

# Feedback Control of E-Cloud Instabilities

CM-12 Progress Report

April 2009

## LARP Ecloud Contributors

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## Overview and Outline- activities June 2008 through April 2009

### Simulation efforts

- Warp
- Head-tail
- Feedback model

### SPS Machine measurements June 2008 and August 2008

- a more sophisticated look at August 2008 data

### Efforts to compare WARP, Head-Tail and Machine measurements

- sliding window FFT ( tune vs. slice vs time)
- Eigenvalue estimation

### Near-term plans

- Lab effort- evaluation of 4 GS/sec. D/A
- Study SPS Measurements from August - compare with simulations
- SPS measurements June 2009

### 5 year Planning for CM-12

## Collaboration Progress and Events

MD measurements

Simulation efforts

Lab technology efforts

Biggest impact - tighter multi-lab collaboration on Feedback and Ecloud

- Mini-workshop October 2008 ( SLAC)
- LBL meeting ( jan 2009)
- SLAC meeting March 2009
- bi-weekly WEBEX meetings

Impact - focus on methods to compare simulations, validate with machine measurements

Can we develop common tool and framework to compare methods?

Common data repository, access to data

Can we validate simulations, for example, with NO ecloud effect?

## Jan - April 2009 focus Compare WARP, Head-Tail

Are we studying similar cases? Do they agree?

bunch properties, lattice, Electron density, etc.

post-processor for head-tail

(non-uniform sampling requires upsampling, re-sampling on uniform time coordinates)

sliding window FFT techniques - check tunes, tune shifts

- within slices
- vs. time

structures within bunch -decomposition into spatial harmonics

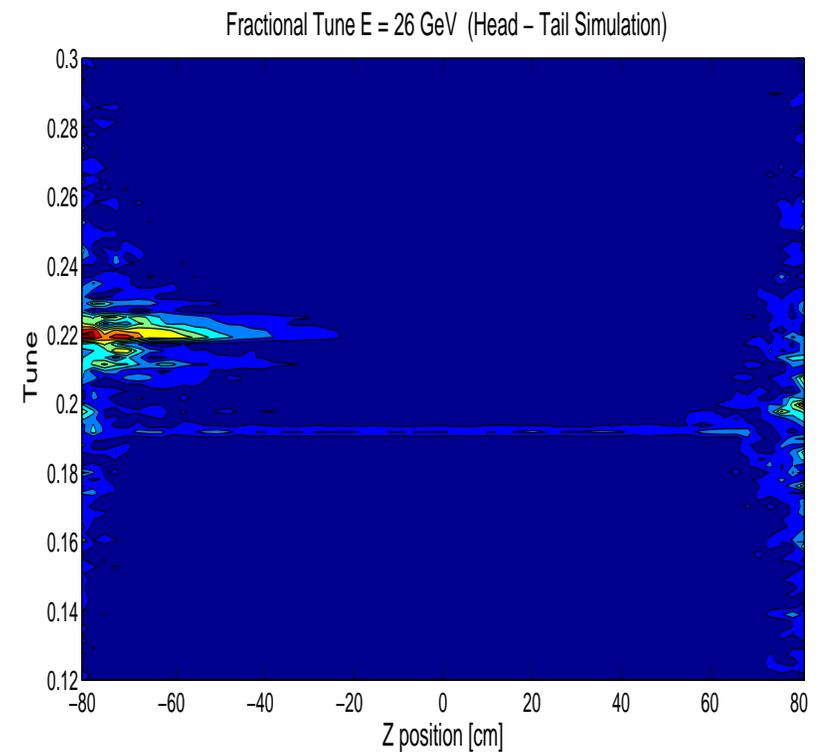
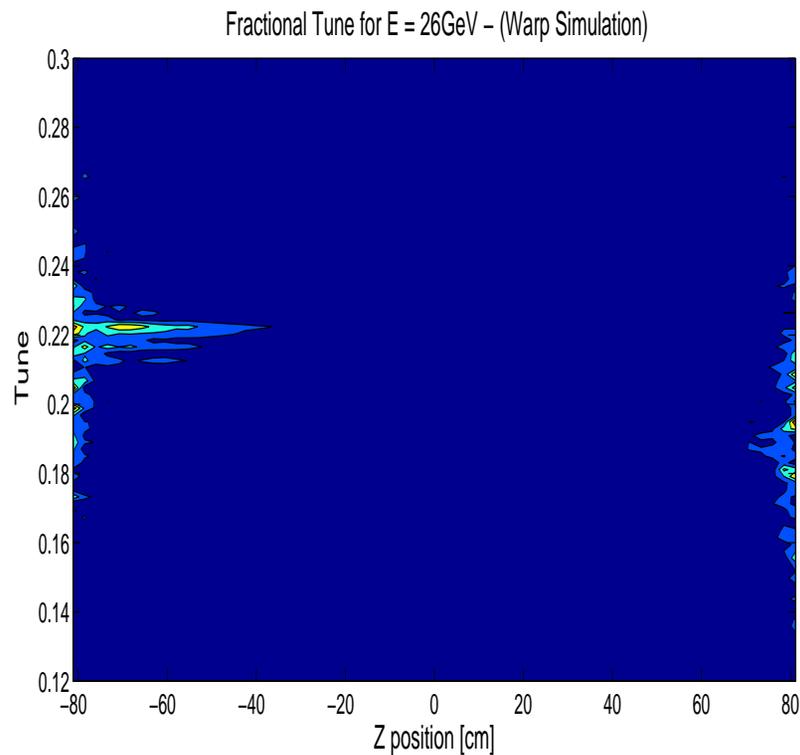
Critical to understand required sampling rate ( bandwidth) of within-bunch controller

## Simulation efforts - Ecloud models

three ongoing directions

- Warp
- Head-tail
- Linear (Feedback evaluation) model

Effort to directly compare WARP and Head-Tail SPS cases for similar initial conditions



## Analysis of Ecloud simulations

Time domain simulations

- Movies are nice, give insight - but quantitatively
- What frequencies are present in the bunch structure?
- How do they evolve over the time sequence?
- Is there useful correlations between parts of the bunch, other bunches?

Goal - develop normal-mode, other formalisms to extract

- Modes within the bunch
- growth rates of modes
- tune shifts, nonlinear effects

use existing PEP-II coupled-bunch model, Eigenvalue fitter

not exactly right, but a starting point

## Feedback Design and Estimation

To design feedback, we first need a linear analytical model system

Understand dynamics, design controllers, evaluate stability, robustness

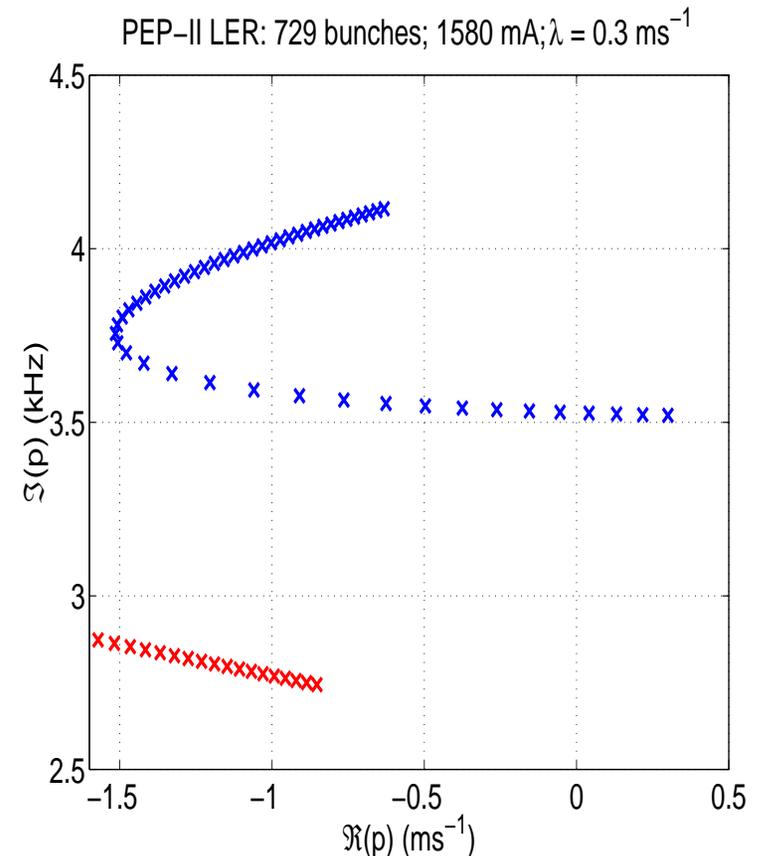
limits of control

- maximum growth rate,
- maximum tune shift,
- maximum excitation with restoration to equilibrium state
- impact of channel noise, offsets on equilibrium state

Only after we have a good controller for a linear system should we try to study this controller on the non-linear time-domain codes

Control theory linear tools ( e.g. Root Locus methods)

- linear system - seconds of compute time
- WARP code - supercomputer cluster, long runs to simulate a few hundred turns in accelerator



## Simulation efforts - Linear Estimation models

extract information from the numeric simulations to use in a linear analytical ( coupled-oscillator) model

Goal - use same technique on SPS data from August 08 and (hopefully) June 09

We can understand dynamics of a linear system, design controllers, estimate limits of control, etc.

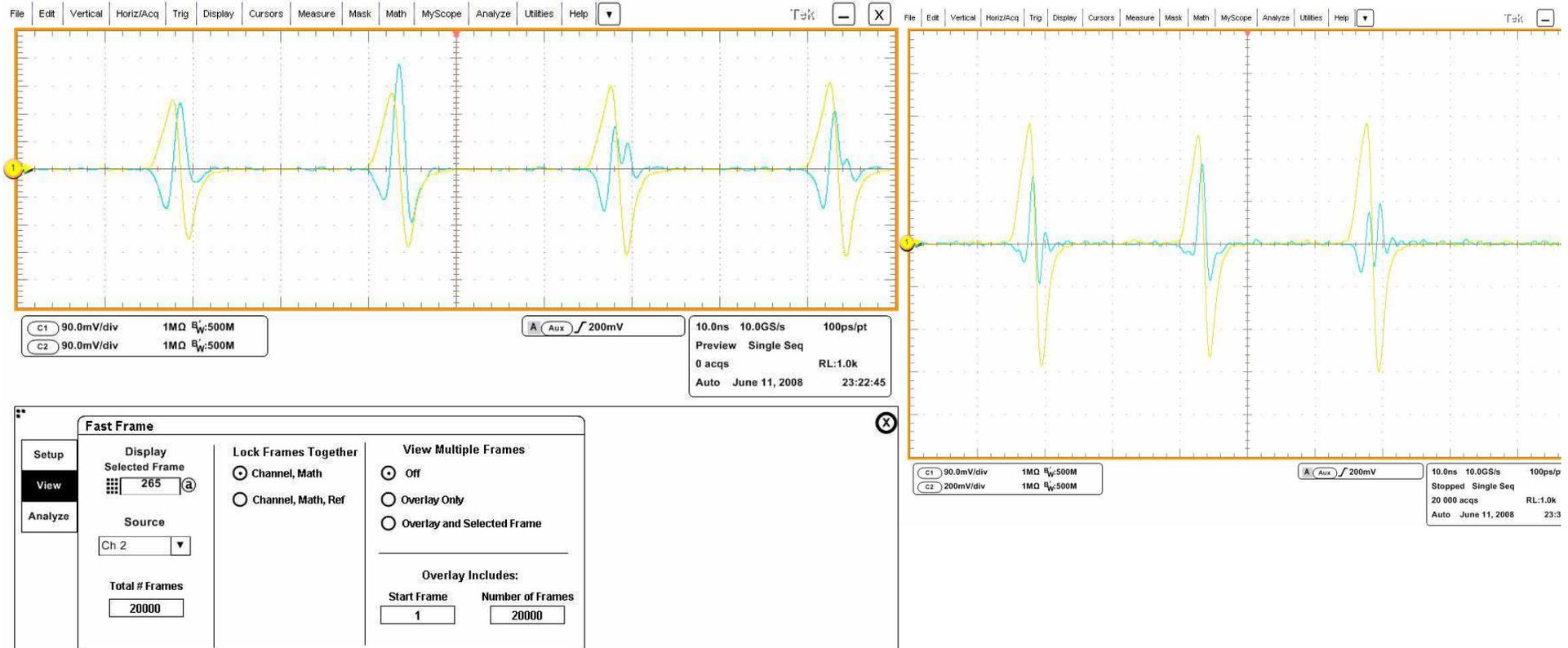
These models are how we design the feedback controllers, estimate dynamics and limits of control

## Results from the June 6 MD

W.Hoefle, G. Rumolo, G. Arduini, R. De Maria, J. Byrd et al -

- Dedicated MD in SPS during machine scrubbing
- intensity  $1E11$  P/bunch, 25 ns separation, 72 bunches/batch, 5 batch injection (4 nominal LHC)
- lowered chromaticity to reduce damping - transverse signal seen after 5th batch injection

Transverse signals from exponential stripline couplers, hybrids (yellow sum, blue vertical)



## Results from the August 12 MD

Follow-on from June MD

J. Fox, W. Hoefle, R. De Maria, G. Arduini, G. Rumolo, J. Thompson et al

Tunnel Access to SPS - measure exponential coupler matching, find/fix lousy connections

Move difference hybrids from tunnel to control room, match lengths of long Heliax

Sort out issues with hybrids, measure best 3, build simple receiver

Prepared data recorder, software, use wideband 2 GHz bandwidth, 50 ohm input Z, etc.

MD rescheduled twice from 8/11, finally get 2 AM to 10AM Aug13

### Results

4 batches  $1E11$  P/bunch, 25 ns spacing, 72 bunches batch- better vacuum than June?

lowered chromaticity per June but 4 not 5 batches

**NO 700 Mhz Transverse signal at high frequency observed** (time or frequency domain)

lots of high-frequency signals  $> 1700$  MHz observed - propagating modes in 10 CM vacuum chamber

added RF voltage modulation to try to excite quadrupole oscillation (increase density)

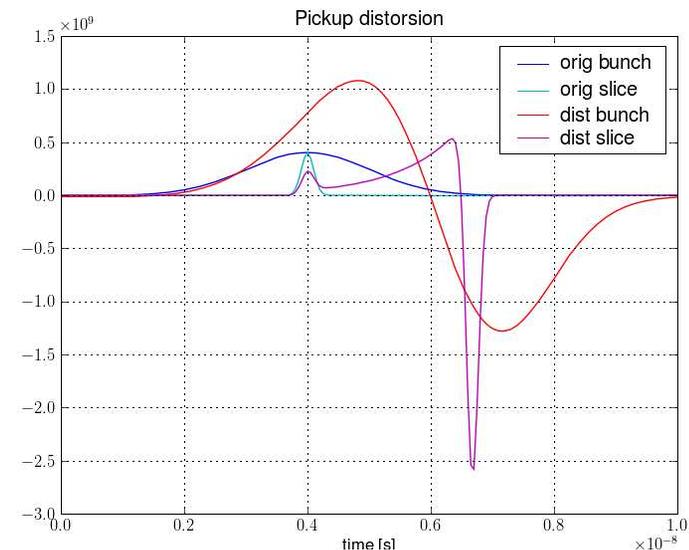
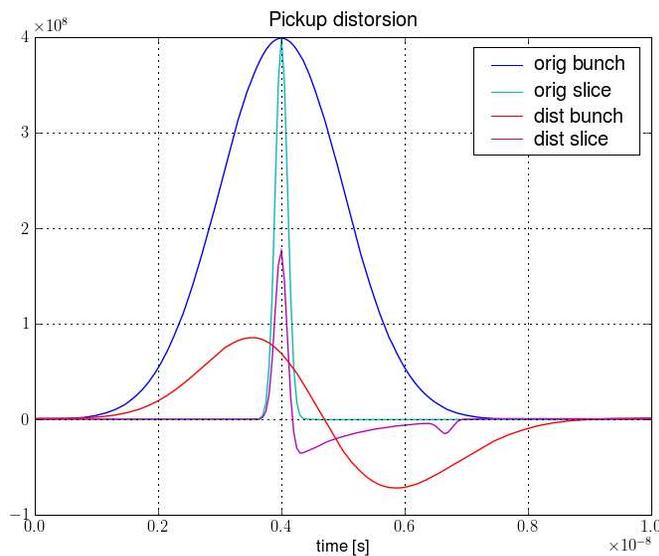
**NO Ecloud-like signal observed at the time of the study**

## A second look at the Measurements of August 2008

At the August 2009 MD, we observed very complicated high frequency signals on the pickups. During the MD we attributed this to propagating TE modes in the 10cm vacuum chamber (cut off estimated at 1800 MHz). We were not able to see very convincing direct signals in the time or frequency domains that looked like the June 2008 data.

Subsequent to the MD, some investigations revealed:

The exponential stripline couplers in the SPS were placed in two orientations, consistent with their use in the p pbar program. By some luck, we were connected on the “downstream” port of a coupler (it was intended for use with oppositely circulating pbar). This gives a response with nonlinear group delay with frequency, other instrumental effects (below, right). Part of the difficulty in interpreting the August data is from this response, part from propagating modes.

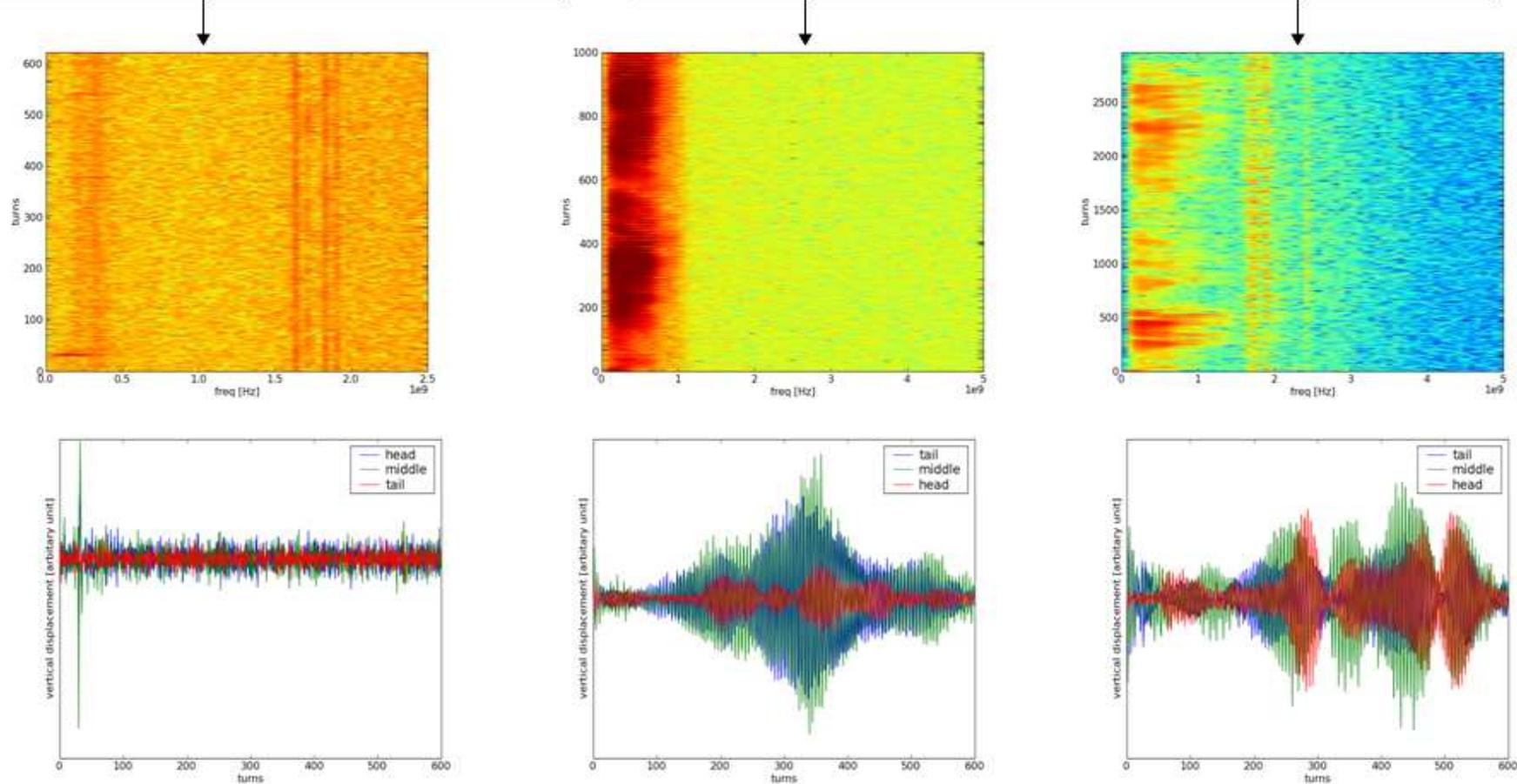


August data equalised and reconstructed by R. De Maria, W. Hofle

**Observations of SPS e-cloud instability with exponential pickup**

Bunch in the first (stable) batch (June)

Bunch in the last (unstable) batch (June and August)



August data (right) after scrubbing period: data filtered from noise