TTF/FLASH 9mA Experiment
Recent Machine Studies Overview

Nick Walker

John Carwardine

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The (International) Shift Team

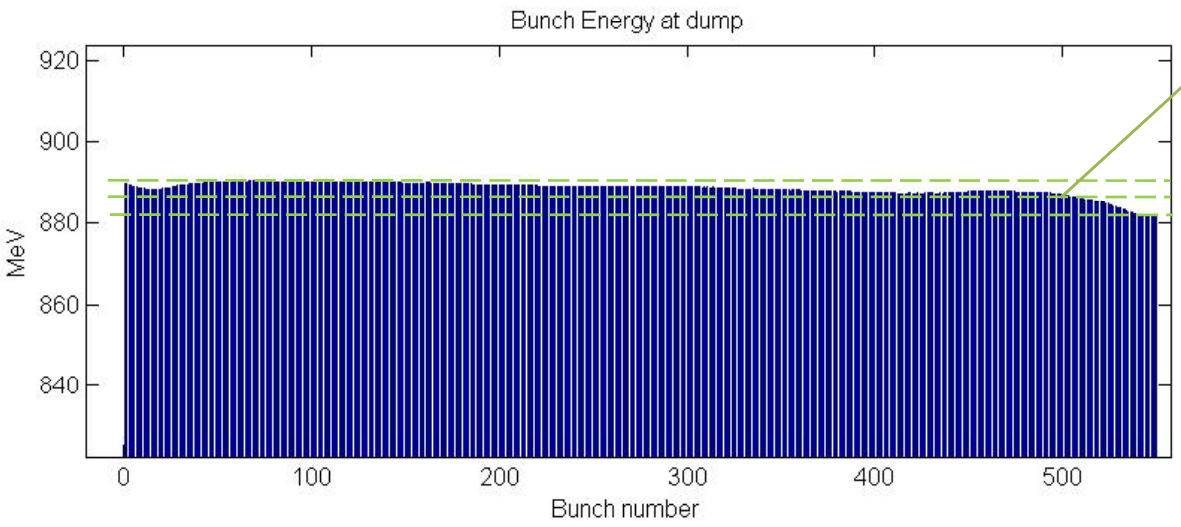
- FLASH Experts (DESY)
  - Siggi Schreiber - laser/gun injector set-up
  - Bart Faartz - general set-up
  - Lars Froehlich - TPS installation / commissioning, BLM calibration
  - Florian Loehl - optics matching & emittance
  - Holger Schlarb - optics & steering
  - Nina & Vladimir - optics calculations
  - Valeri Ayvazyan - LLRF set-up and tuning
  - Mariusz Grecki - LLRF set-up and tuning
  - Waldemar Koprek - LLRF set-up and tuning (mostly gun)
  - (Jacek Sekutowicz - HOM absorber measurements)
  - Nick Walker - overall coordination
- ANL
  - John Carwardine - LLRF / overall coordination
- FNAL
  - Brian Chase - LLRF (experiment & data analysis)
  - Gustavo Cancelo - LLRF (experiment & data analysis)
  - Michael Davidsaver - DAQ applications programming
  - Jinhao Ruan - laser setup
- KEK
  - Shinichiro Michizono - LLRF (experiment & data analysis)
  - Toshihiro Matsumoto - LLRF (experiment & data analysis)
- SLAC
  - Shilun Pei - LLRF (experiment & data analysis)
- SACLAY
  - Abdallah Hamdi - TPS installation / commissioning

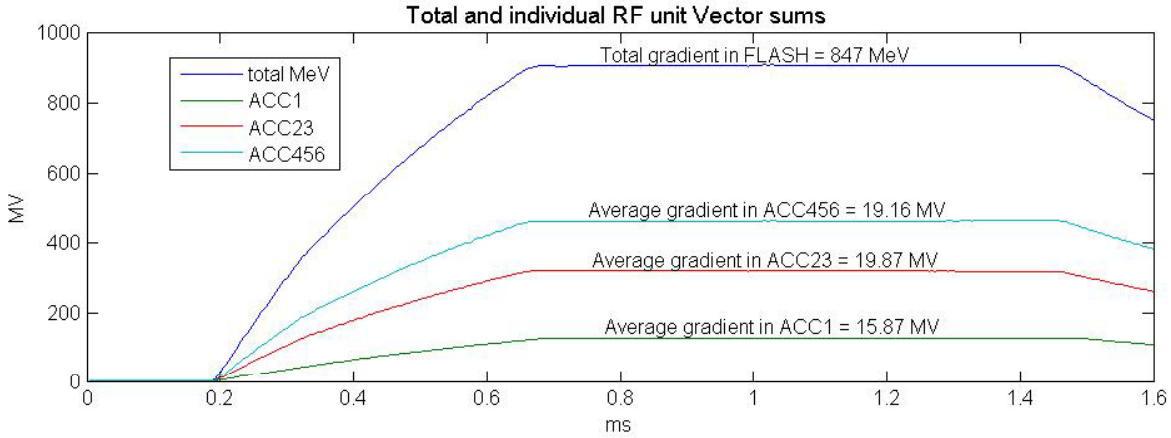
Primary Goals for September Run

Goal			
Calibrate by-pass BLM	1.5 shifts	✓	
Install/commission by-pass TPS	1.5 shifts	✓	software mask problem prevented long-pulse operation until Friday AM
Injector set-up for 3nC bunches (laser/gun set-up) Loss-free transmission to dump via bypass (optics & steering)	3 shifts	✓	Achieved complete loss-free transmission up to our max of 550 bunches (after LLRF tuning)
Gradually increase bunch number @ 1MHz (3mA) as far as possible; identify problems and constraints. HOM absorber measurements	3 shifts planned ¾ shift achieved	✓✘	• Actually achieved* ~2.5 mA with (max) 550 bunches (μs) at ~880 MeV to dump after about four-hours tuning (LLRF). • An average beam power of ~6 kW (final goal 36 kW). • ΔT reported on HOM absorber consistent with current.
Not planned!!		✘	Dump vacuum failure at ~13:00 on Friday 26.09

*) 3nC at gun – but ~20% was estimated to be lost at gun collimator to reduce downstream losses

High Beam-Loading Long Pulse Operation





10 MeV over 550 bunches (~1%)
(~4 MeV over 1st 500)

- 450 bunches achieved with stable operation
  - Few hours of archived data
  - Currently under analysis
  - (vacuum OK)
- Long bunch trains with ~2.5 nC per bunch:
  - 550 bunches at 1MHz
  - 300 bunches at 500KHz
  - 890 MeV linac energy
- All modules (RF) running with 800us flat-top and 1GeV total gradient
- Increase from 450 to 550 bunches eventually caused vacuum incident
  - The “straw that broke the camels back!”

General comments

- **From an RF perspective, we made tremendous progress**

- RF control worked well, and ramping up the number of bunches was surprisingly smooth and rapid
- LLRF systems needed expert tweaking to maintain transmission along the bunch train as the number of bunches and beam loading were increased

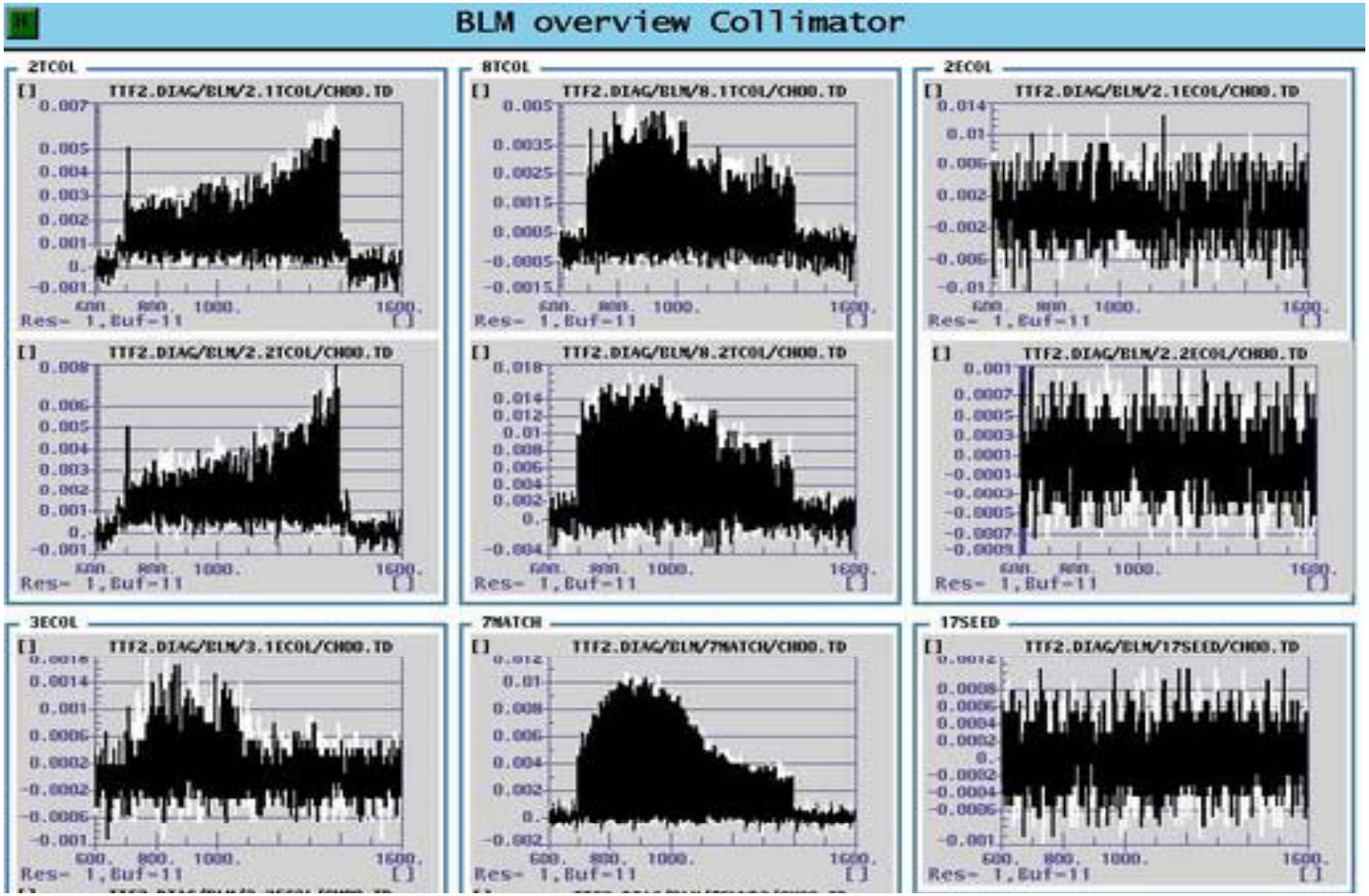
- The three LLRF setup shifts were invaluable in preparing for the long pulse operation

- There is work to be done before a 9mA studies run

Data analyses

- Sufficient data collected to allow initial assessment of:
  - Energy aperture scans (correlate energy with BLMs)
  - LLRF contribution to energy variations within bunch train and pulse to pulse
  - Cavity field amplitude tilt vs beam loading
  - Beam energy vs gradient vector sum
  - Lorentz force detuning vs gradient
  - Peak vs mean klystron forward power
  - (Perhaps) limited information on drift
- Analysis of bpm data should allow some assessment of the quality of information from the energy server

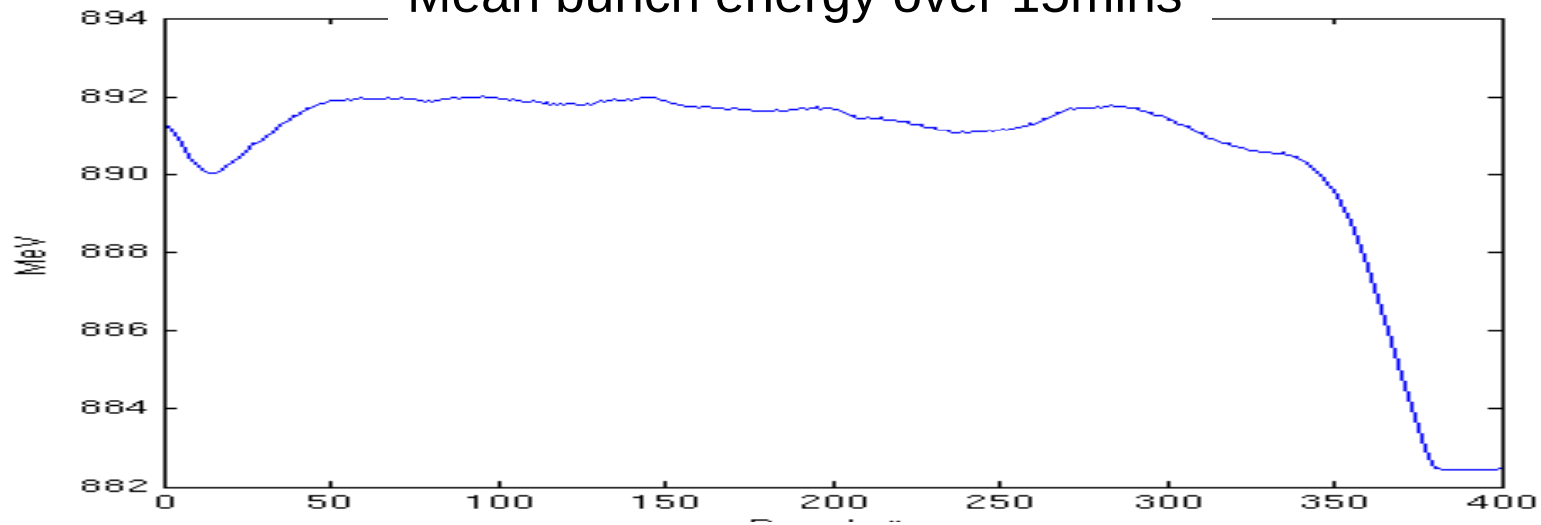
BLM signals for long bunch trains



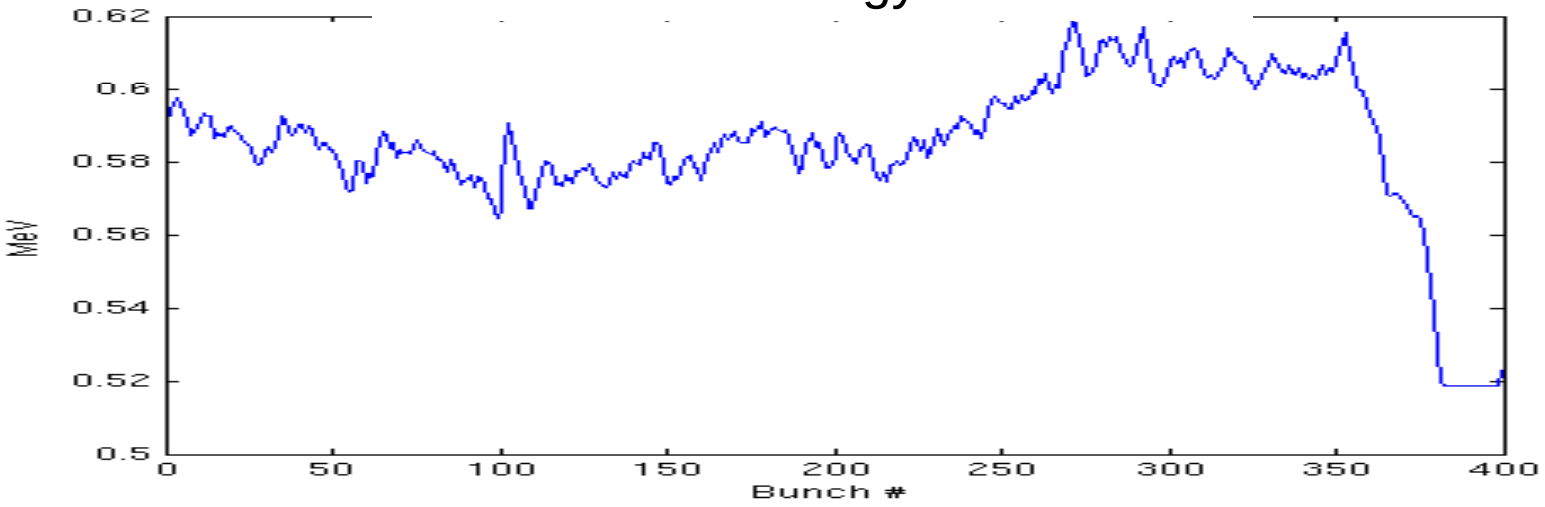
- BLM signals have structure over bunch train
- Will look for correlations with other signals, eg energy

Energy along bunch train

Mean bunch energy over 15mins



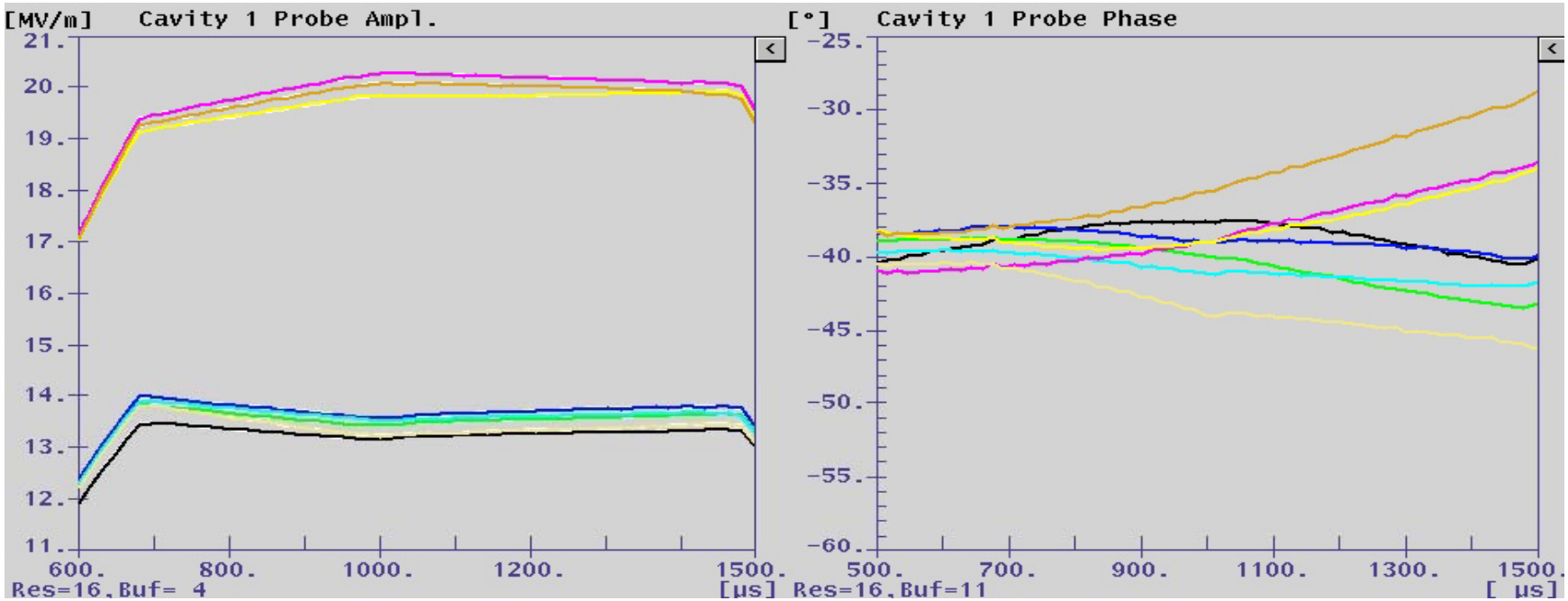
Std Dev bunch energy over 15mins



Cavity tilts on ACC1

(300 bunches, 2.5 nC/bunch at 1MHz)

- Without beam, each cavity is set up to have a flat vector sum
- With beam, high gradient cavities drive vector-sum up toward quench limits while low gradient cavities droop.
- At 2.5mA the slope is 2.8MV/m per ms



Feed-forward / feedback

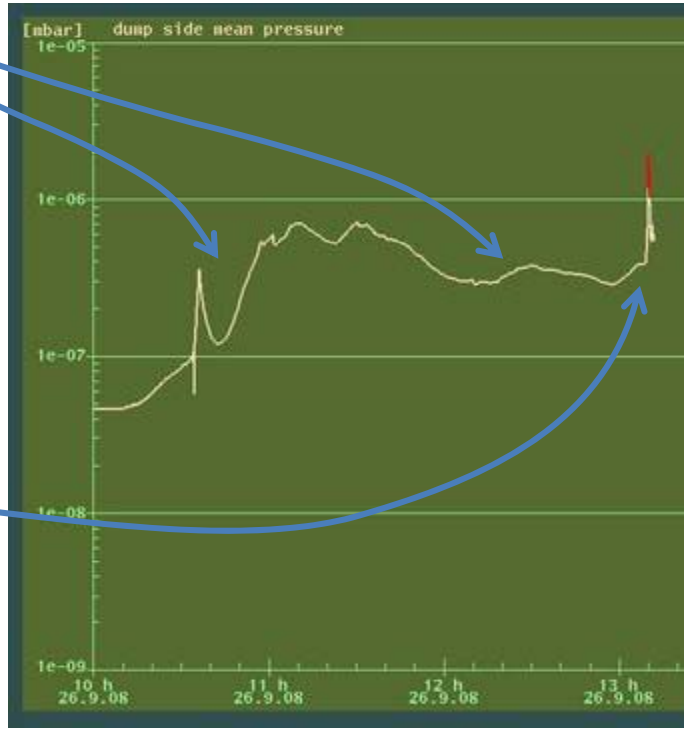
- There is a lot of ongoing discussion on feed-forward, *adaptive* feed-forward, feedback

- Modifications/improvements of adaptive FF are needed at ACC2/3, ACC4/5/6 and ACC1, e.g.
  - Add more consistency checks, boundary conditions …
  - LLRF systems should be pre-loaded with the known bunch structure and nominal beam charge
  - All LLRF systems should use the same AFF algorithm
  - ACC23 & ACC456 will need upgrading to SimconDSP

- Should be less reliant on adaptive FF
  - Improve feed-forward tables and rely more on fast feedback
  - General opinion is that the feedback gains should be higher (caveat: may run into HLRF limitations)

Vacuum Incident

- Original vacuum threshold (2×10^{-7}) was surpassed at 08:10 on Friday (26.09)
  - 350 bunches @ 500kHz
  - Raised by vacuum expert to 10^{-6}
- Increase to 450 bunches (1 MHz) showed increased vacuum, but signs of 'out-gasing'
- Further increase to 550 bunches caused vacuum trip.
  - Later followed by vacuum failure
  - Assumed cause thermal cycling
- Further instrumentation (MPS) required before replacing damaged beamline segment
  - *And* before running high power beams to the dump!



Beam dump area

Summary

- Despite rather severe vacuum incident, shifts were a success
  - Demonstrated that we can cleanly transport high-power beam through by-pass (up to 550 ms)
  - By-pass TPS up and running
  - LLRF experience / data with ~3mA beam-loading

- Vacuum repair critical for further work
  - Better MPS instrumentation needed before more high-power beam experiments
  - (learning to deal with high beam powers is part of the game!)
  - Schedule of final repair still unknown
    - Current fix limits running to 30×1nC bunches

- Continue to plan for full 9mA tests
  - Full analysis of data and “lessons learnt” from September run
  - Write report !
  - Identify interim work for January / May.
  - December workshop ? (move to January?)

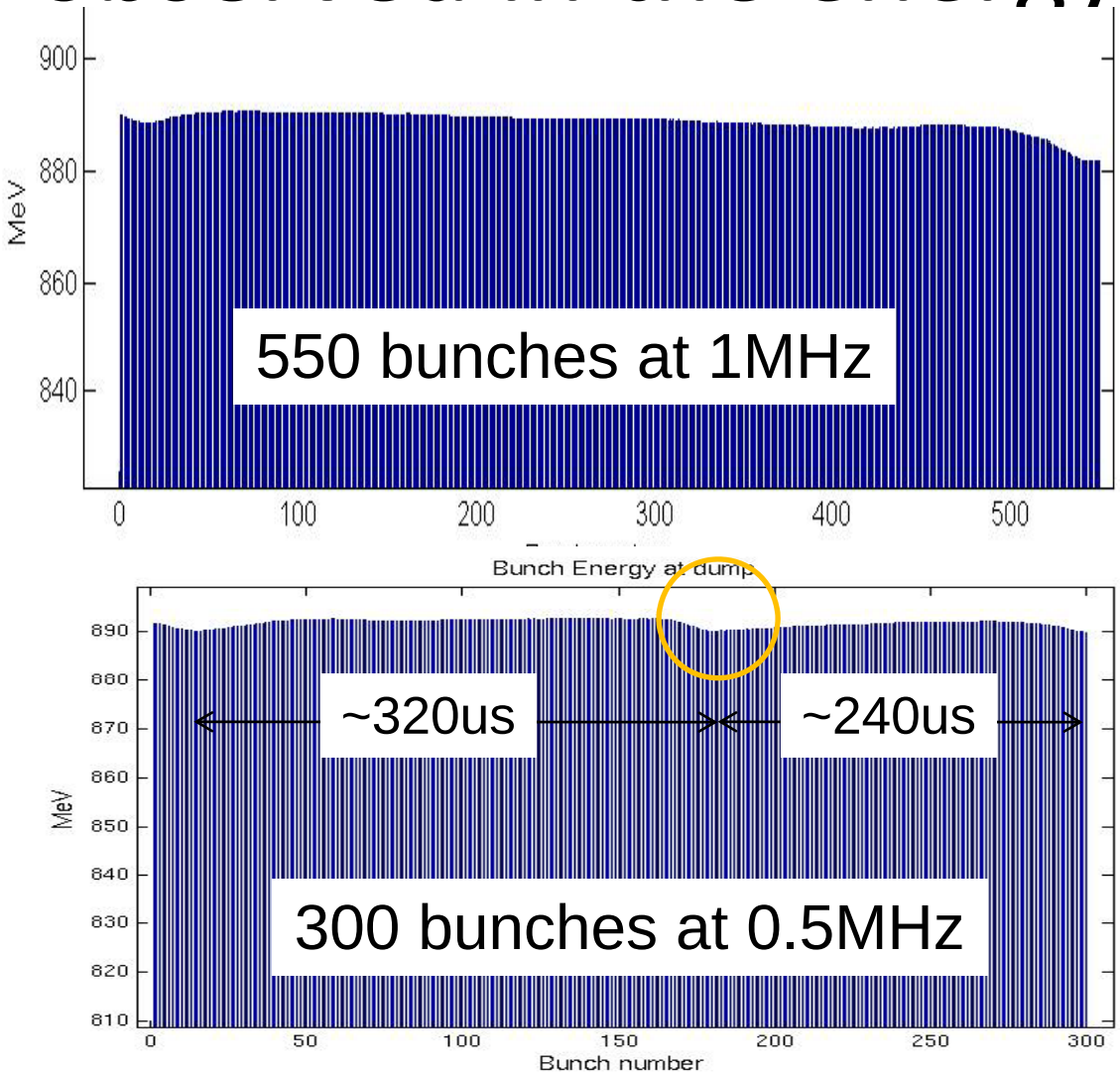
Other items

- Adaptive feed-forward (ACC23 and ACC456)
  - Slow reaction time is a problem, eg to change in number of bunches
- 250KHz ripple on ACC23 and ACC456
  - Bleed-through correction via ripple tables
  - Shows up inconsistently as noise on several DAQ channels
- Parametric tuning studies eg cavity tuners, energy, etc
  - Not done
- Look at ACC1 when running close to quench
  - Not done
- Check LLRF system responses to early pulse termination
  - Done. Responses not as desired. Needs work.
- Vector sum calibration with higher beam loading
  - Not done
- Exception handling was not tested at all. It is needed for the full 9mA studies.

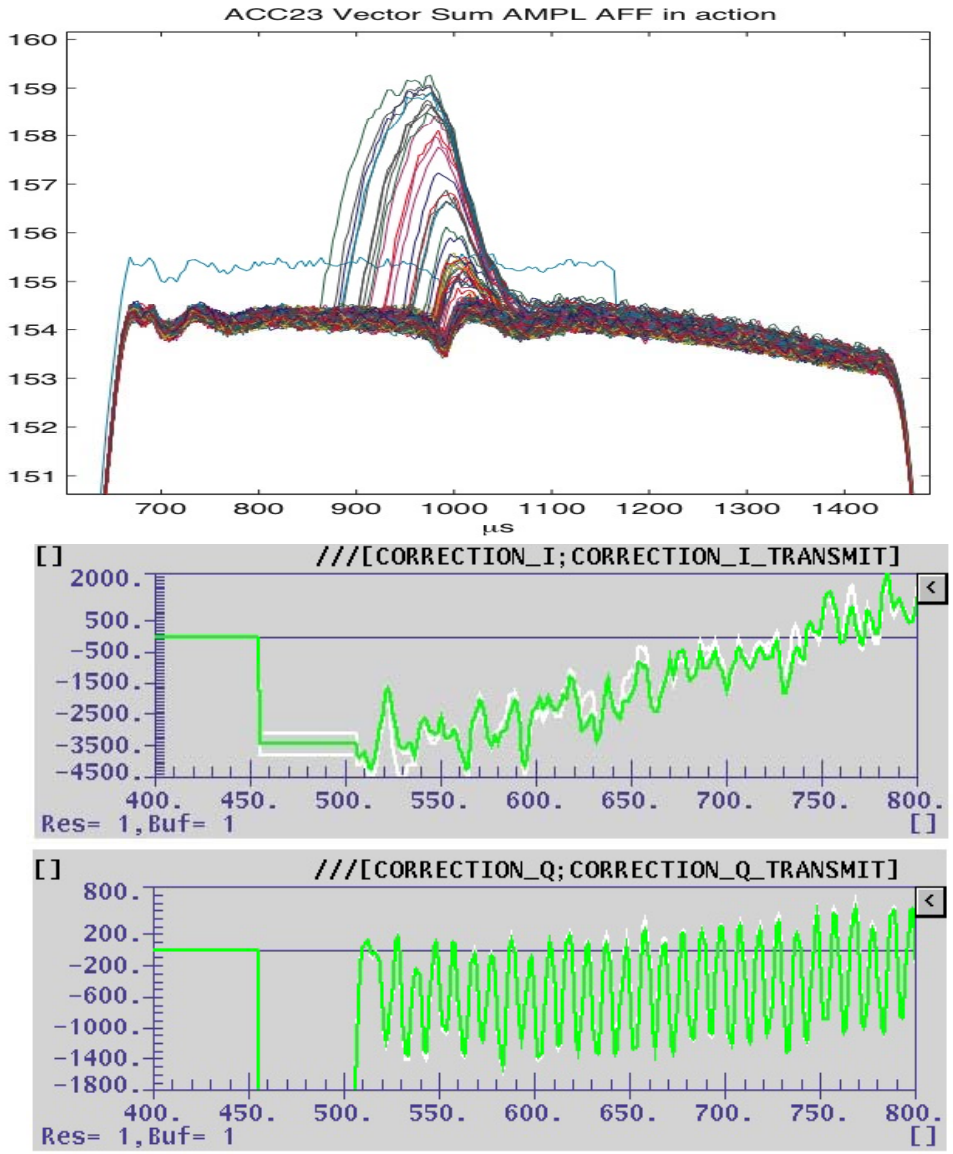
Additional Information (Technical Details)

Taken from John Carwardine's presentation at 07.10.08 meeting

Dips observed in the energy profile



ACC23 adaptive FF tables



- False corrections from early terminated pulses
- AFF response to 100KHZ bunch train – is this the *desired* response…?

A few assorted concerns

- Power limit of the circulators or other HLRF components and their interaction with AFF and feedback.
- Interplay between the TPS, AFF and feedback systems. Boundaries are quench limits, power limits, beam loss.
- Regulation of beam energy inter- and intra-pulse.
- Control of cavity gradient tilt.
- Accuracy of vector sum at the RF station level and algorithm for computing global vector sum. Early simulations show that beam energy and gradient do not directly correlate.
- Accuracy of the beam energy server in the bypass line

Data access

- *The DAQ archiver is our main tool for collecting & archiving data.*

- For the channels for which data was correctly stored the system works well and we have a tremendous amount of data available
- It was not possible to get correlated data across all interesting channels because some front ends do not support correlated archiving (buffer# or DAQ), including Simcon and DSP front ends

- Access to the DAQ system is currently only available through a MATLAB extension that is at the beta level of testing and there are no ‘easy’ ways to get access to the data
- Several matlab scripts have been written to speed analysis and provide an interface that is more consistent with the matlab environment

Some key follow-up items

- Plans for upgrading ACC23 and ACC456 LLRF systems
  - We should strongly support MSK plans for installing SimconDSP in ACC23 and ACC456
- Develop requirements for exception handling
- Improve tools for accessing DAQ archived data