Some Beam Physics Aspects of DHRF Upgrade

C M Warsop (D J Adams, C R Prior)

- Develop Measurements

Evolution of longitudinal pulse shapes & tomography

- Simulations

1D Longitudinal Tracking Code with Space Charge

- Basic Experiments and Tests

Manipulation late in cycle at high intensity
Use of chopped beams
Dual Harmonic θ Phasing Errors

- Understand Dual Harmonic Trapping Process

Revisit Theory, Simulation, Experiment

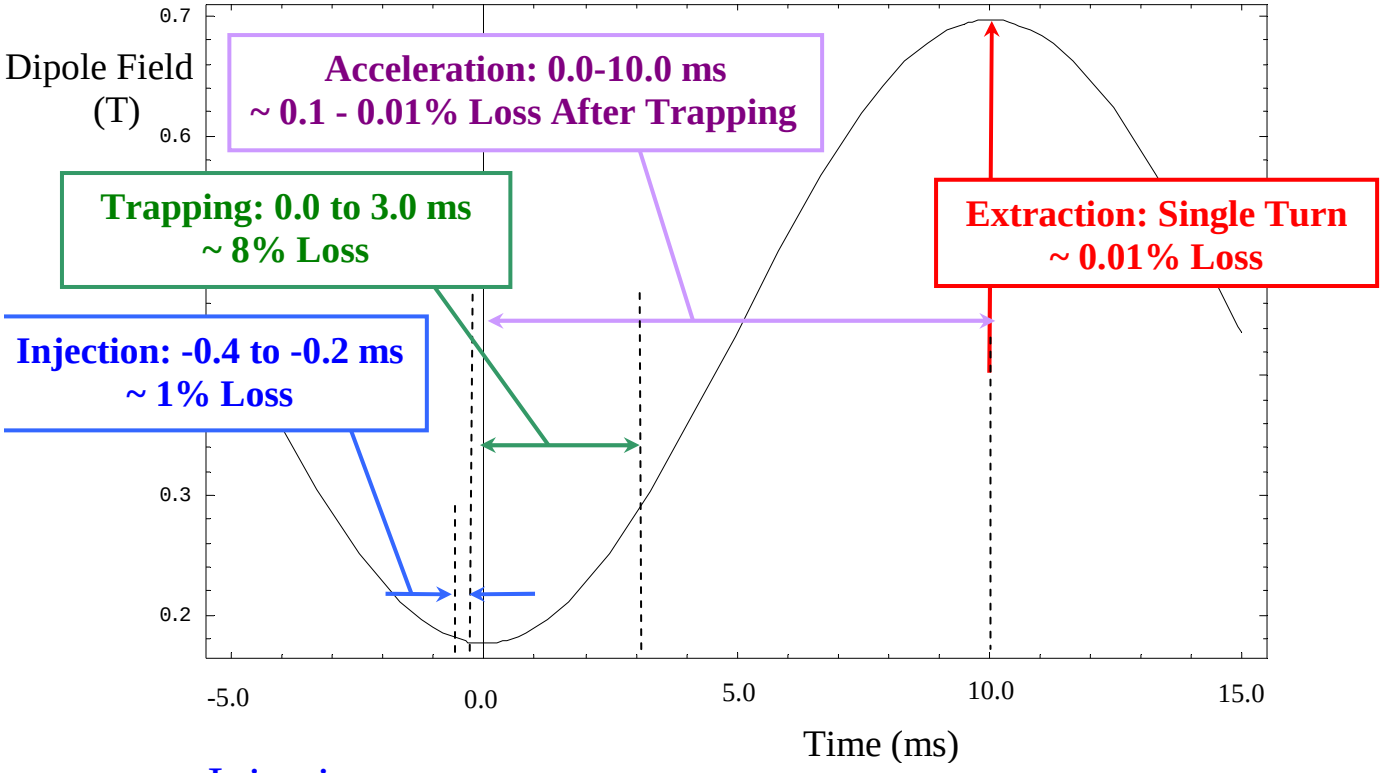
- Energy of loss?

- Achieve successful operation on a real 3D machine

- Details of Lost Beam ~ Limiting Factor?
  amount, energy, radial motion & destination

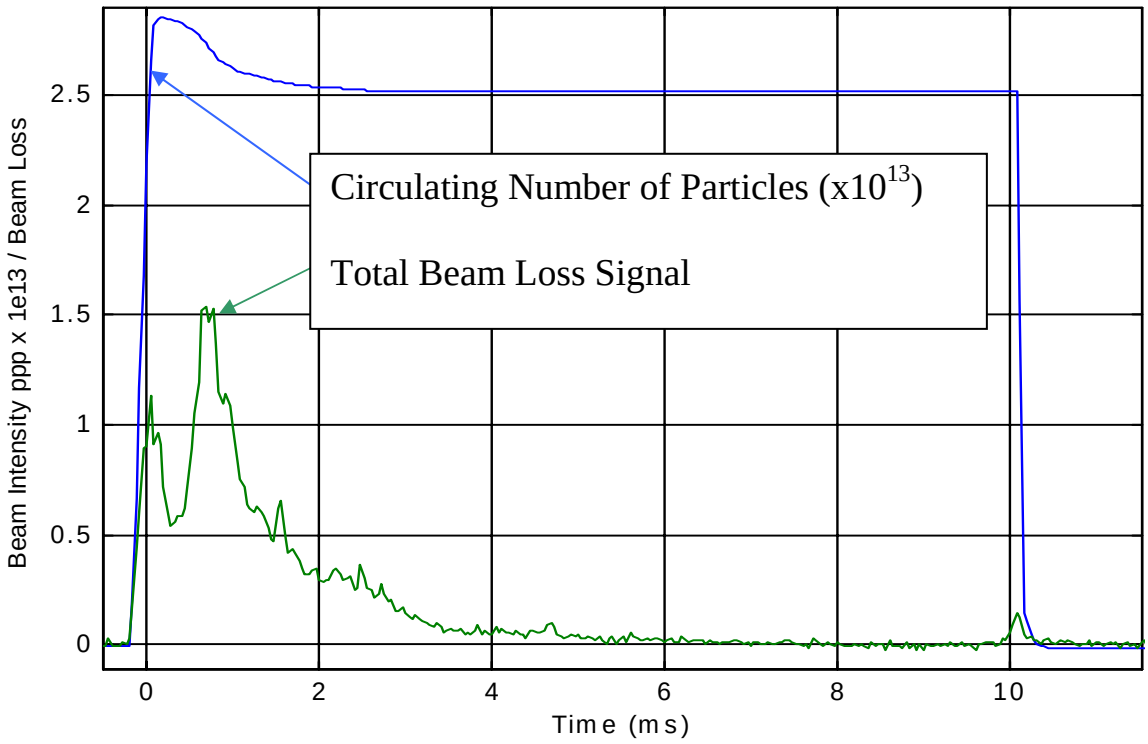
ISIS Ring Operation

Relation to 50 Hz Main Magnet Field



- Injection
  Accumulate 2.8×10^{13} Particles over 130 turns
  Anti-correlated horizontal and vertical painting
- Trapping
  Rapid Bunching in ~ 1 ms under space charge
  Most Losses ≤ 100 MeV
- Acceleration
  Rapid 70-800 MeV Ramp in 10 ms: RF 140 kV/turn
- Extraction
  Single turn, Fast kicker (rise time 200 ns)

ISIS Ring Losses



ISIS Synchrotron Parameters

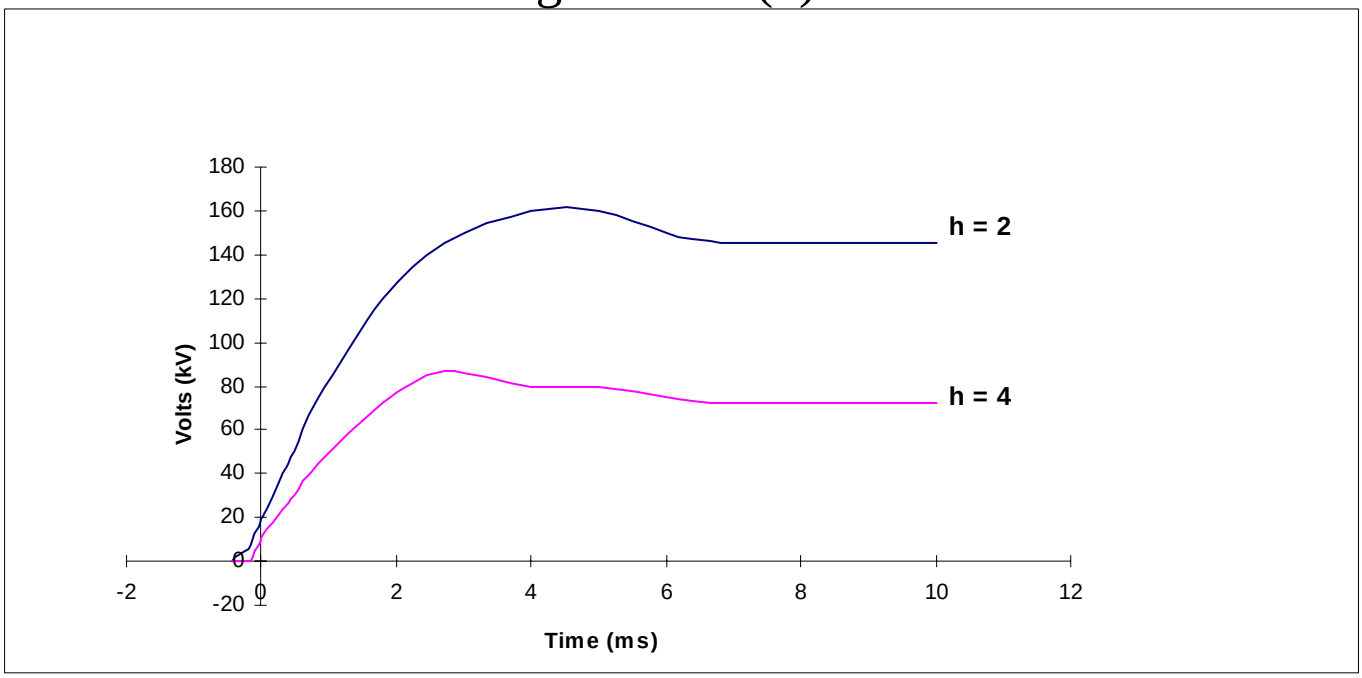
	Present Operation	Upgrade
Energy Range	70 - 800 MeV	
Intensity	2.5×10^{13} ppp	3.8×10^{13} ppp
Rep Rate	50 Hz	
Mean power	160 kW	240 kW
Mean Current	200 μA	300 μA
Injection	130 turn, charge-exchange paint injected beam of ~ 25 π mm mr	
Acceptances	horizontal: 540 π mm mr with dp/p ± 0.6% vertical: 430 π mm mr	
RF System f_{RF} *sweep* V_{RF} *peak*	Single Harmonic h=2 1.3-3.1 MHz 140 kV/turn	Dual Harmonic and h=4 2.6-6.2 MHz 80 kV/turn
Extraction	single turn, vertical	
Nominal tunes	Q_h=4.31, Q_v=3.83 *adjusted with trim quads*	

- 240 kW Upgrade - *being installed*
- ISIS Second Target Station - *approved*
- ISIS 1-5 MW Upgrades - *under study*

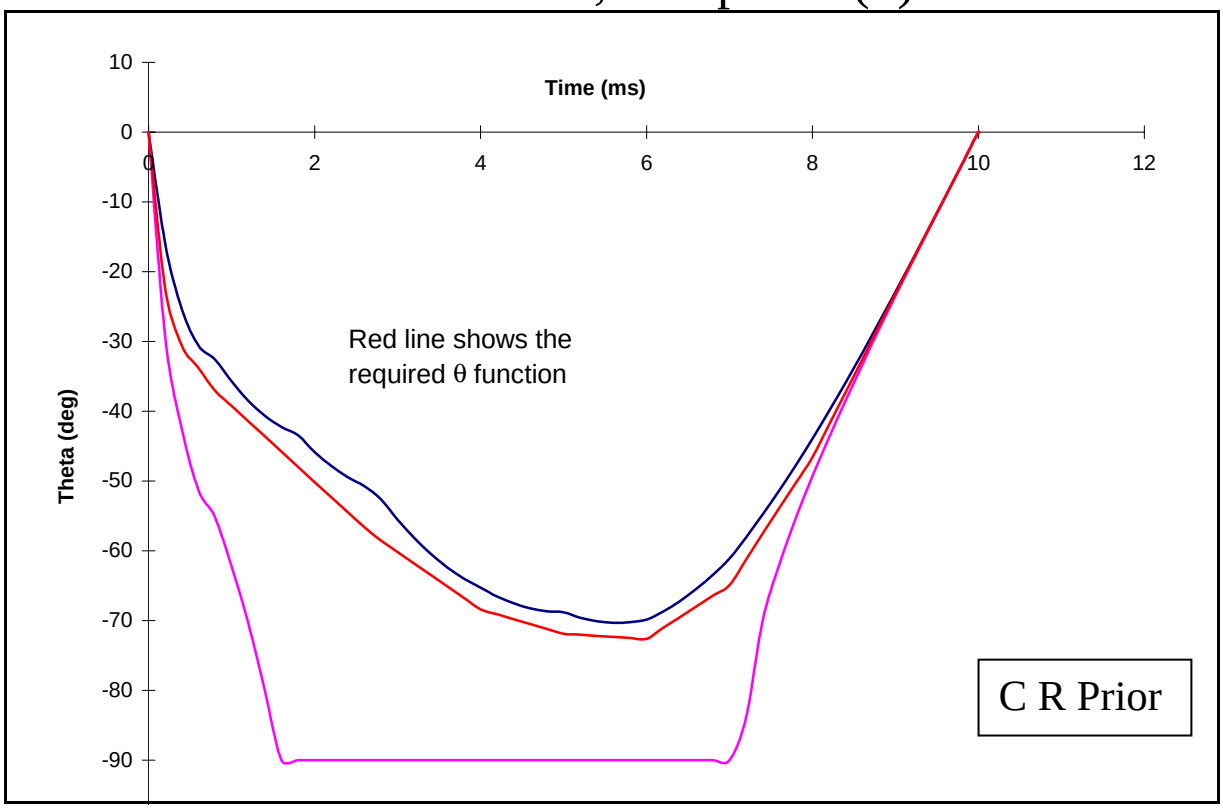
ISIS Dual Harmonic RF Law

$$V(\phi) = \hat{V}\left[Sin(\phi_s) - \delta \cdot Sin(2\phi_s + \theta)\right]$$

Voltage Levels (δ)



Relative h=2, h=4 phase (θ)



ISIS Dual Harmonic RF Simulation

C R Prior

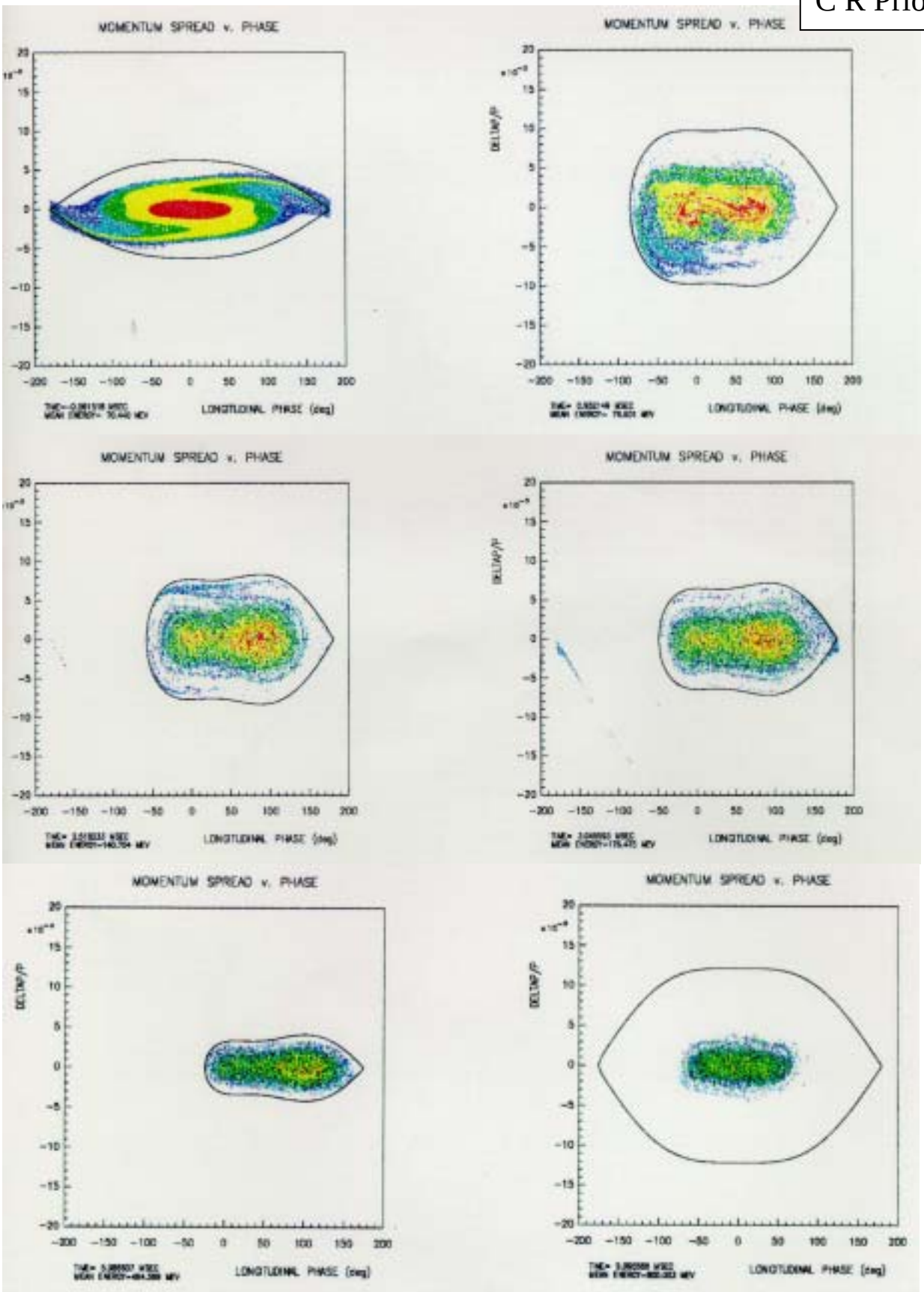
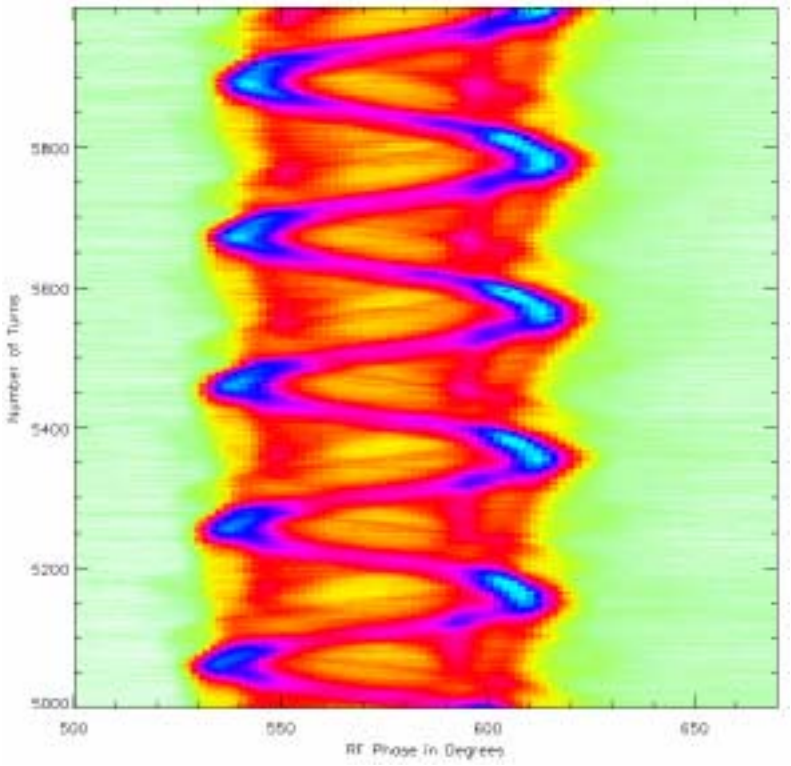


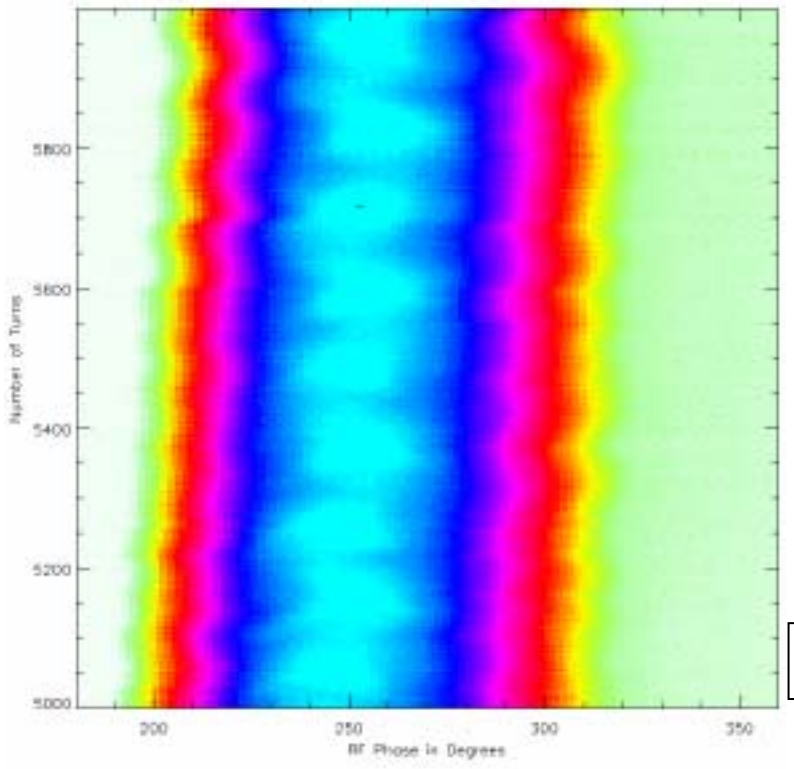
Figure 9. Phase-space plots for the injection and acceleration to $800MeV$ of a beam of 3×10^{13} protons per pulse in ISIS.

Measured Longitudinal Profiles at High and Low Intensity

Low Intensity Diagnostic Beam



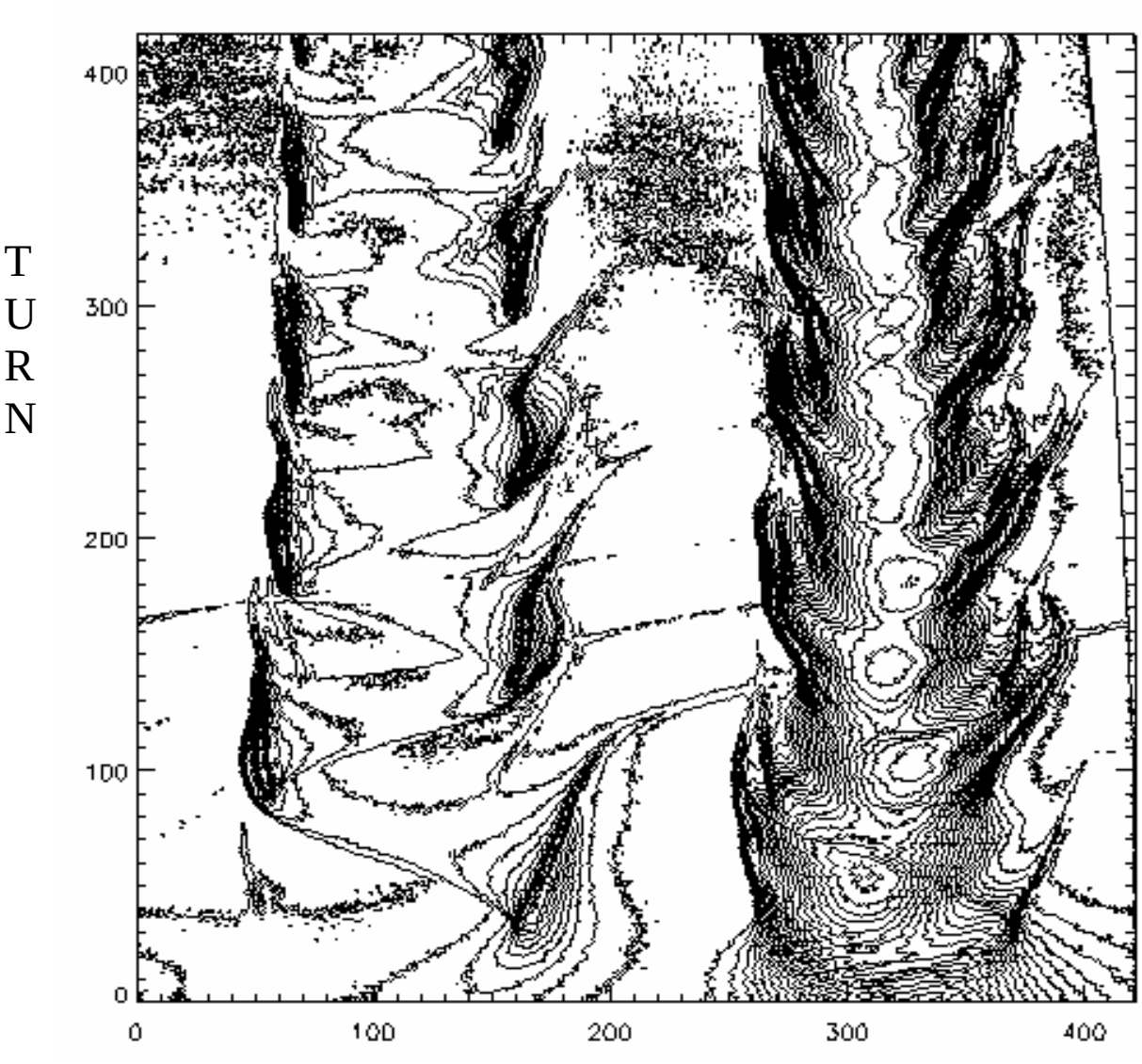
High Intensity Beam



D J Adams

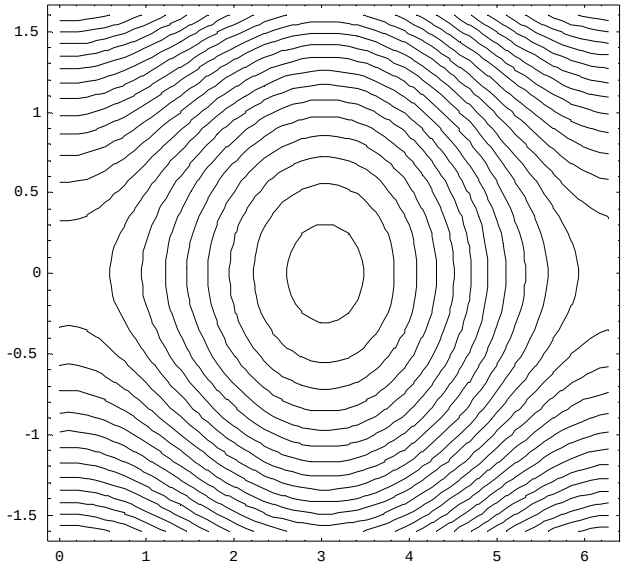
Longitudinal Profile Measurement - Chopped Beam

Development of 700 ns chopped beam over 400 turns

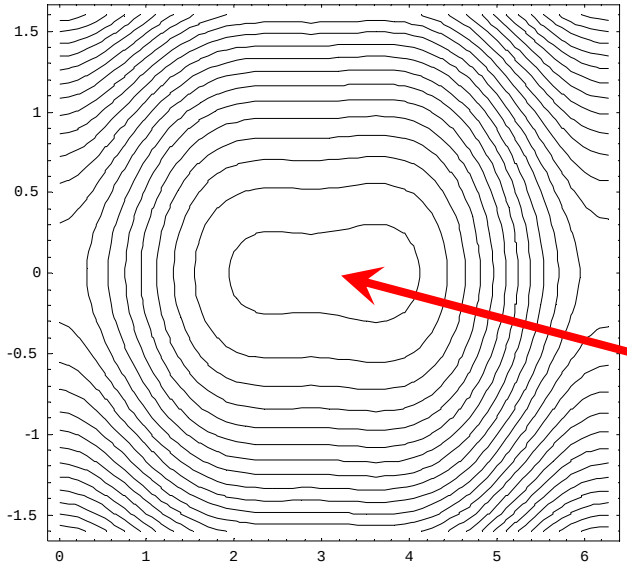


- Short pulse length (chopped) beams reveal longitudinal structure not otherwise visible. Here a beam pulse occupying less than one turn is captured partially in the left hand bucket, and more fully in the right hand. Synchrotron dipole oscillations are clear on the left, as are non trapped particles crossing between bunches.

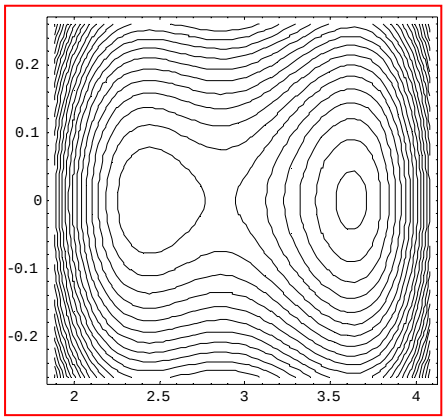
Comparison of Single and Dual Harmonic Longitudinal Bucket Structure



SH-RF bucket
(arbitrary units)



DH-RF bucket
(arbitrary units)



- Short pulse length (chopped) beams may allow detailed study of DHRF bucket structure, by observing motion near the SFP's and separatrices.