High Intensity Beam Physics at the University of Maryland Electron Ring

46th ICFA Advanced Beam Dynamics Workshop on High-Intensity and High-Brightness Hadron Beams

Sept 27-Oct 1, 2010

Institute for Research in Electronics and Applied Physics

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Acknowledge: S. Bernal, T. Koeth, R. Kishek, I. Haber, D. Sutter, P. O'Shea and M. Reiser

Revolutionary Research . . . Relevant Results

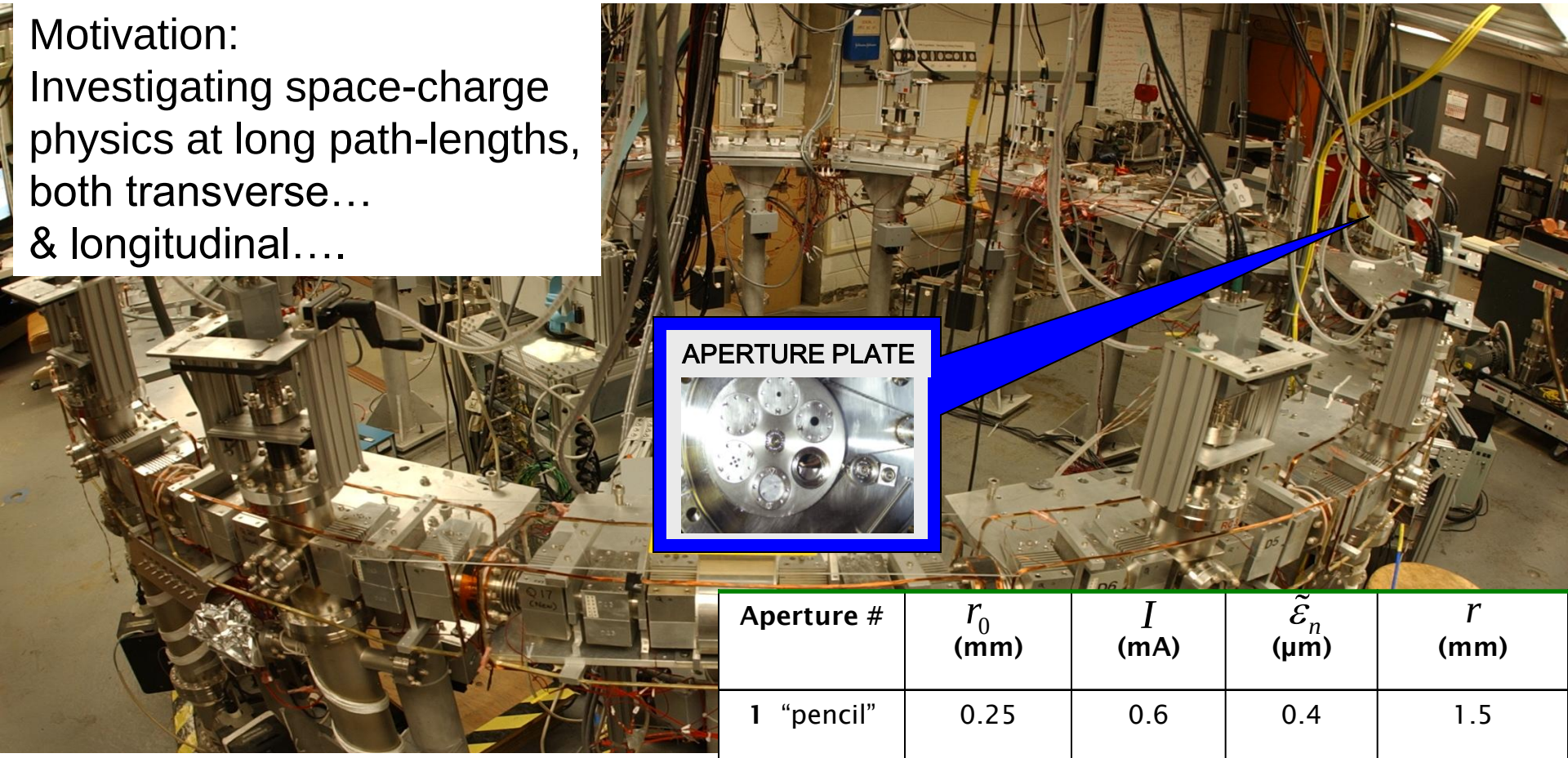
INSTITUTE FOR RESEARCH IN ELECTRONICS & APPLIED PHYSICS

Outline

- **Introduction and Motivation: The University of Maryland Electron Ring (UMER)**
- Studies of transverse dynamics
- Studies of longitudinal dynamics and the need for confinement
- Conclusion and future plans

UMER – Introduction & Motivation

Motivation:
Investigating space-charge physics at long path-lengths, both transverse…
& longitudinal….



Aperture #	r_0 (mm)	I (mA)	$\tilde{\varepsilon}_n$ (μm)	r (mm)
1 "pencil"	0.25	0.6	0.4	1.5
2	0.875	6	1.2	3.2
3	1.5	23	2.0	4.9
4	2.85	78	4.3	8.7
5	3.2	104	4.9	9.9

System Parameters

Beam Length 5 ns(30 cm)-132 ns(8 m)
Circulation Time 197 ns
Beam Energy 10 keV

Optics Layout

DC Magnetic Quadrupoles

Wide Pulsed Quadrupoles

DC Bending Dipole

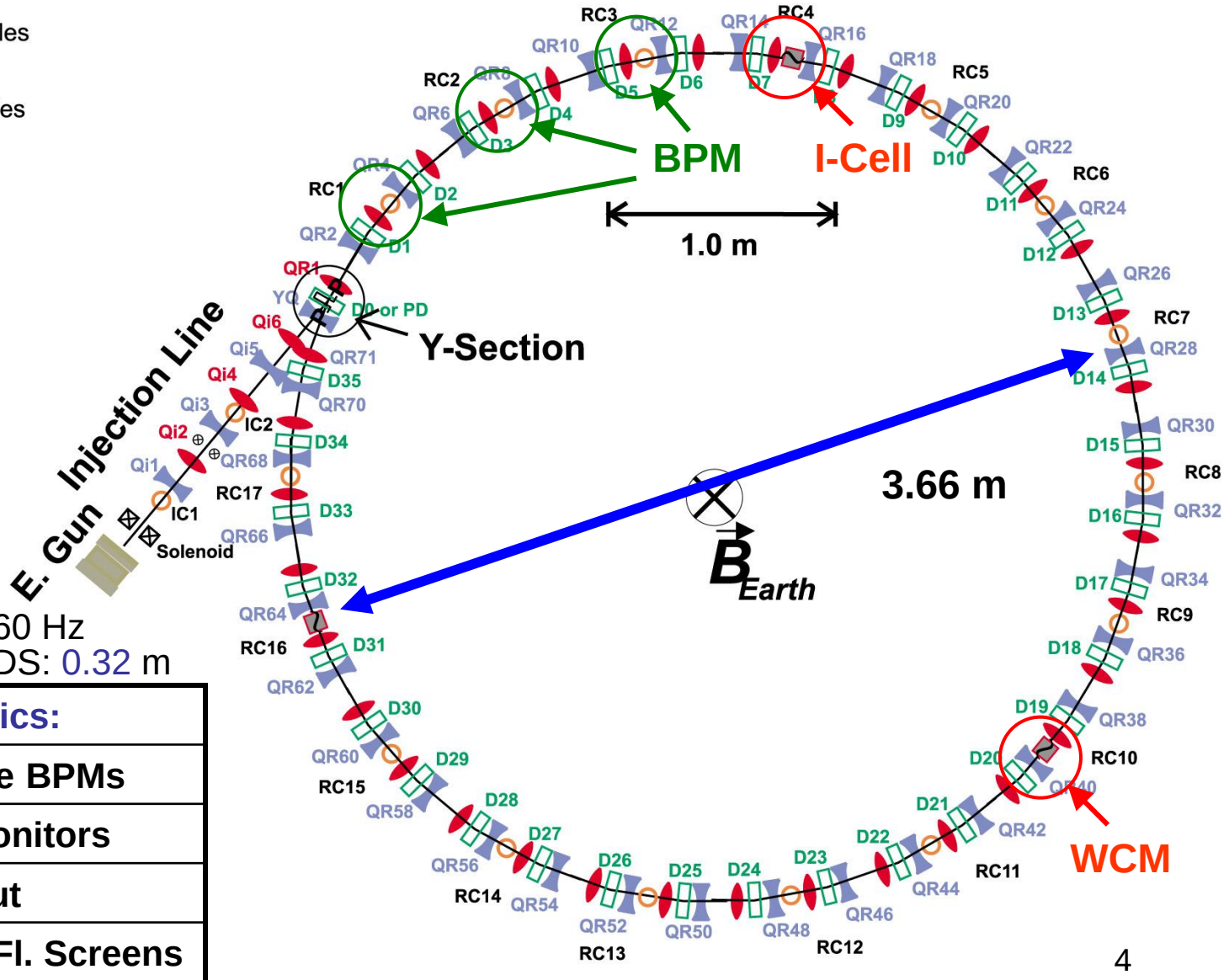
Solenoid

Pulsed Dipole

Bergoz Coil

Induction Gap

Diagnostic Chamber



Single turn injection at 60 Hz
FULL LATTICE PERIODS: 0.32 m

Ring Diagnostics:
14 Fast, Capacitive BPMs
1 Wall Current Monitors
RF-Knockout
Slow and Fast Fl. Screens
OTR Screens

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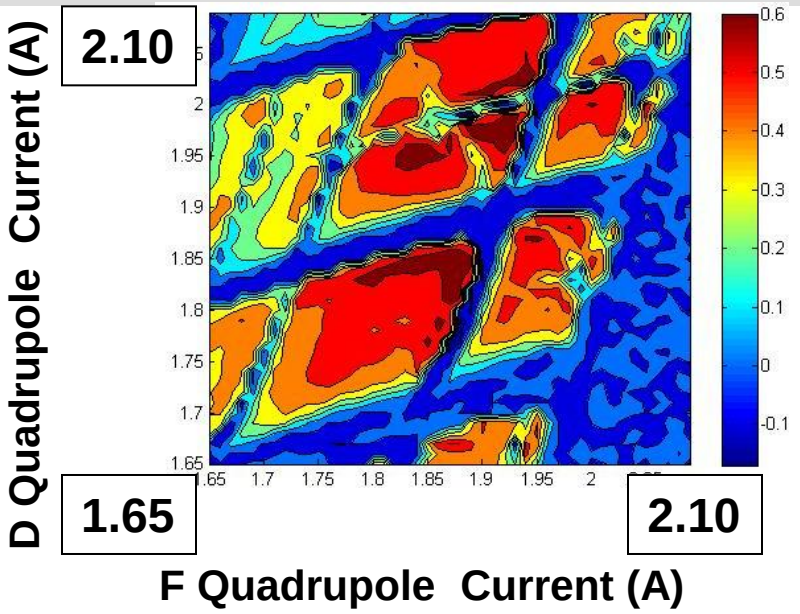
Tune Measurement / Calculation

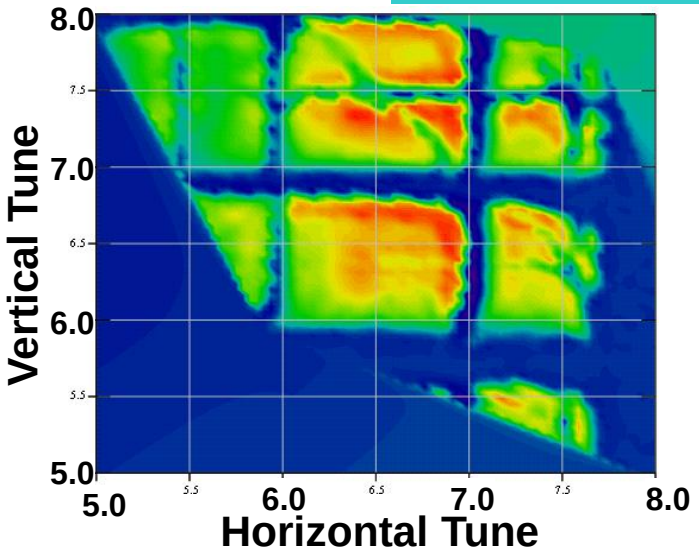
Quad Current Space → Tune Space

6.0 mA @ 10 keV: Transmitted Fractional Currents at 20th turn: 2025 (I_F,I_D) points

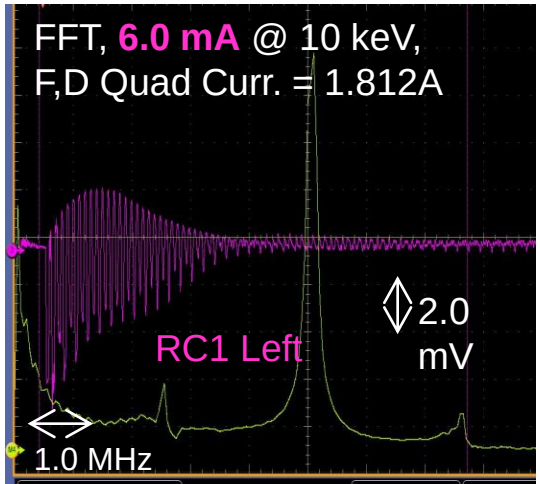
nth turn relative to the Injected turn

$$Ratio_n = \frac{I_n}{I_0}$$



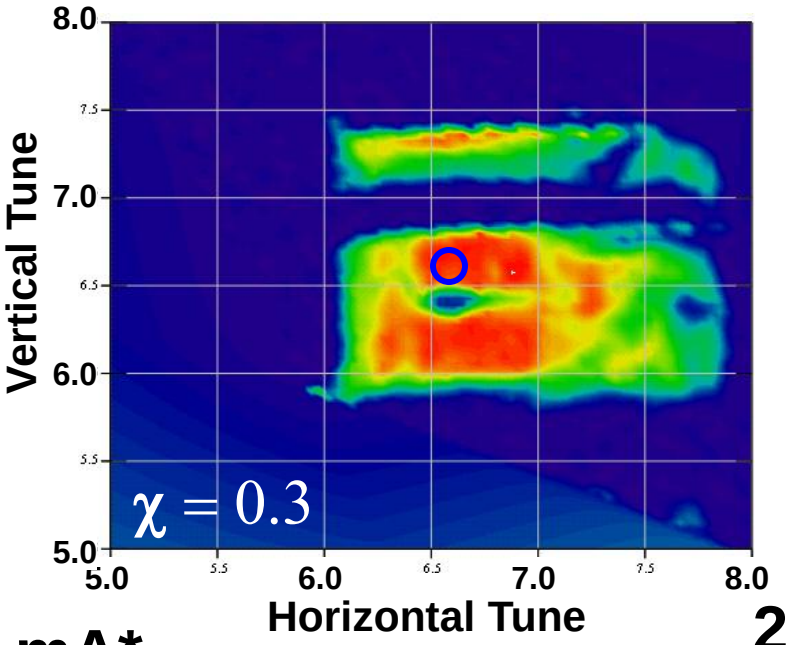


Lattice/Beam Model + Measured Tunes

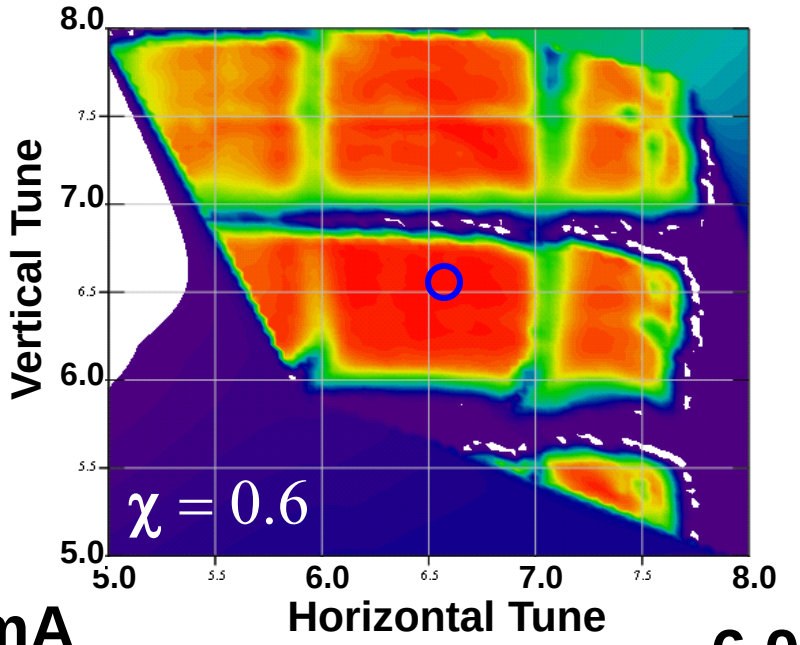


$$\chi = 0.6$$

5th Turn - Transmitted Current

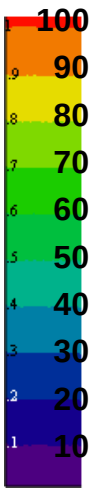


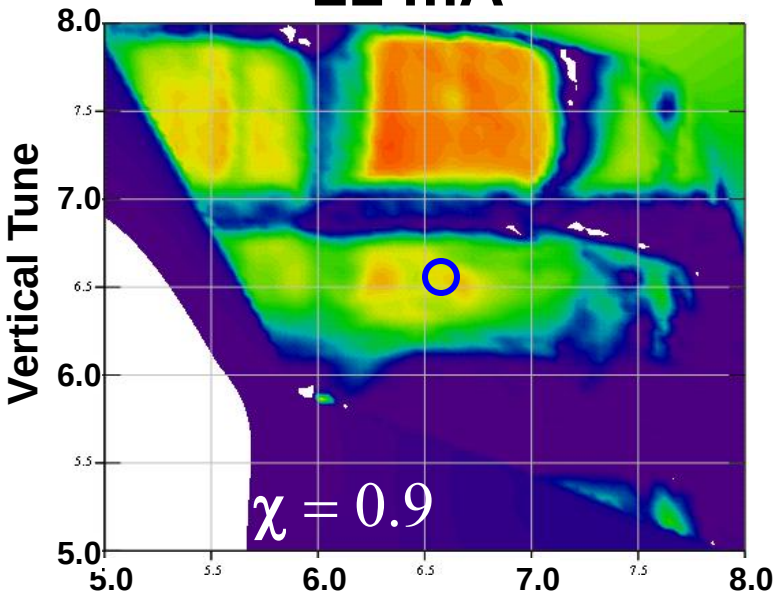
0.6 mA*



21 mA

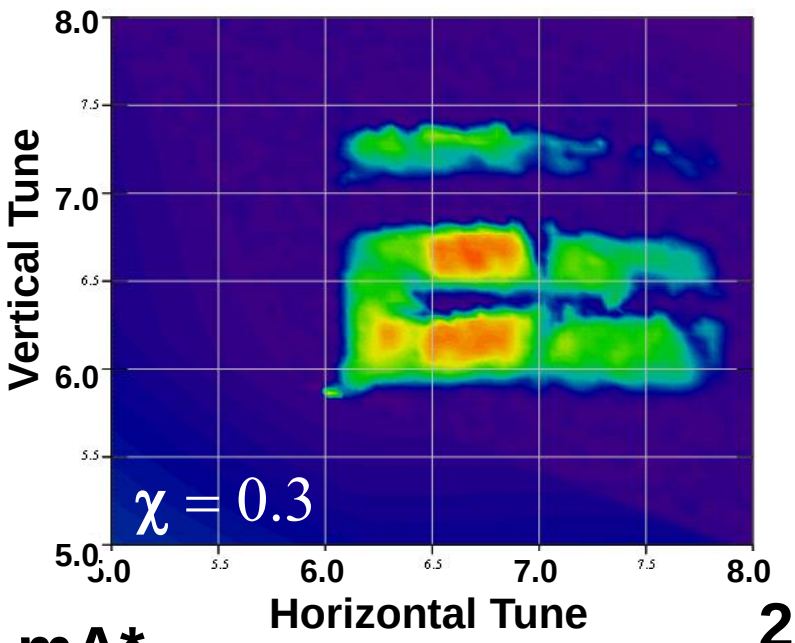
6.0 mA



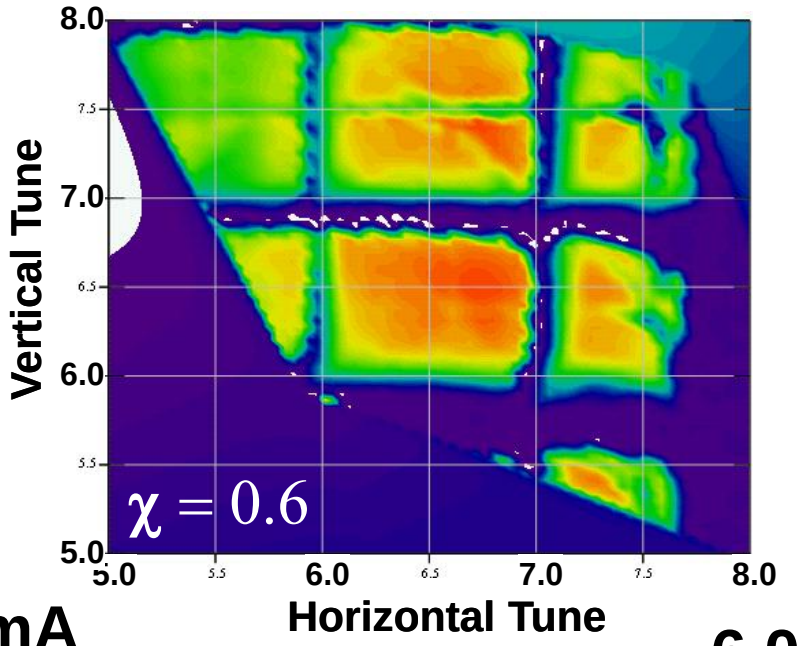


*0.6 mA: with or w/o long. focusing

10th Turn - Transmitted Current

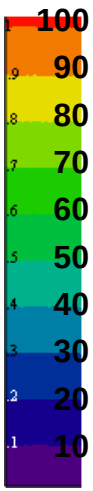


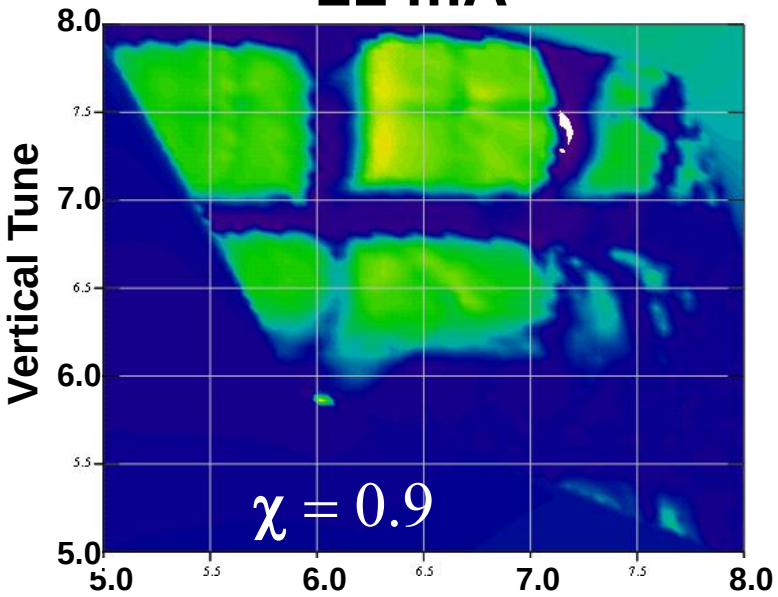
0.6 mA*



21 mA

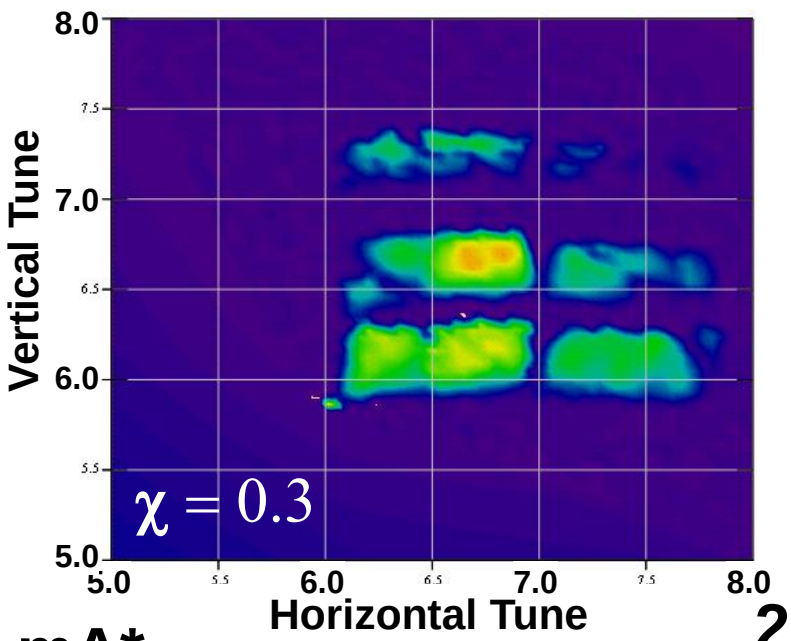
6.0 mA



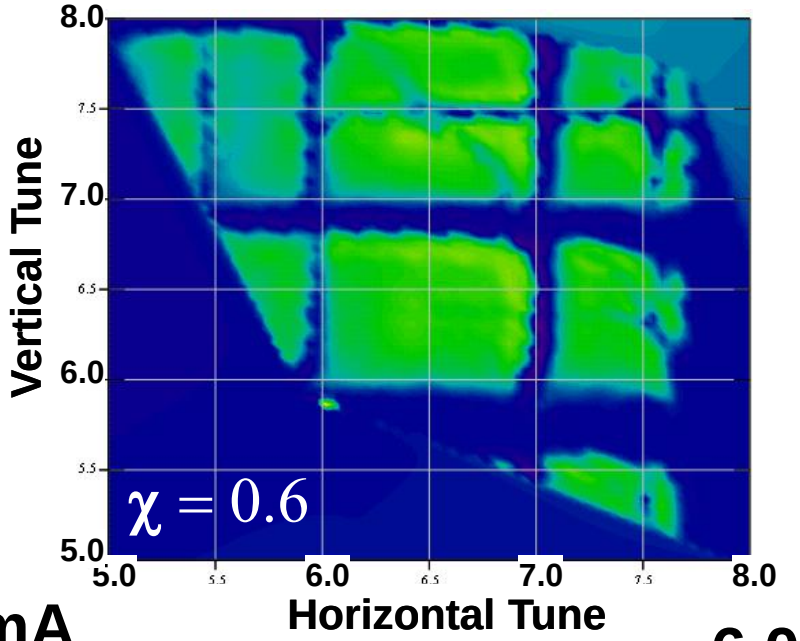


*0.6 mA: with or w/o long. focusing

20th Turn - Transmitted Current

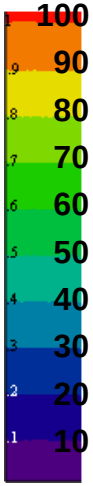


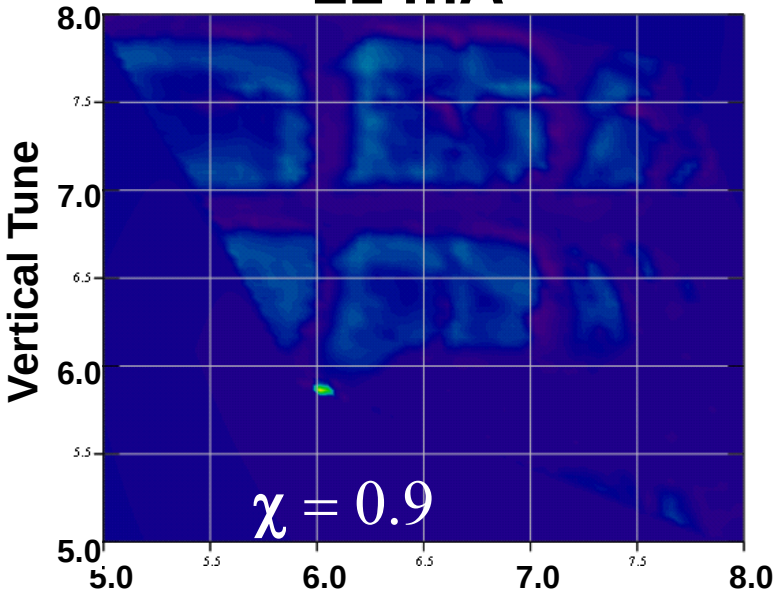
0.6 mA*



21 mA

6.0 mA

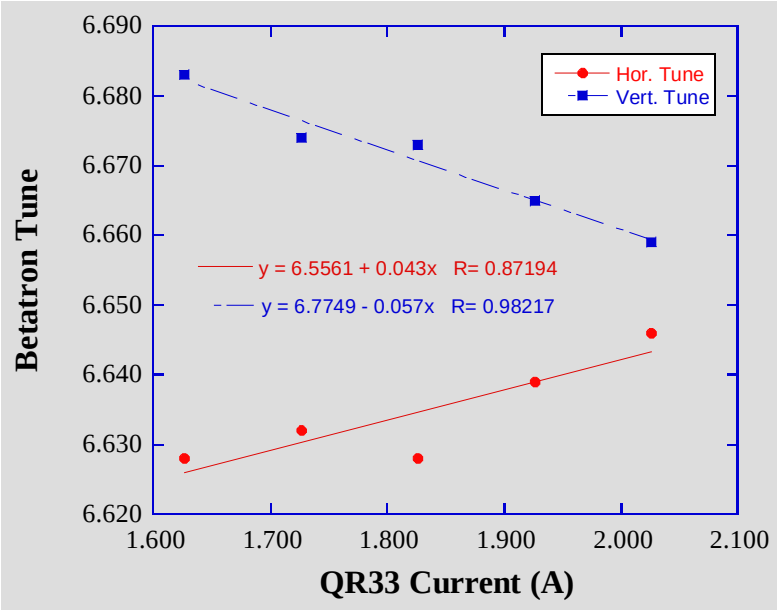




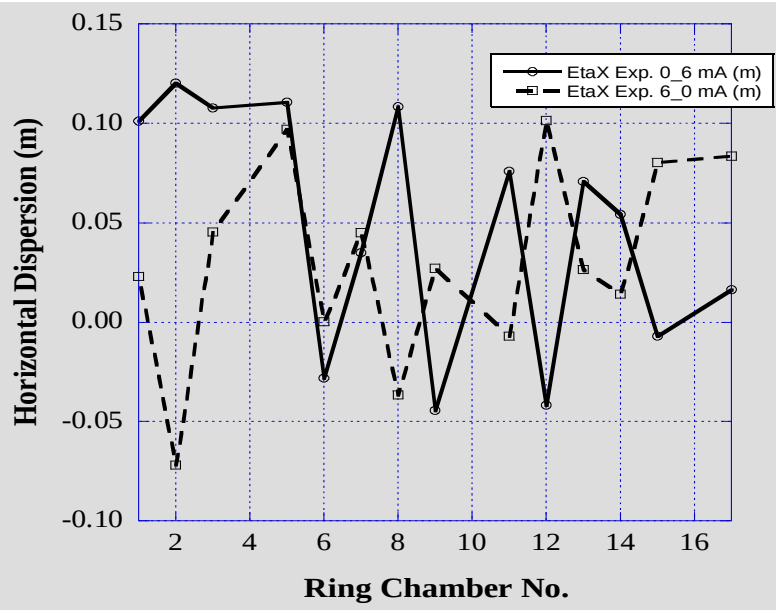
*0.6 mA: with or w/o long. focusing

LATTICE FUNCTIONS

Betatron Function (6.0 mA)
Measurement at QR33



Horizontal Dispersion Function
for 0.6, 6.0 mA beams



$$\beta_{0X,Y} \approx \pm 4\pi \frac{\Delta \nu_{X,Y}}{\Delta k}$$

$$\beta = \frac{\beta_{0X,Y}}{Tune\ Depression}$$

- Exp. Av. Disp. 0.6 mA = 4.9 cm
- Exp. Av. Disp. 6.0 mA = 3.1 cm

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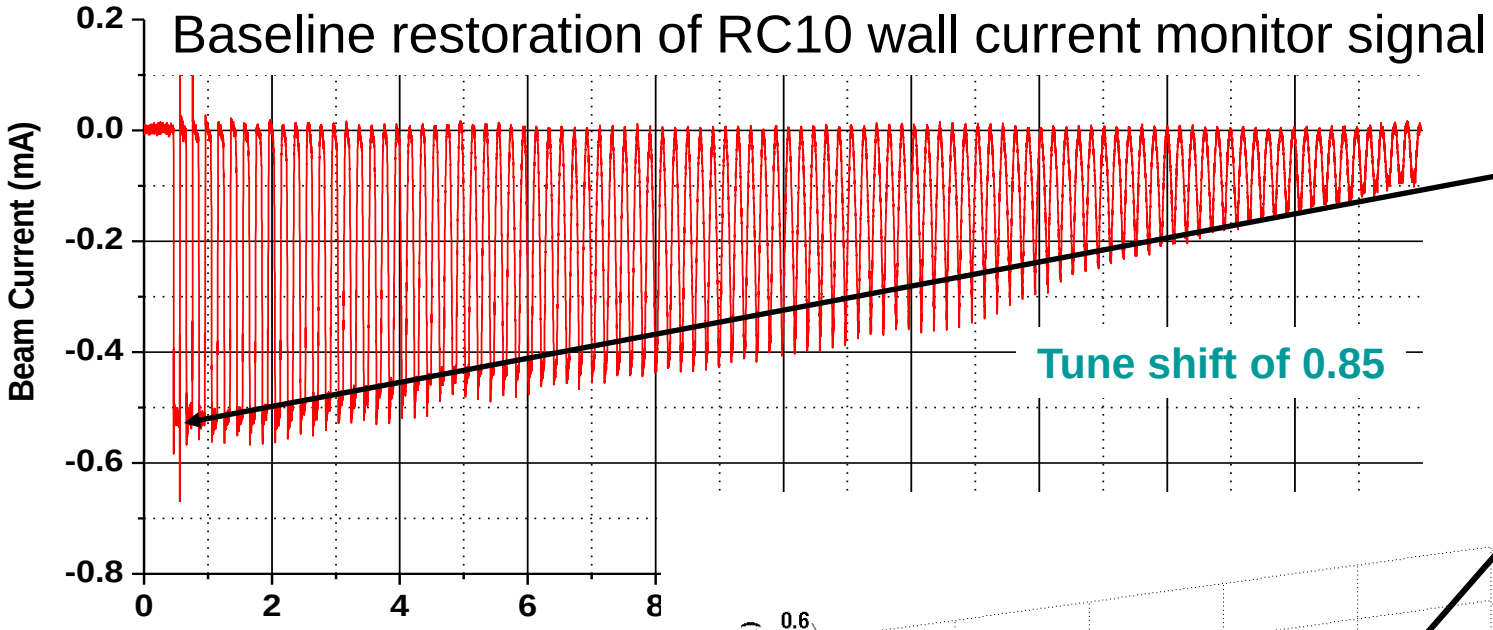
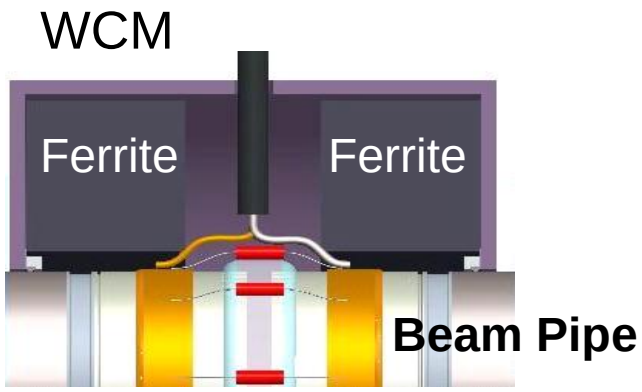
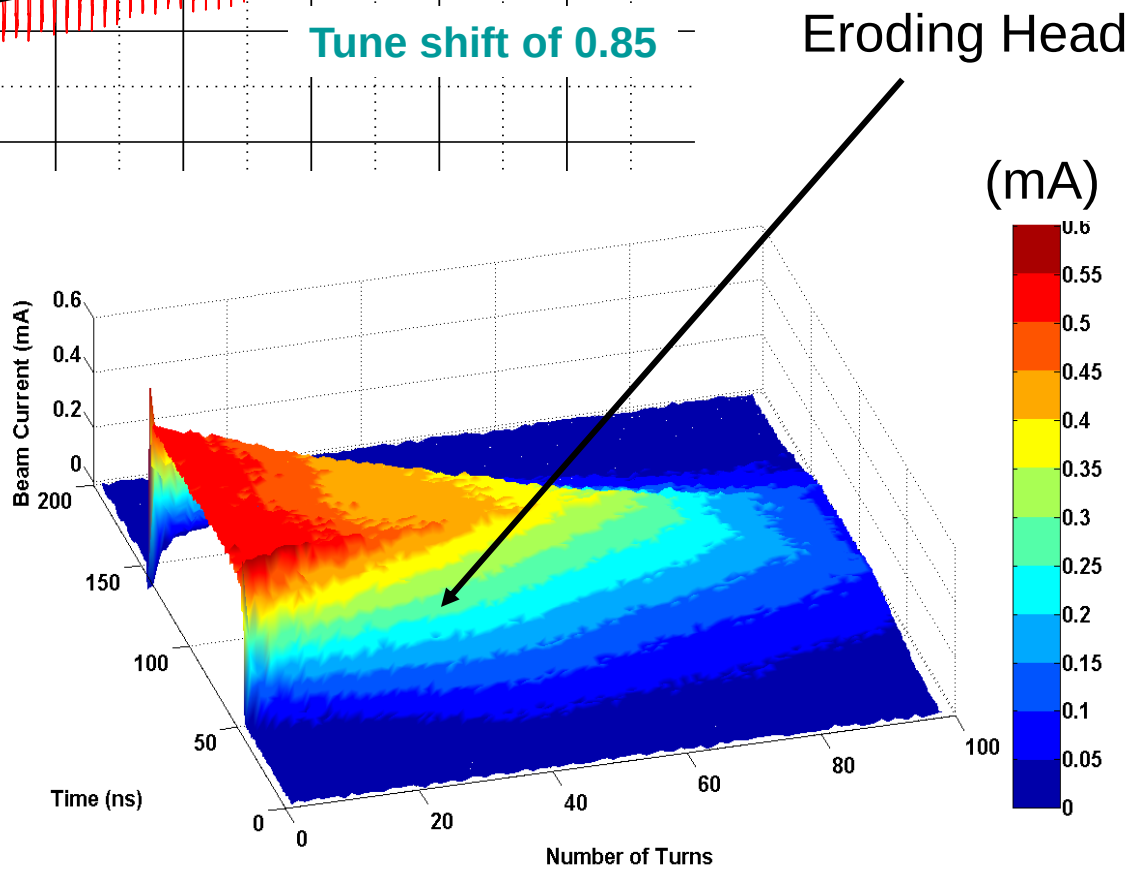
Longitudinal Head and Tail Erosion

(No Longitudinal Focusing)



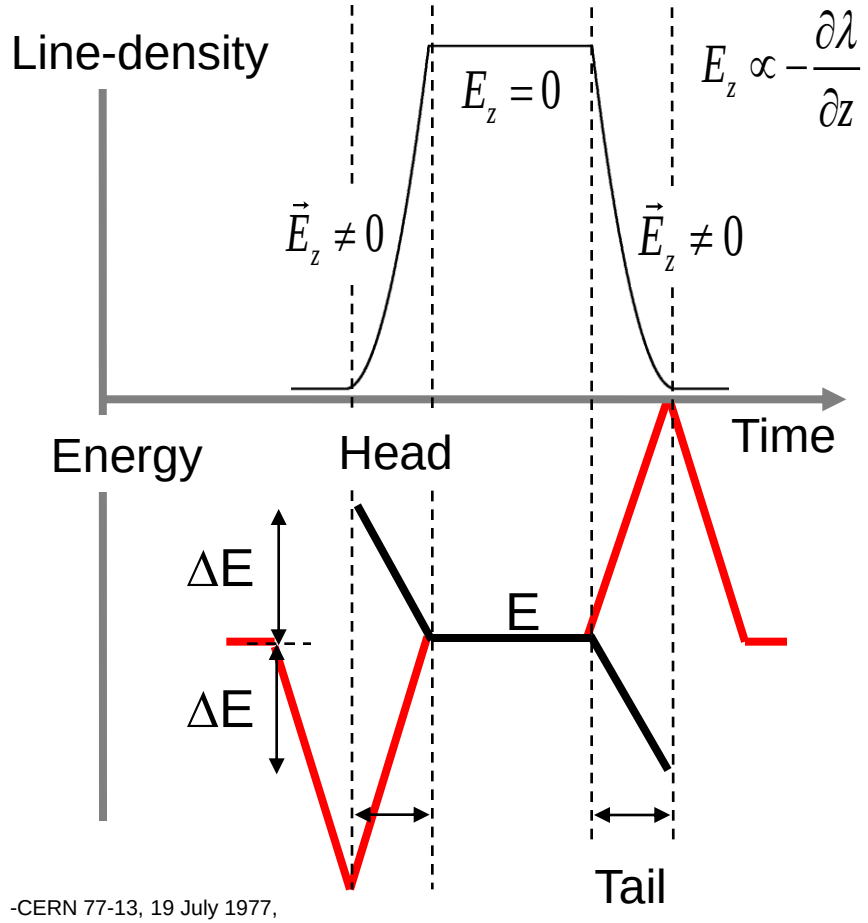




Longitudinal Synchronization for Confinement

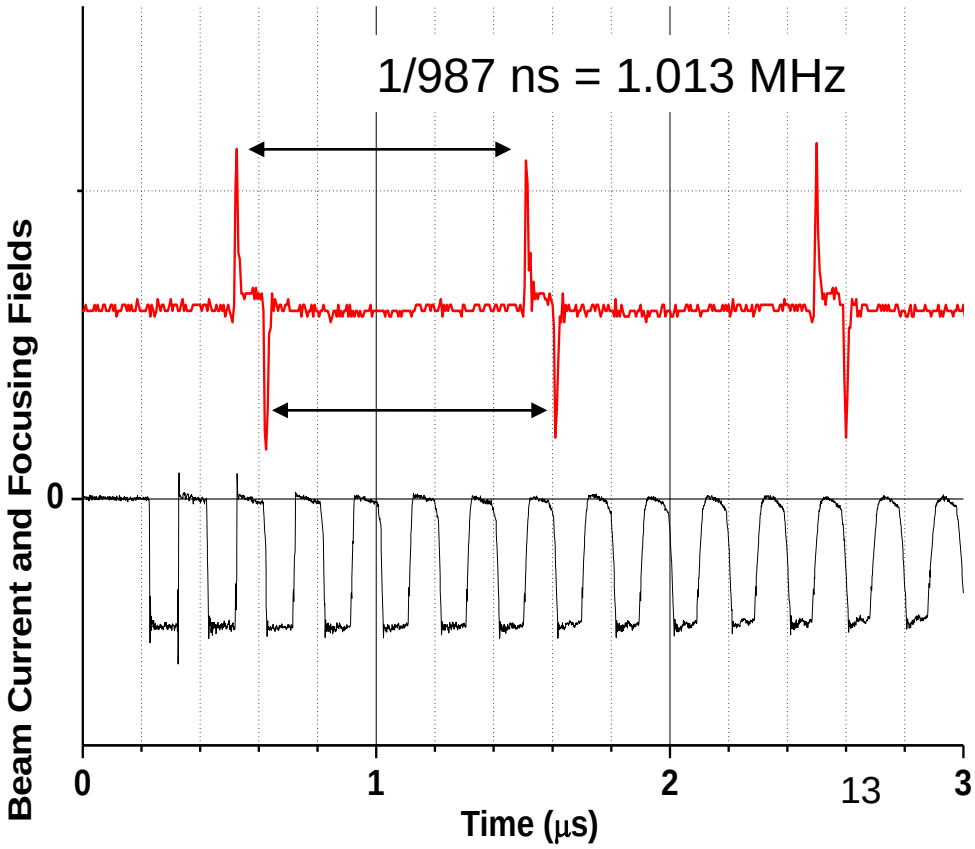
Selectable focusing frequencies (f_{rev} = 5.066 MHz)

Frequency (MHz)	1.013	0.844	0.723	0.633	0.562	0.506
Sub-harmonic #	1/5	1/6	1/7	1/8	1/9	1/10



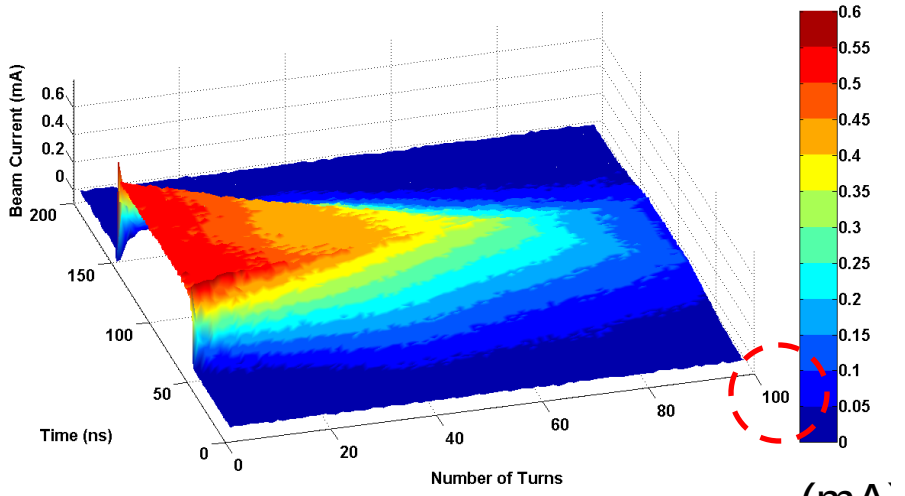
-CERN 77-13, 19 July 1977,
"Theoretical Aspects of the Behavior of Beams in Accelerators and Storage Rings

Synchronization between bunch and fields

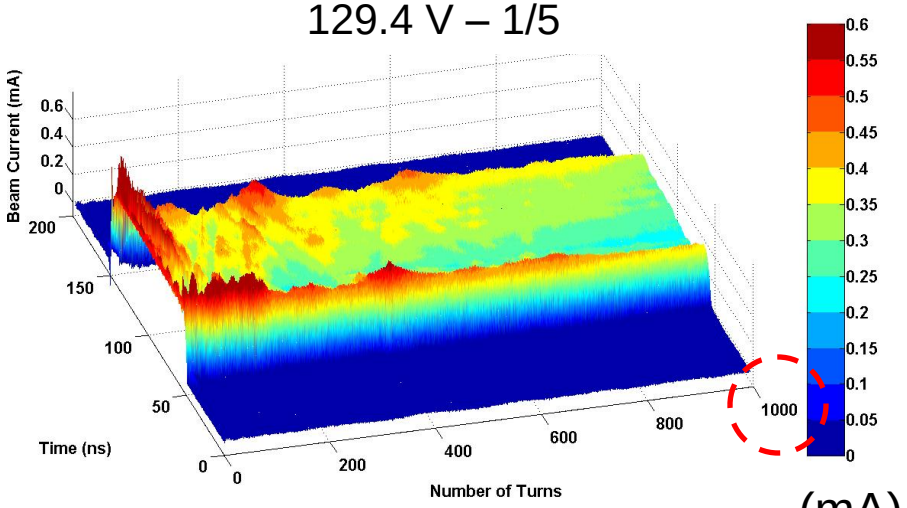


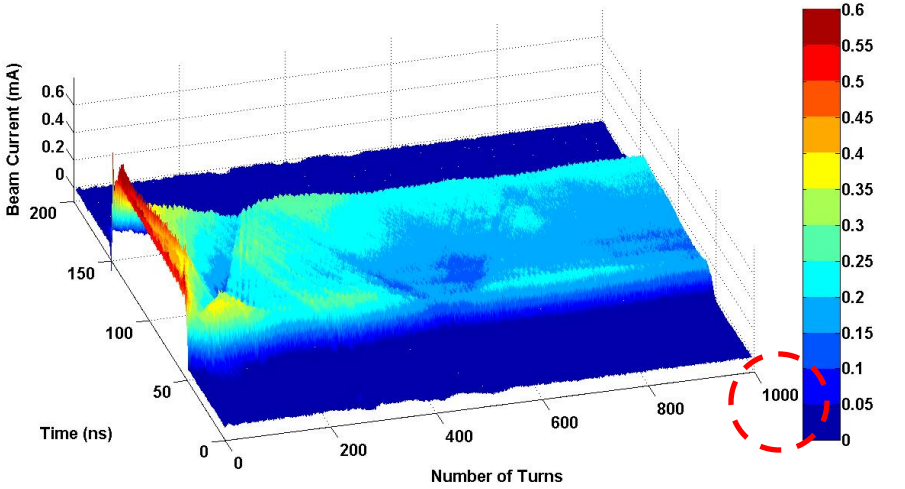
Unbunched and Bunched Beam

NO Confinement

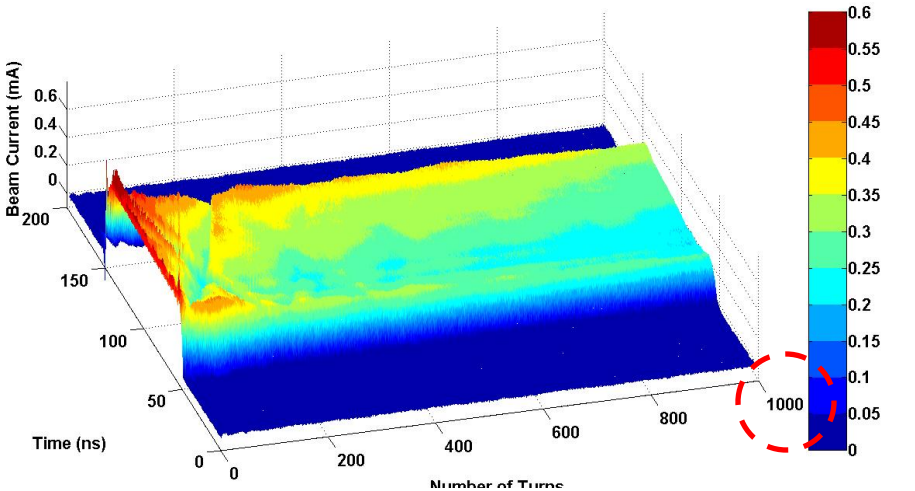


Launching of Multiple Waves
129.4 V – 1/5





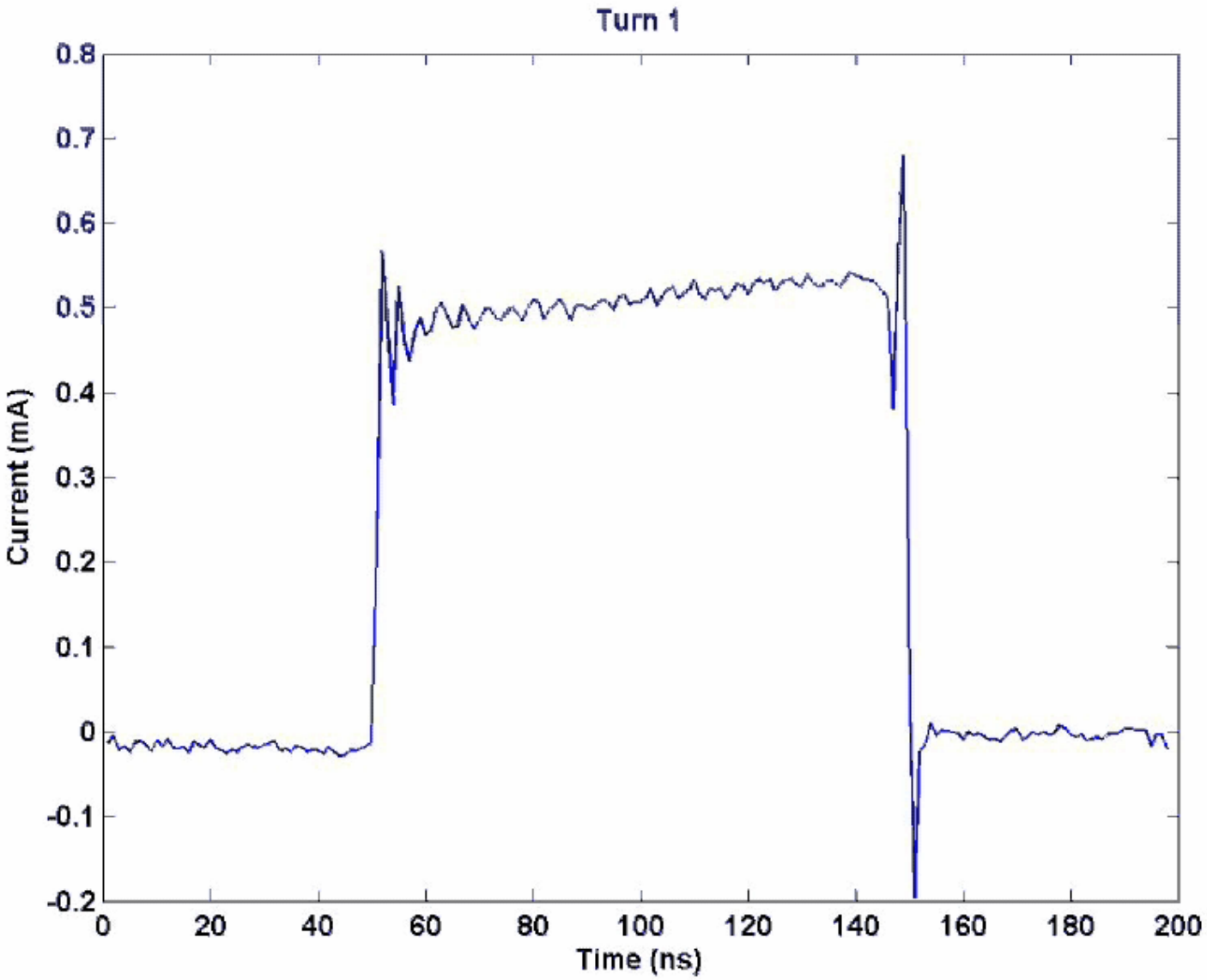
59.6 V – 1/10
Leaky Confinement



59.6 V – 1/5
“Good” Confinement

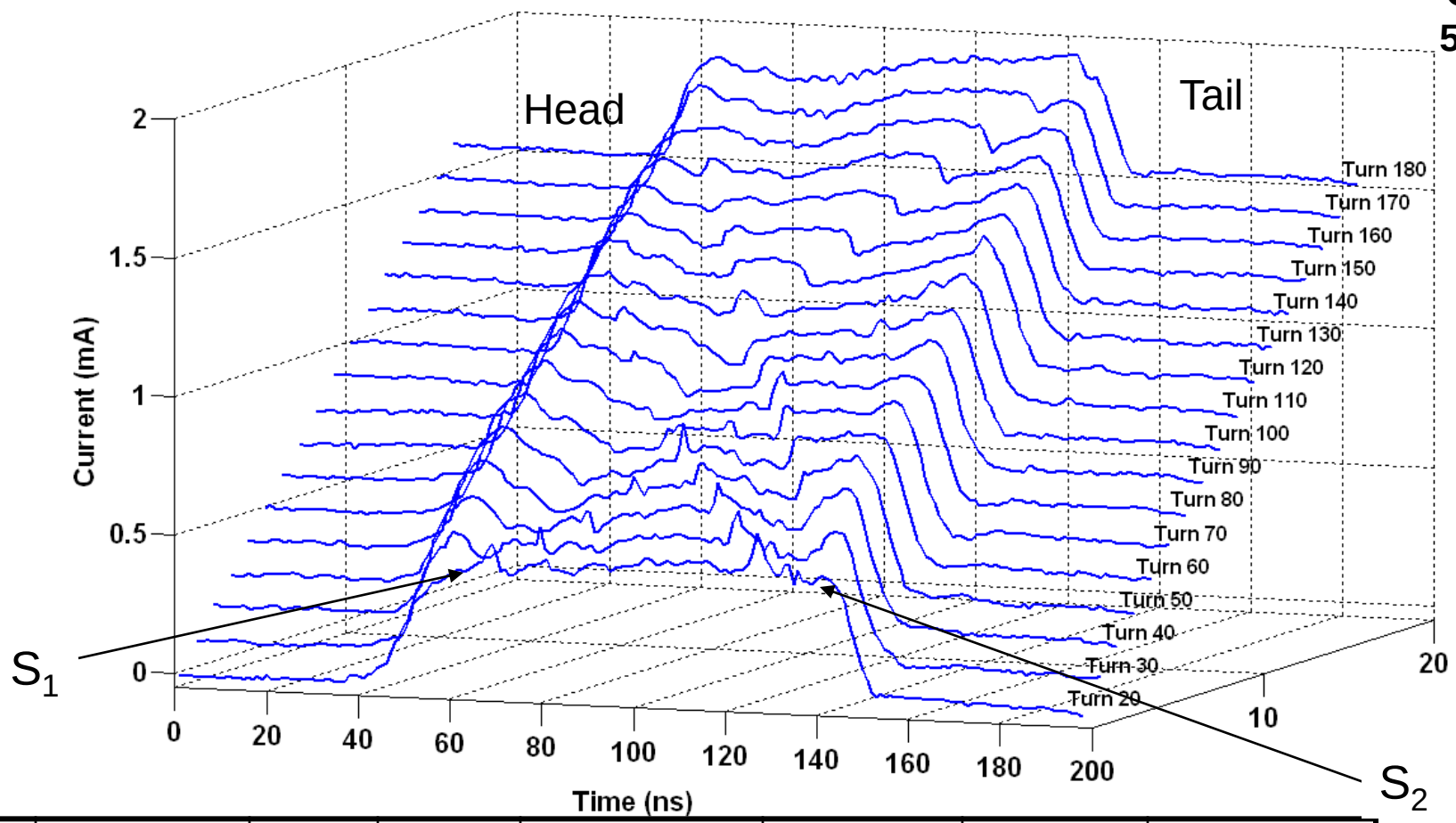
Longitudinal Mismatch Induced Waves

“Good” case
59.6 V – 1/5



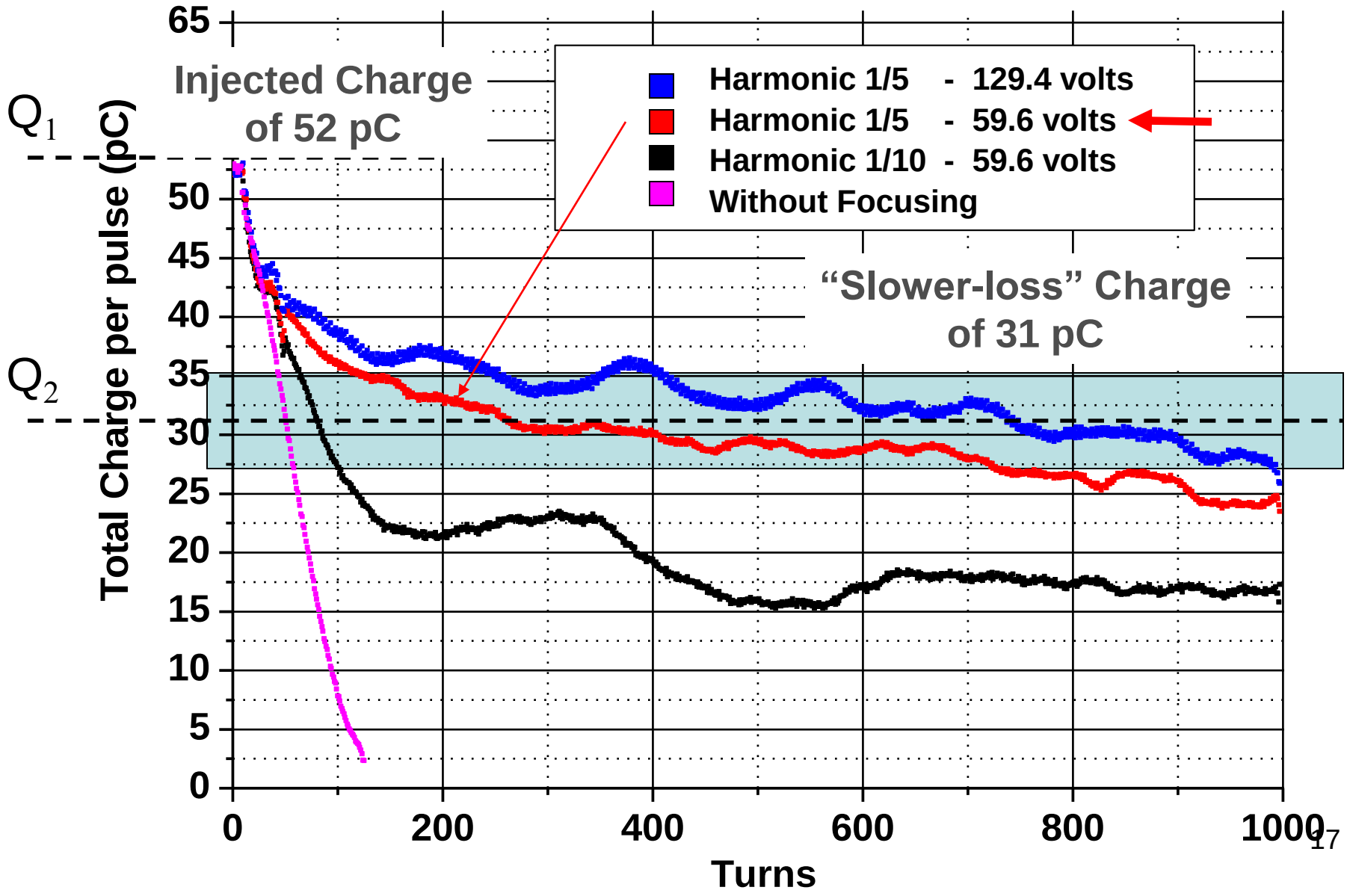
Estimation of Beam Size from Sound Speed Calculations of Induced Waves

"Good" case
59.6 V – 1/5



	Mean Current (mA)	S (m)	v_o (m/s)	Initial Emittance (mm-mr)	Beam radius (mm)	C_s- Theory (m/s)	C_s- Measured (m/s)
S_1	0.425	1854.7	5.836E7	7.86	1.56	**2.42E5**	**1.84E5**
S_2	0.425	1693.4	5.836E7	7.86	1.56	**2.42E5**	**2.01E5**
				62.9	**4.19**	**1.94E5**	

Charge Preserved with Focusing



Concluding Remarks and Future Plans

- Observed linear resonances over wide range of parameters.
- Demonstrated longitudinal confinement of the low-current beam beyond a 1000 turns, exceeding design by a factor of 10.
- We are currently researching the optimization of confinement.
- **Plans:**
  - Work around injection section for better matching.
  - Exploring resonance scans with longitudinal confinement.
  - Alternate longitudinal focusing solutions could minimize the number of wave induced distortions of the bunch shape.
  - Next stage for longitudinal focusing is to move on to the 6 mA beam, increasing space-charge and thus the tune shift.