ORBIT Benchmark of Microwave Instability in PSR

Goal: Benchmark ORBIT's longitudinal impedance algorithm with experimental data. (Partial response to ASAC request for benchmark of ORBIT impedance capabilities).

Background:

1999 – 3 ferrite inductive inserts placed in PSR to provide longitudinal space charge compensation.

→ Inserts lead to unacceptably large microwave instability, were removed.

1999, 2000 – Heating of the inserts was shown to cure instability while still providing space charge compensations. Two new heated inserts were engineered, are now used in PSR.

2004 – Chris Beltran models impedances of both sets of inserts using MAFIA (PhD thesis). Results allow for detailed simulations of instability (ESME, ORBIT, etc).

Experimental Evidence of Microwave Instability at PSR

- 3 inductive inserts @ 25º C.
- Beam intensity = 650nC (4×10^{12} protons)
- Instability peak @ 200 μs (150 μs after injection)

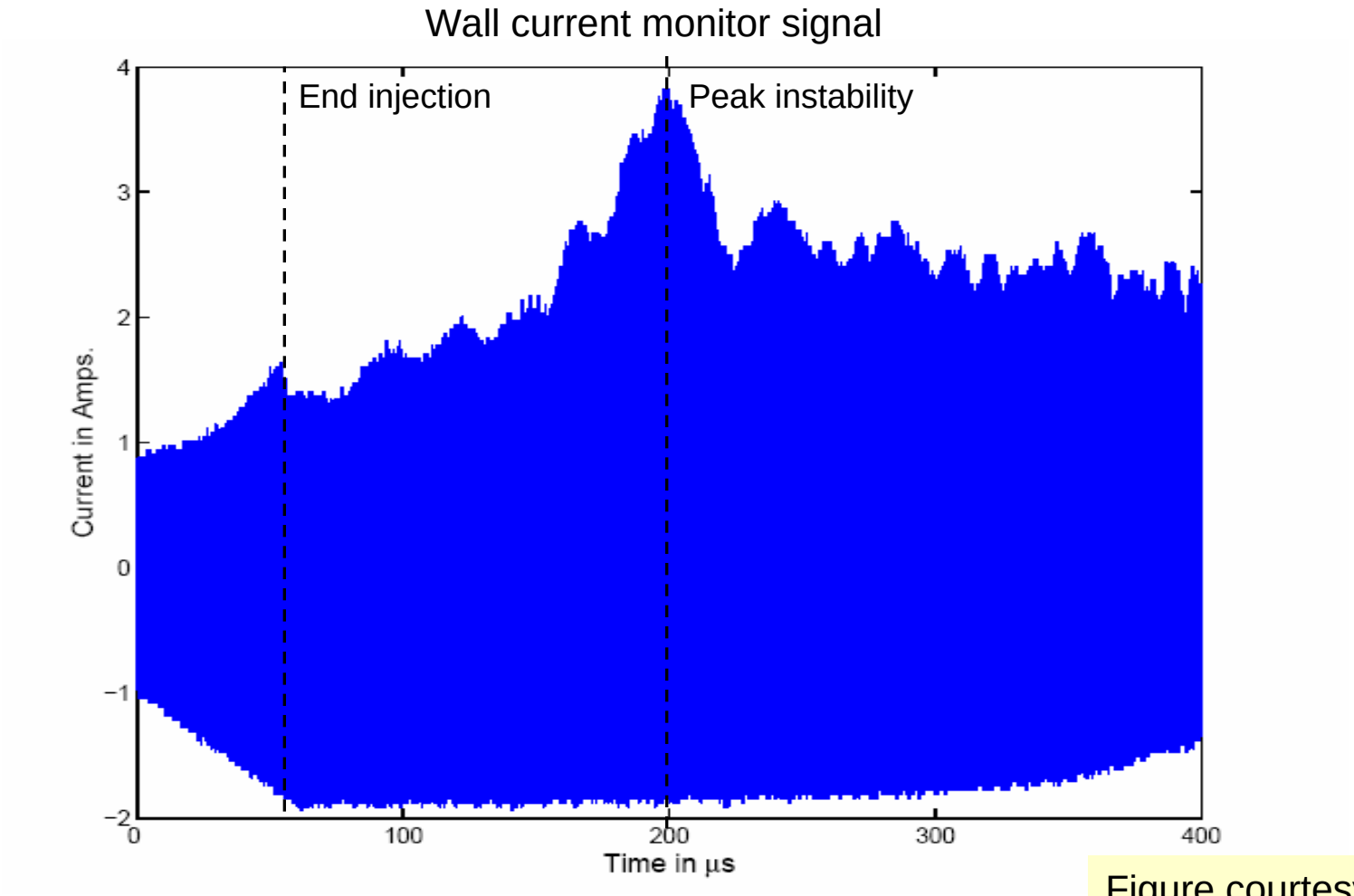
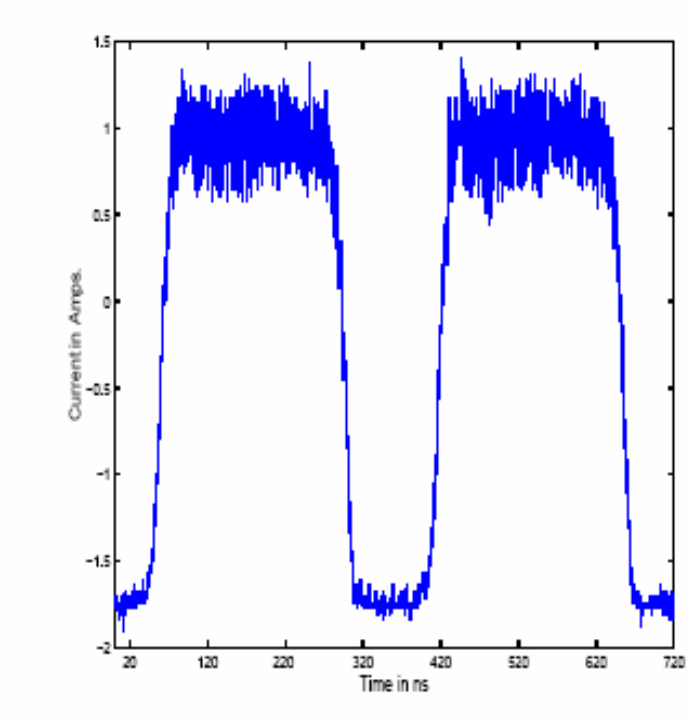


Figure courtesy C. Beltran, doctoral thesis.

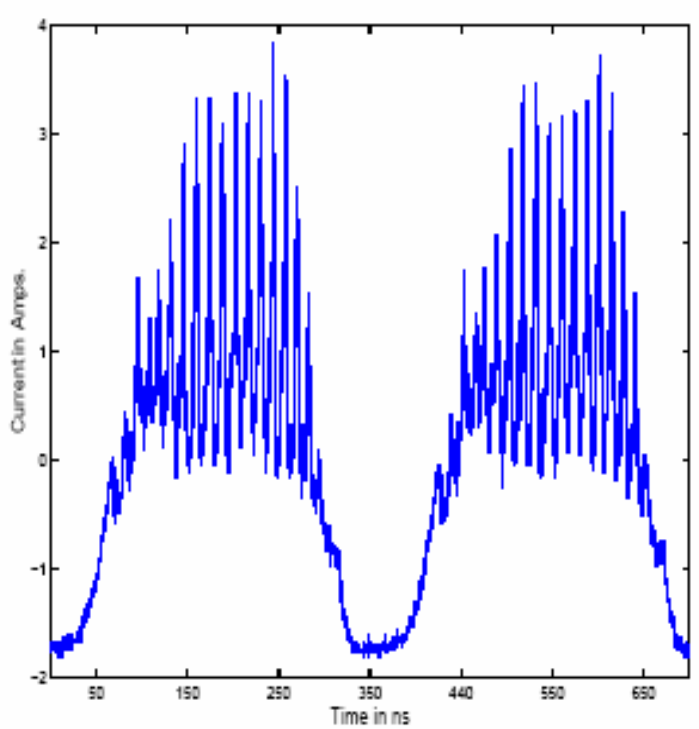
2 Turn Wall Current Monitor Signal (Experimental)

Instability Frequency = 72 MHz (harmonic = 26)

Signal for 2 turns at end of injection



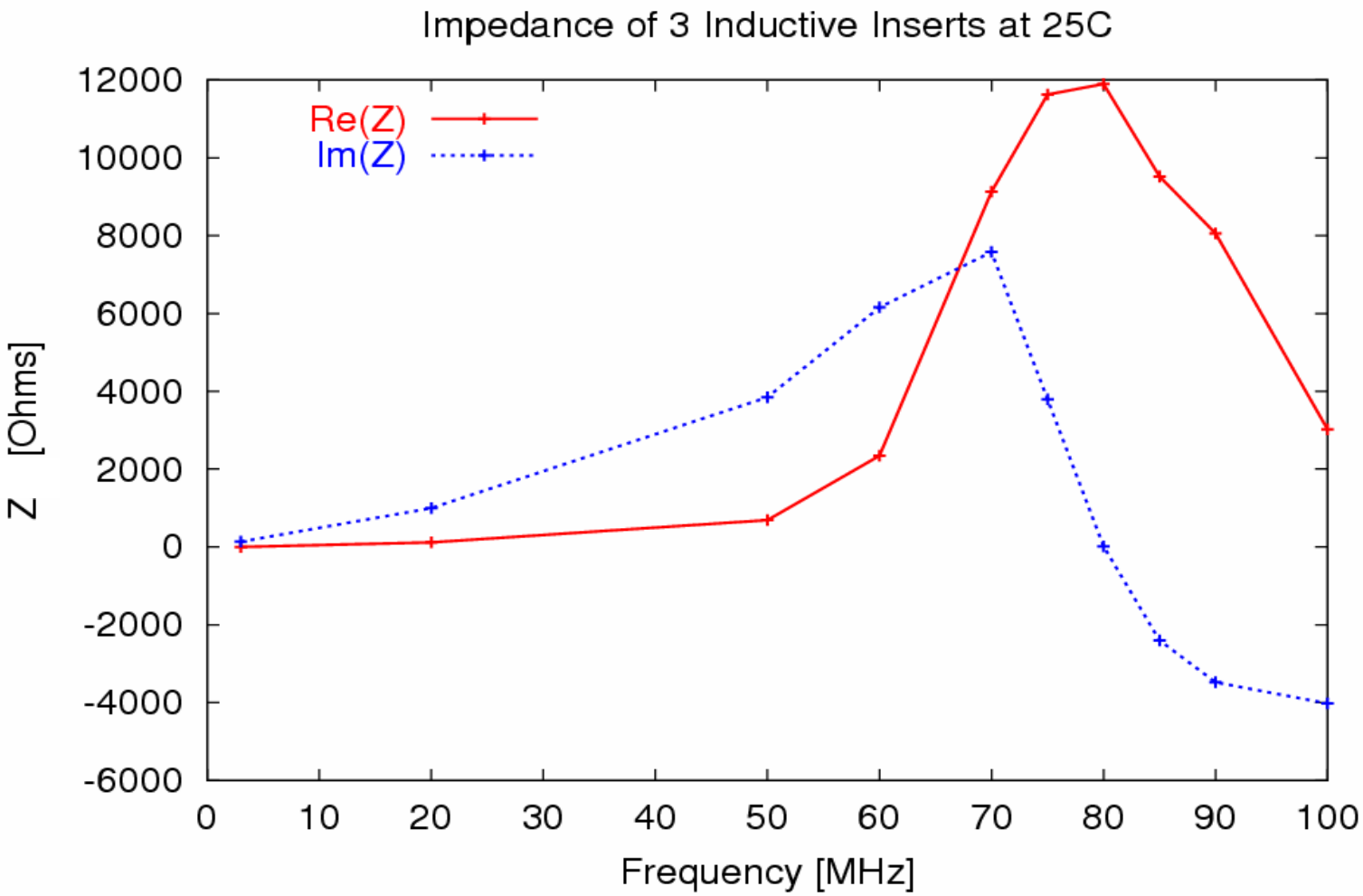
Signal for 2 turns at peak of instability



Figures courtesy C. Beltran, doctoral thesis.

Impedance of Inductive Inserts

Impedance of inductive inserts derived using MAFIA (C. Beltran)

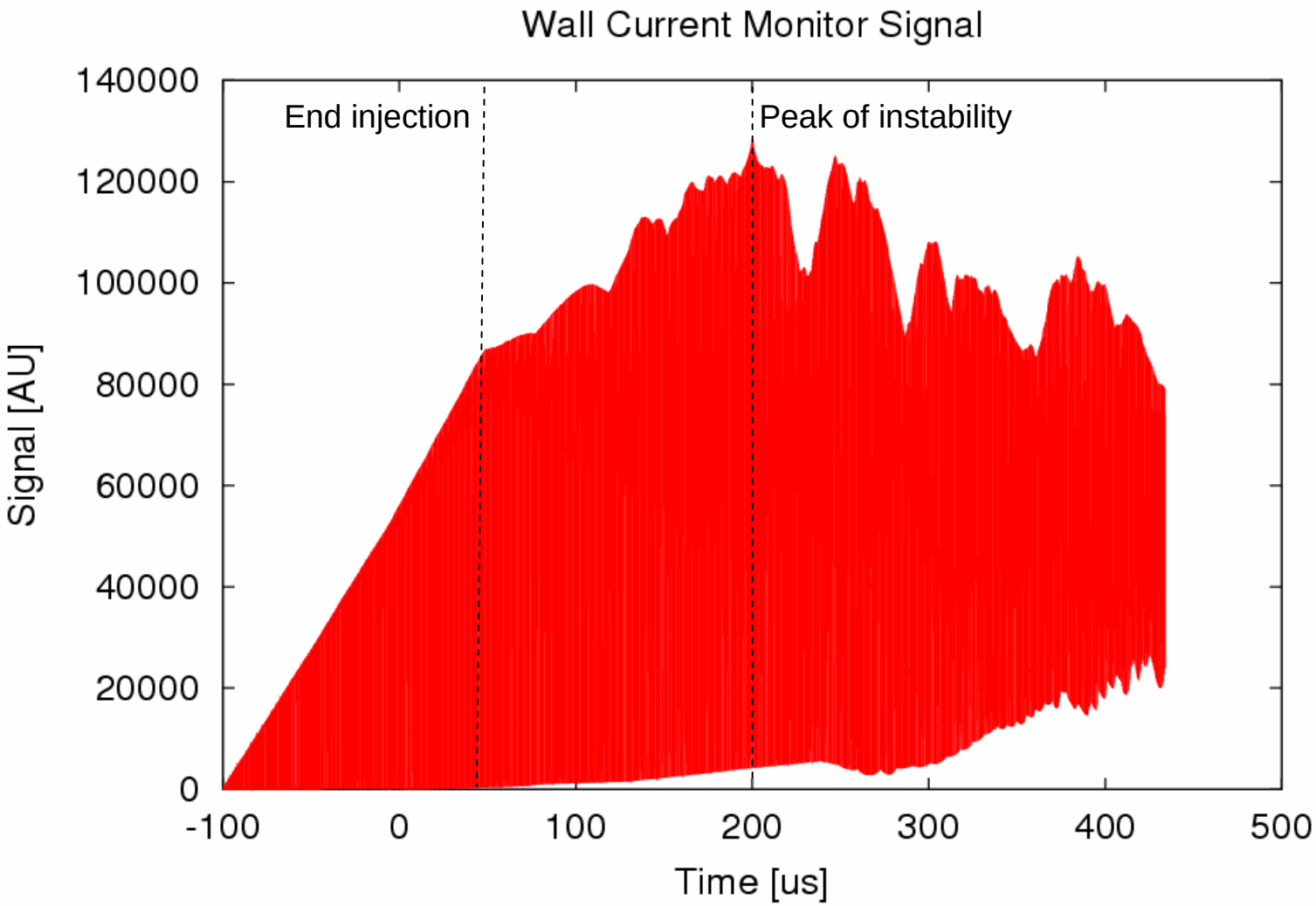


ORBIT Simulation Parameters:

- 650 nC (~4×10^{12} protons)
- 150 us accumulation time (~400 turns), + 200 us storage (~600 turns)
- Z/n as computed by C. Beltran
- $\Delta p/p$ as bi-Guassian, 66% with $\sigma=6.9\times10^{-4}$, and 34% with $\sigma= 2.8\times10^{-4}$
- Longitudinal tracking only
- From a numerical convergence study performed, used:
  - 256 longitudinal bins
  - 8×10^{6} macroparticles

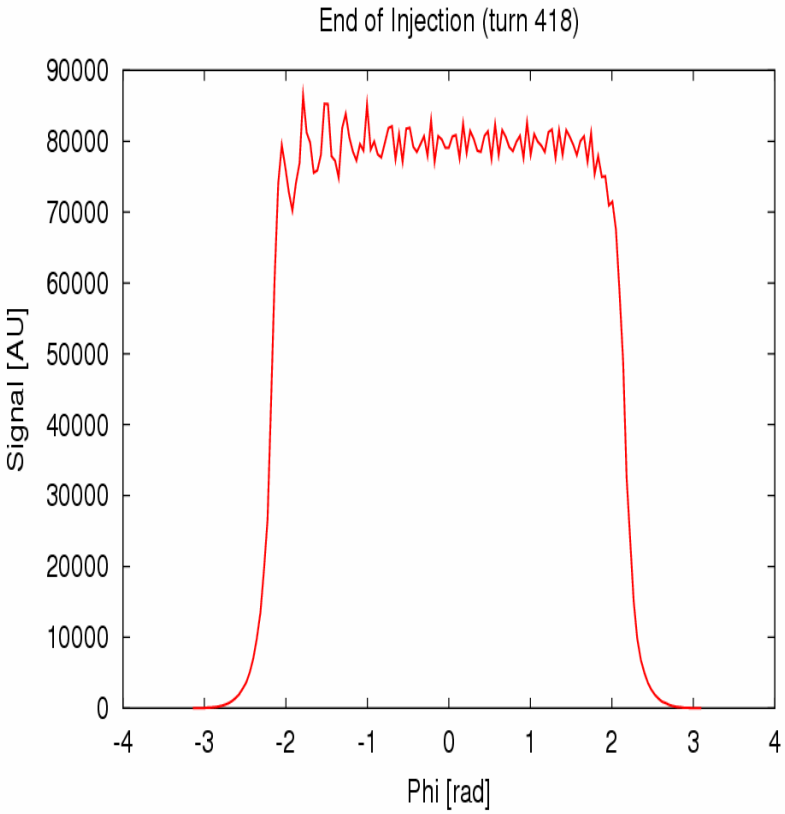
ORBIT Benchmark Results

- Instability peak @ 200 μs (150 μs after injection)
- Unexplained behavior after instability peak

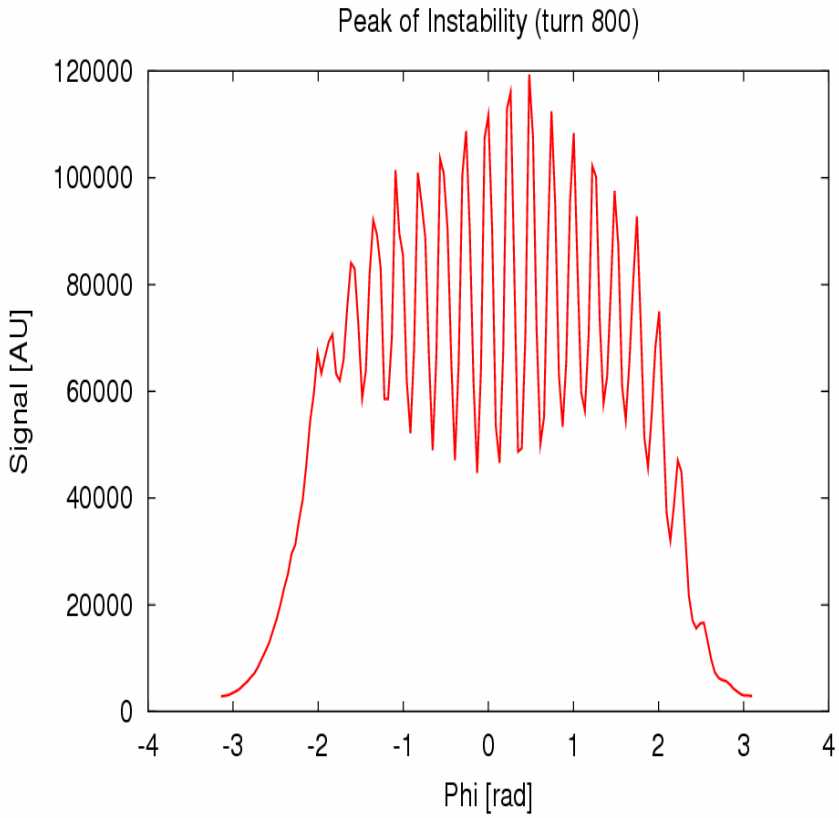


Simulated One-Turn Wall Current Monitor Signal

Bunch profile at end of injection



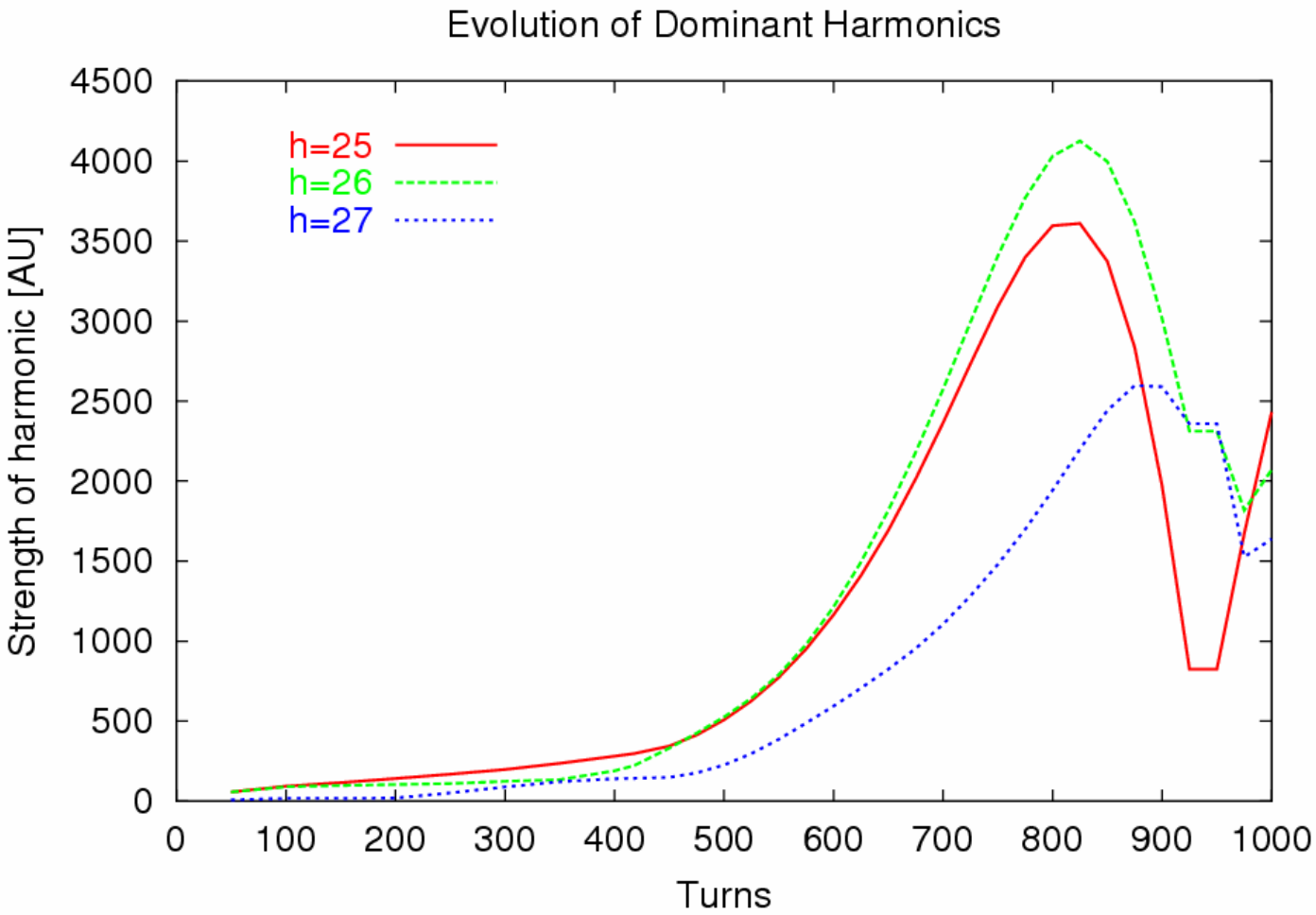
Bunch profile a peak of instability



(Peak current during instability) / (Current @ end of injection) ≅ 1.5

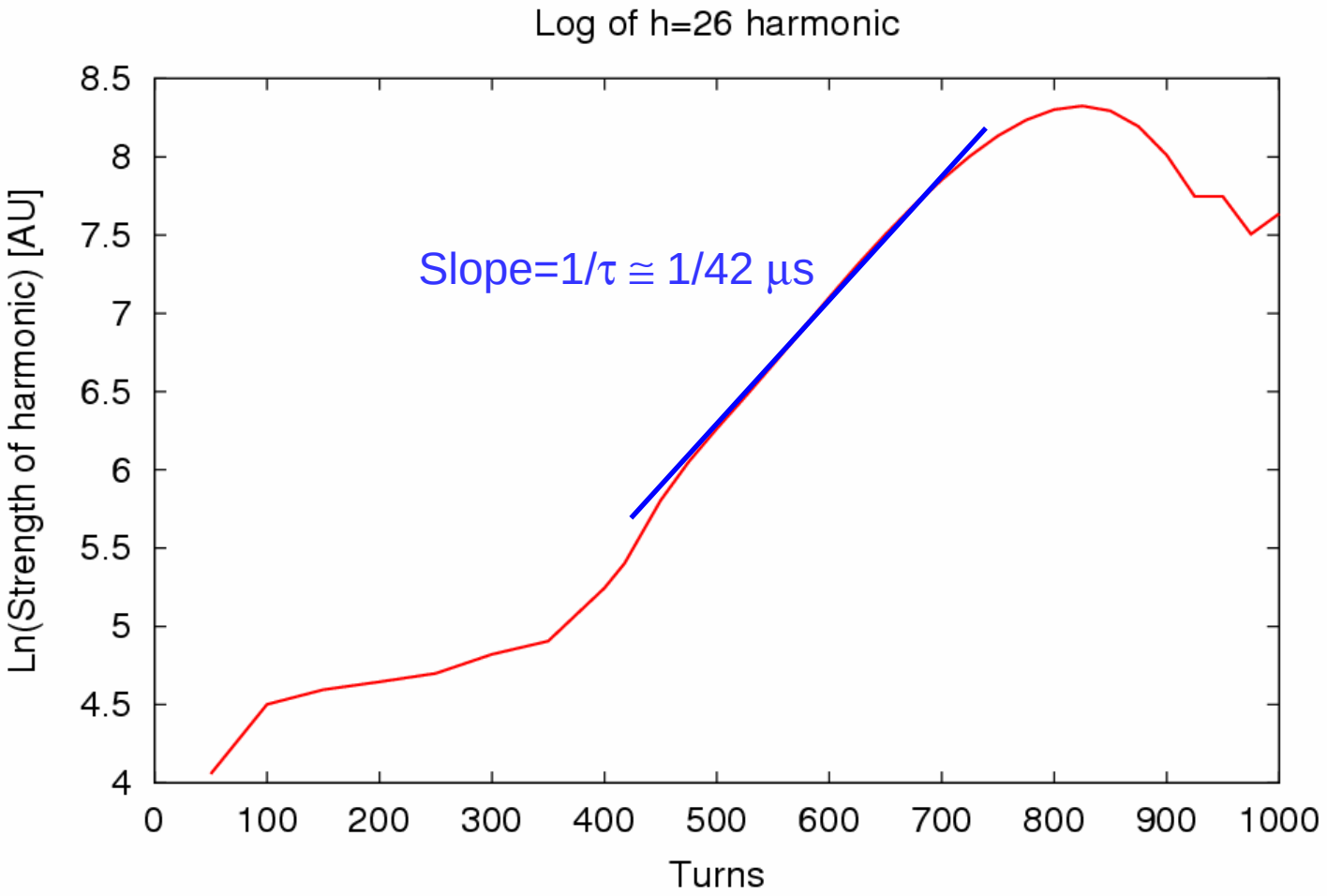
Evolution of Dominant Harmonics

- Exponential growth of harmonics observed.
- Dominant harmonic is h=26.



Growth Time of Instability

Growth time of instability, $\tau \cong 42\ \mu s$



Summary and Δp/p Sensitivity Study

Instability is sensitive to Δp/p distribution.

→ ±20% error on nominal distribution used (C. Beltran).

Summary of Benchmark Results and Sensitivity Study

	Experiment	ORBIT; Δp/p nominal	ORBIT; Δp/p -20%	ORBIT; Δp/p +20%
Duration after injection until instability saturation	**~150 μs**	**~150 μs**	~100 μs	~210 μs
(Peak current) / (Current @ end inject)	**~1.7**	**~1.5**	~1.7	~1.2
Dominant harmonic	**26**	**26**	26	25
Instability growth time, τ	**33 μs**	**42 μs**	-	-

- No instability is seen in simulations using the impedance for the heated inductors.
- 3D tracking in ORBIT (using generic injection parameters) produces same results.

Question: Does experimental data exist for benchmarking the instability threshold?