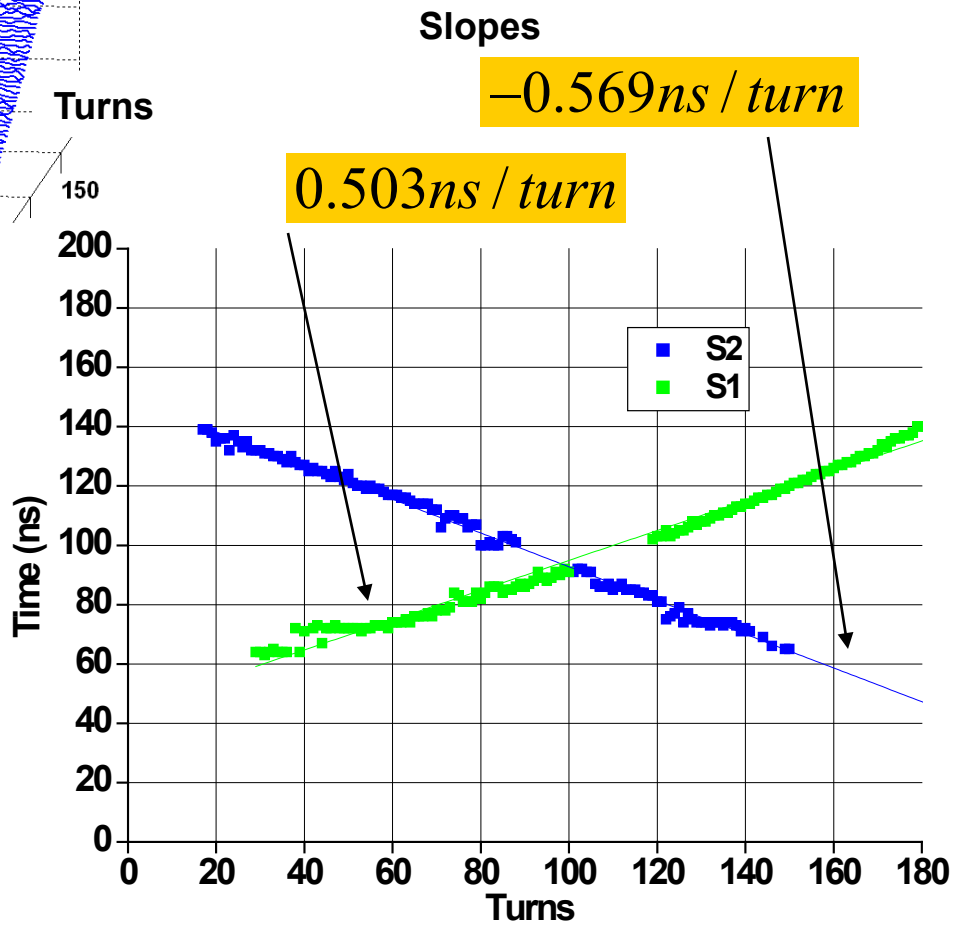

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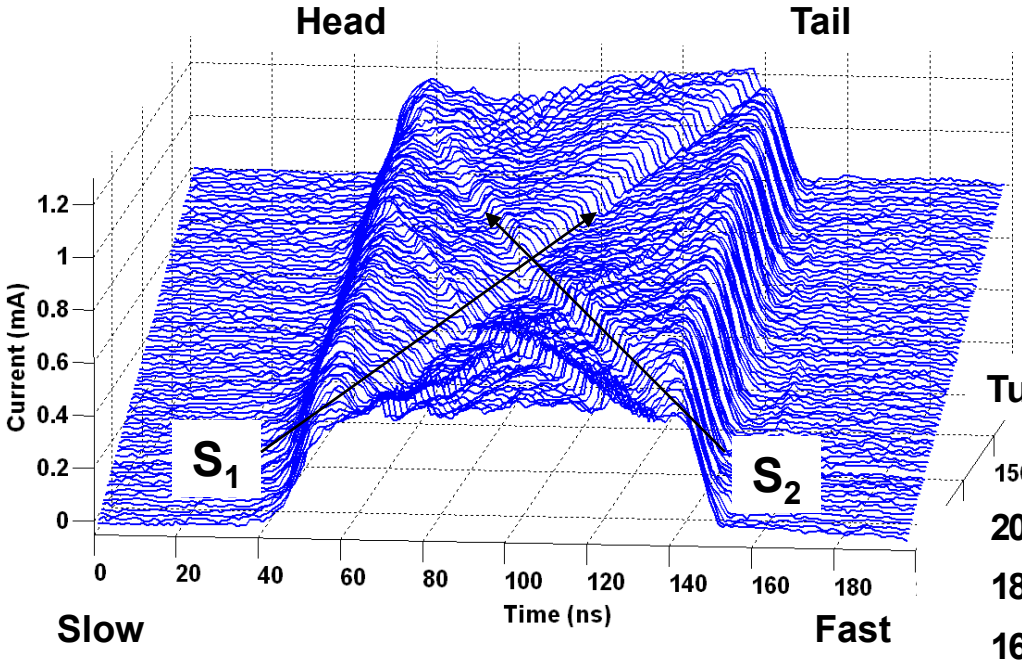
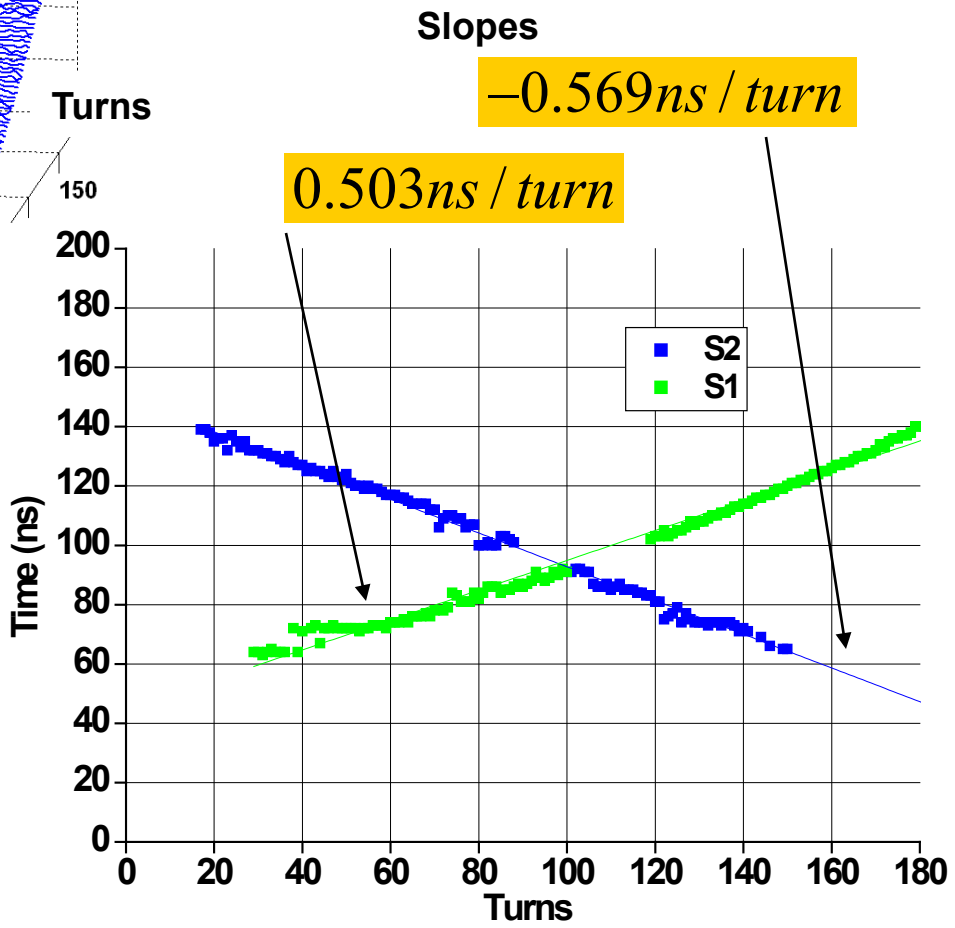


$$a = \frac{b}{e^{\frac{2C_s^2 \pi \varepsilon_o \gamma_o^5 m}{q\lambda_o}} e^{-\frac{1}{4}}}$$

$$C_s = slope \times \frac{v_o^2}{11.52}$$



	Sound Speed ($1x10^5$ m/s)	Beam Size (mm)
Analytical	2.52	1.56
$S_{1\text{-measured}}$	1.49	11.31
$S_{2\text{-measured}}$	1.68	8.44

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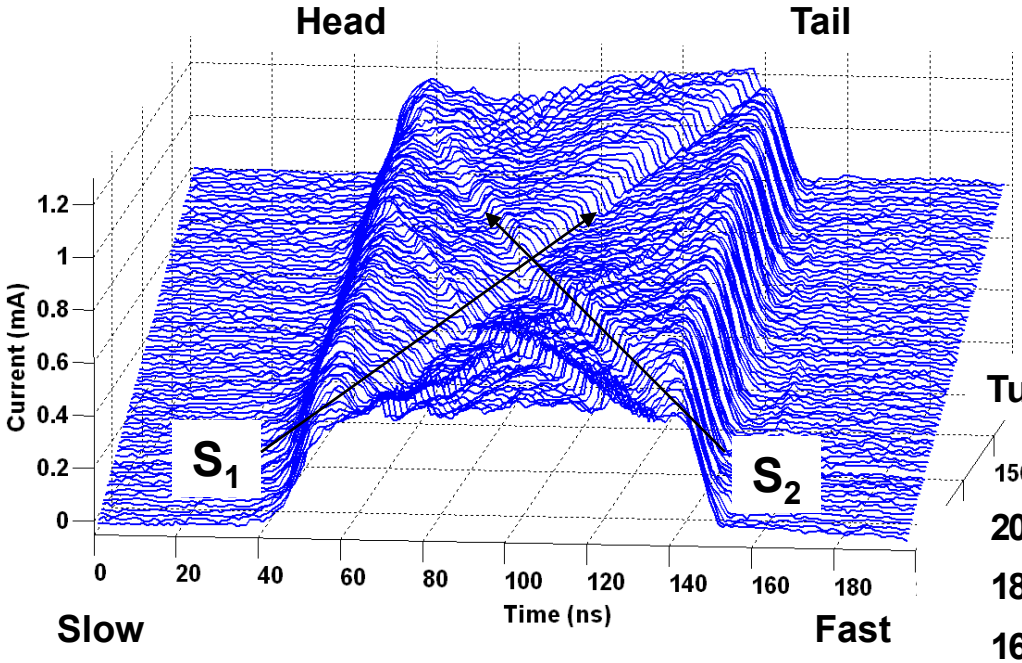

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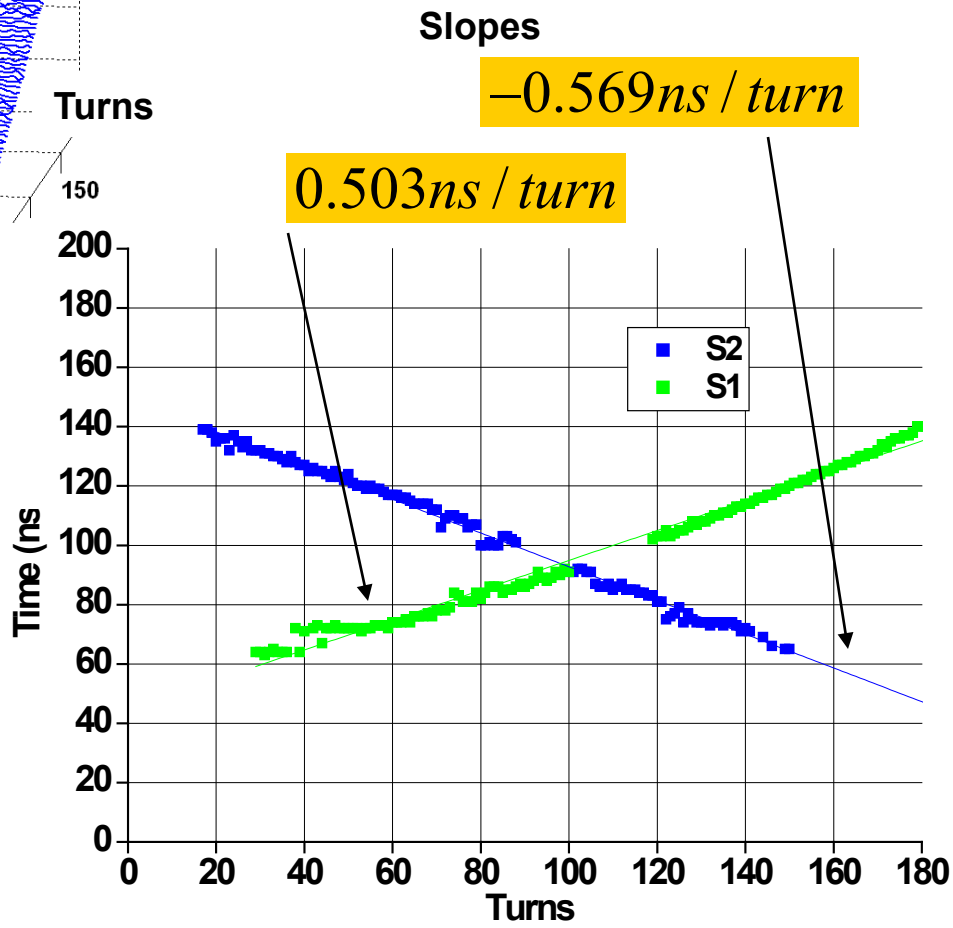

A factor of (5.4-7.2) growth in beam size

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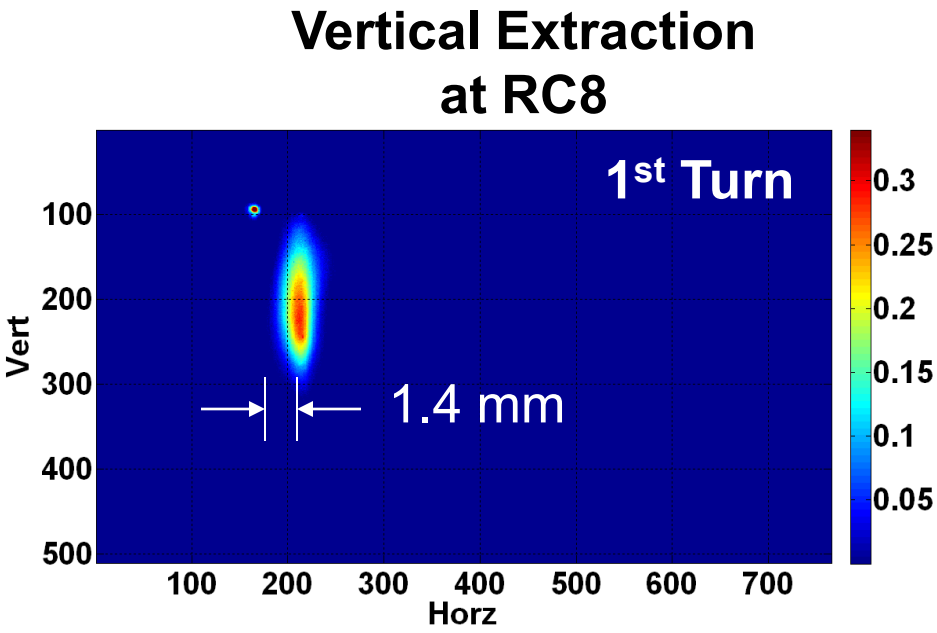
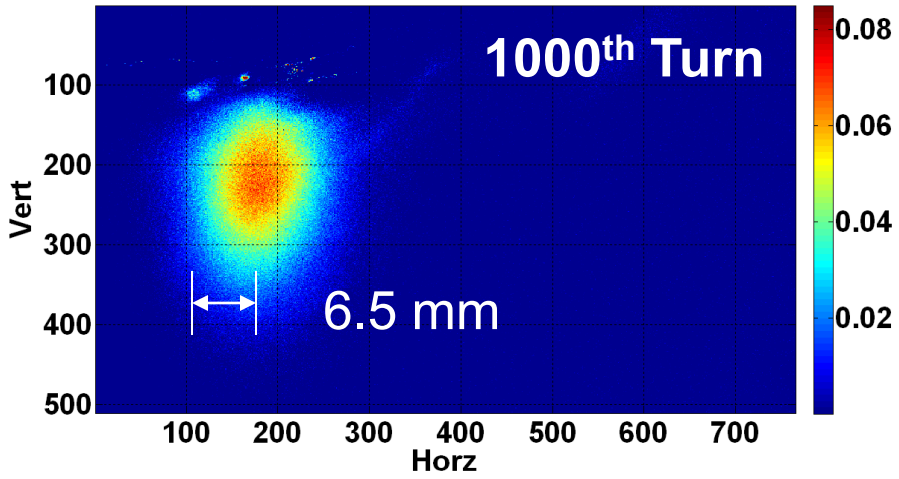
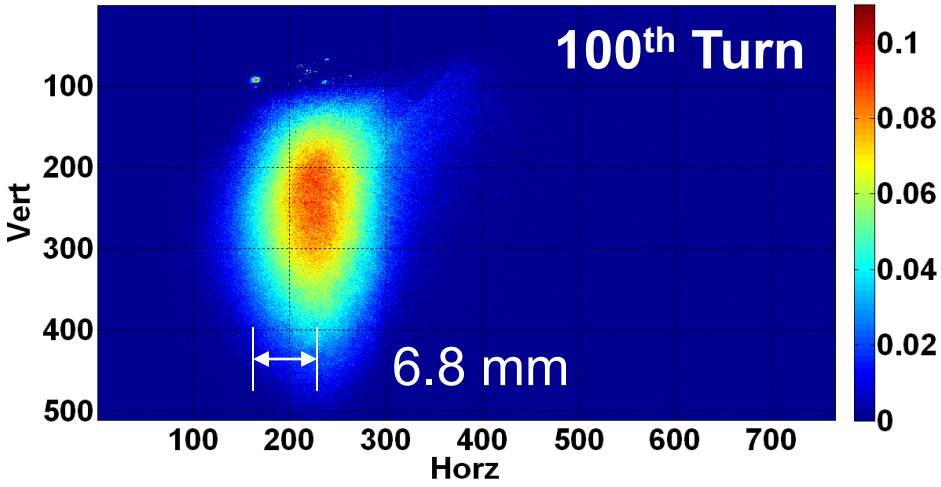
Measurements Predicted a Transverse Growth

Preliminary







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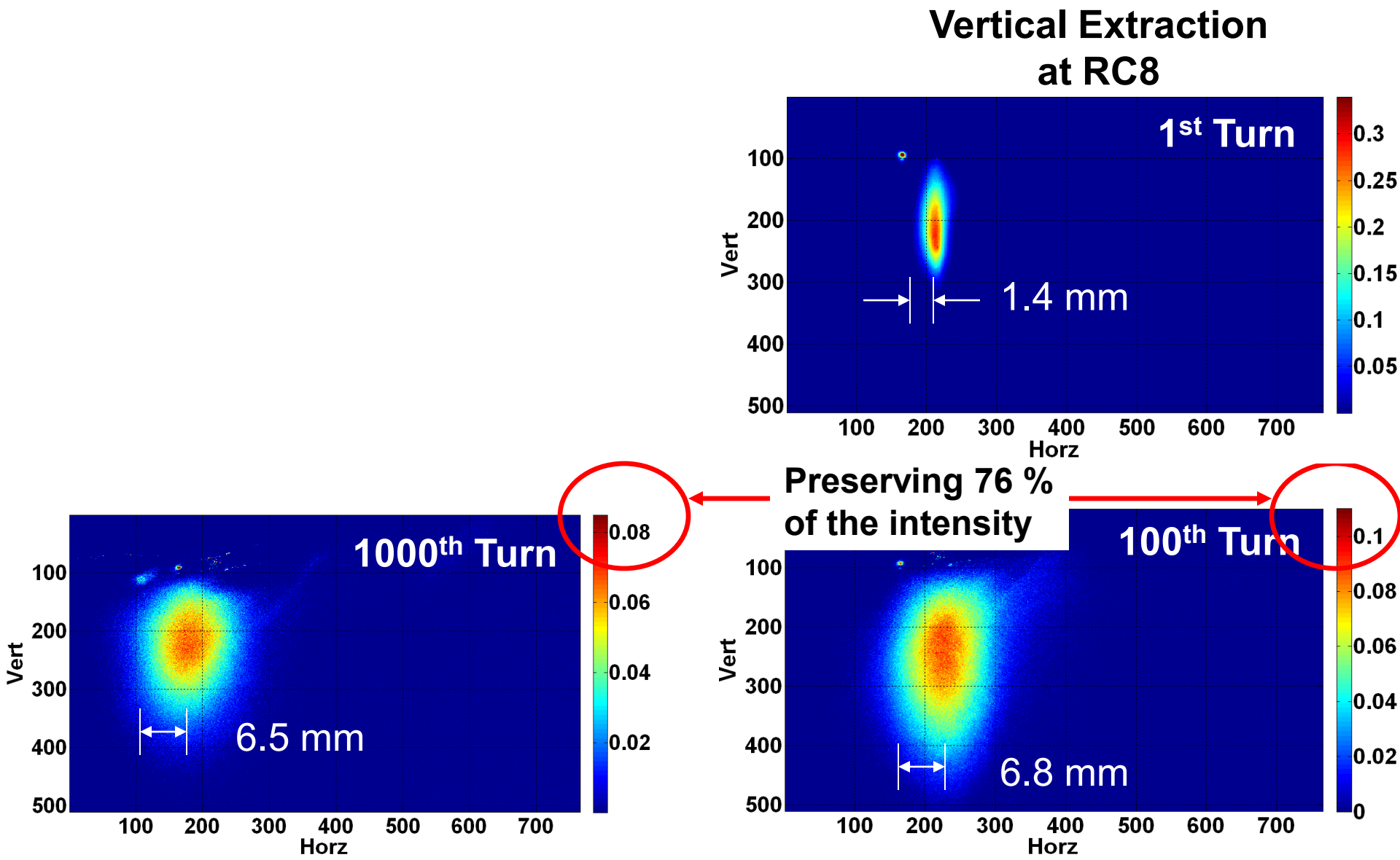

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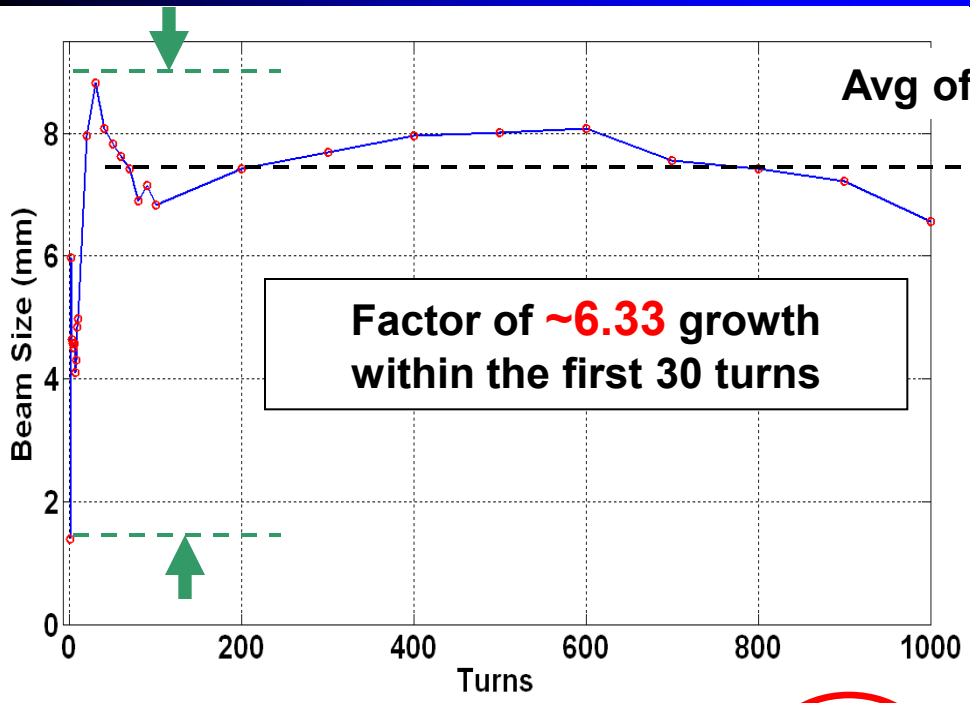
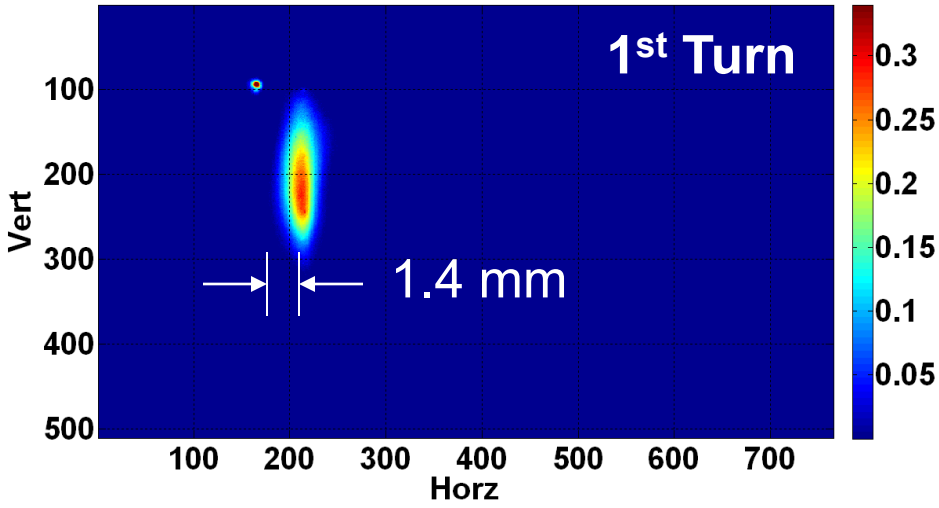
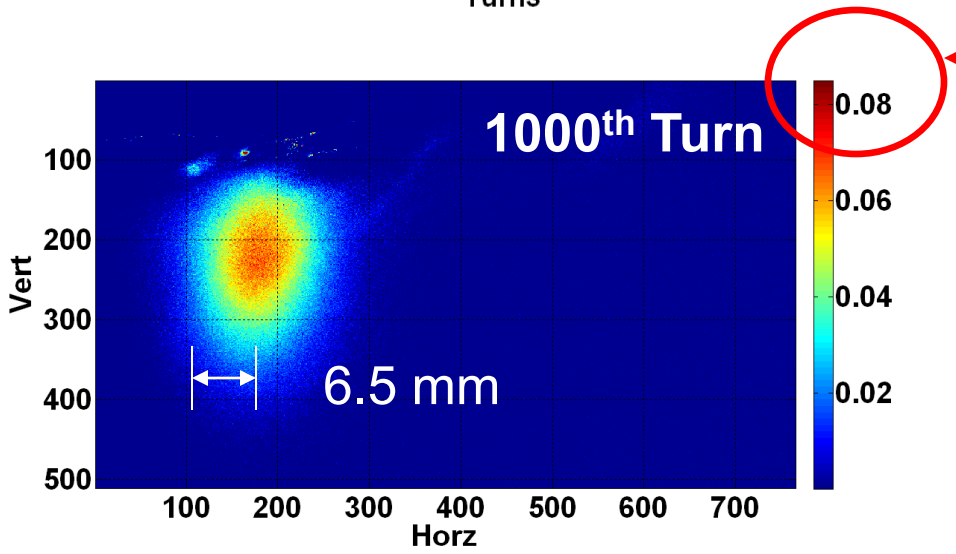
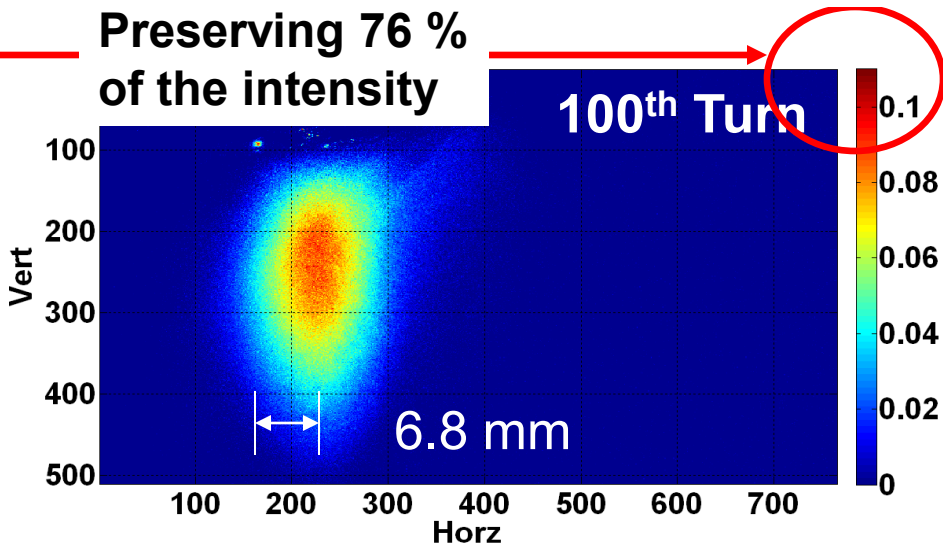


Vertical Extraction at RC8



Preserving 76 % of the intensity





Summary and Concluding Remarks

- Using Induction focusing, we have succeeded in maintaining the bunch shape as well as transporting a beam with an injected tune shift of 1.0
- The longitudinal bunch dynamics are dependent on the focusing gradient and application frequency
- We observe space-charge waves when the longitudinal focusing is too strong
- Currently under investigation: Mechanisms for beam size growth and operating point dependence