# PLL

# Systems and Studies

# "New Opportunities"

Peter Cameron

# Outline

Criteria for the next 10 months

Systems overview - PLL and BBQ

Relevant previous results from PLL and BBQ

- coupling
- skew and non-lin chrom
- instabilities
- bunch train tune shift

Possible PLL systems Plan for Run06/07

# Criteria and goals for Run06/07:

- **primary - Low Material Costs**
- **primary - Large added value**
- **secondary - Labor Intensive**

This new circumstance is an excellent opportunity to add a lot of valuable functionality to PLL/BBQ/TW Schottky systems, to the benefit of both C-AD **and** LARP

Goals

- Tune/coupling feedback - improve ramp efficiency
- bunch-by-bunch tune, chrom, emittance, dp/p - diagnostics for eCloud and beam-beam

# PLL Systems overview

**245MHz system (PLL)**

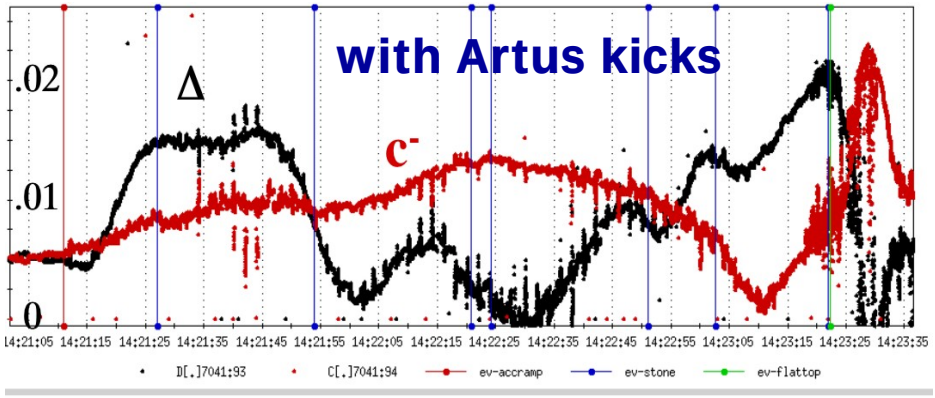
- capabilities
  - high resolution **relative** tune measurement (linewidth)
  - gated measurement - 1μsec resolution along bunch train (resonant PU)
- weaknesses
  - dynamic range - rev line at $\gamma_t$ and with 197MHz RF on (also LFS)
  - coupling and eigenmode hopping

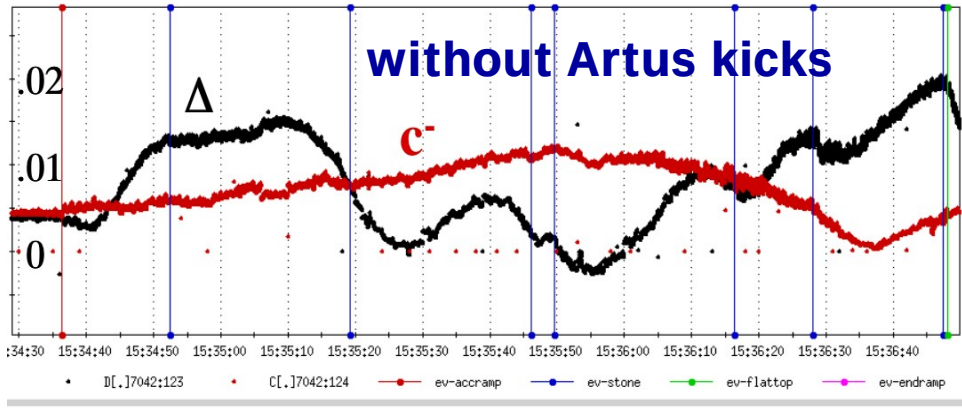
**Baseband tune system (BBQ)**

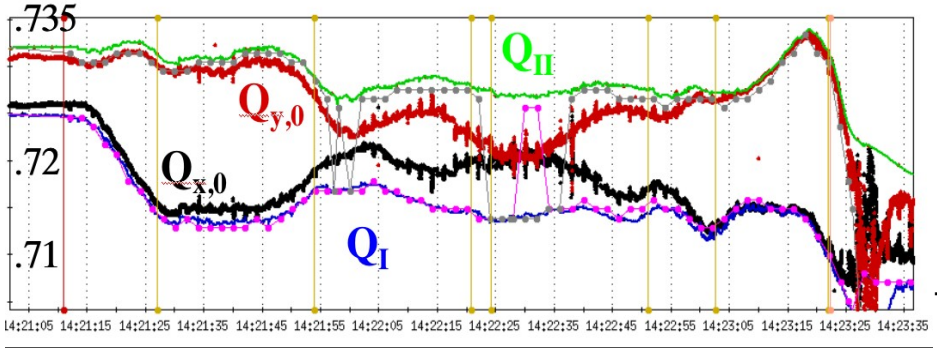
- capabilities
  - high sensitivity ~10nm
  - higher absolute accuracy than 245MHz PLL - 60MHz LP on diodes?
  - pretty much immune to rev line
  - continuous measurement of all 8 eigenmode projections
  - possibility of improved coupling measurement/correction/feedback
- weaknesses
  - interference from mains harmonics
  - gated measurement along bunch train not possible (???)
  - chromaticity measurement not possible

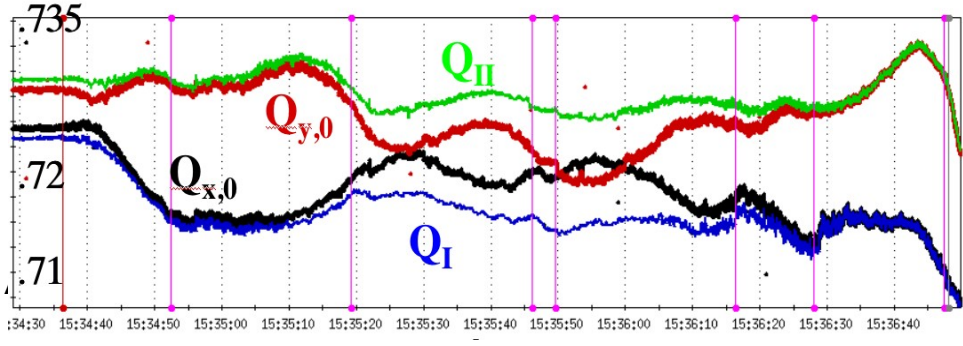
**measured eigentunes ($Q_I$ and $Q_{II}$), calculated set (D) and coupled ($c^-$) tune splits, and calculated unperturbed tunes ($Q_{x,0}$ and $Q_{y,0}$) for two successive ramps in RHIC.**

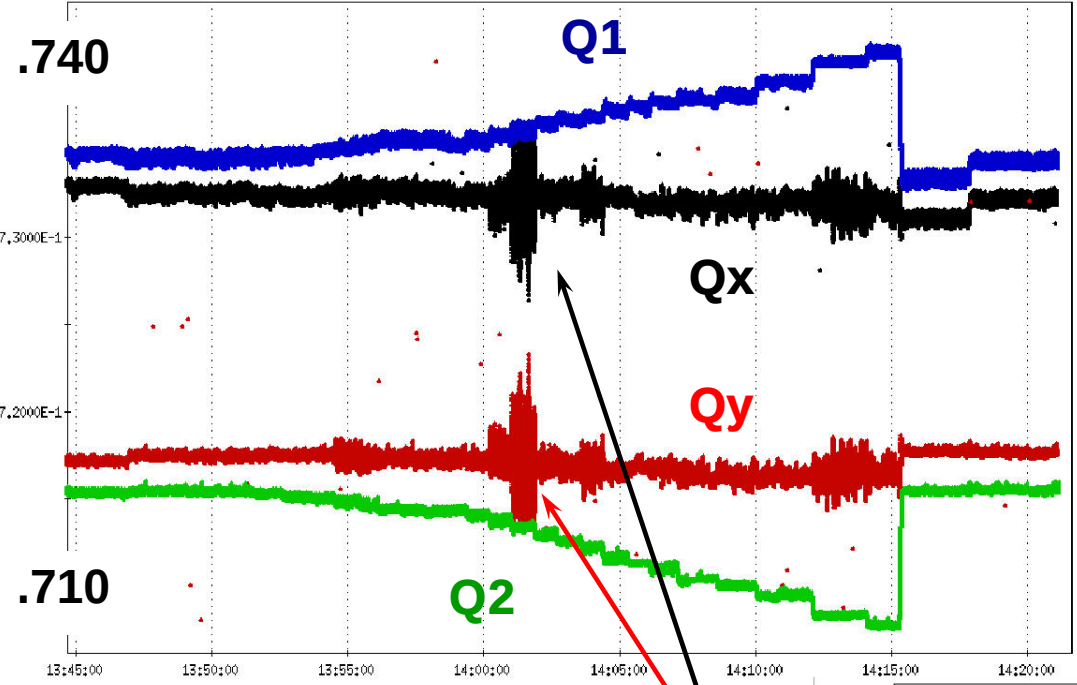
Note perturbation of Artus kicks (left image only) on coupling (due primarily to strong sextupoles)






Ram/Vincent/Todd

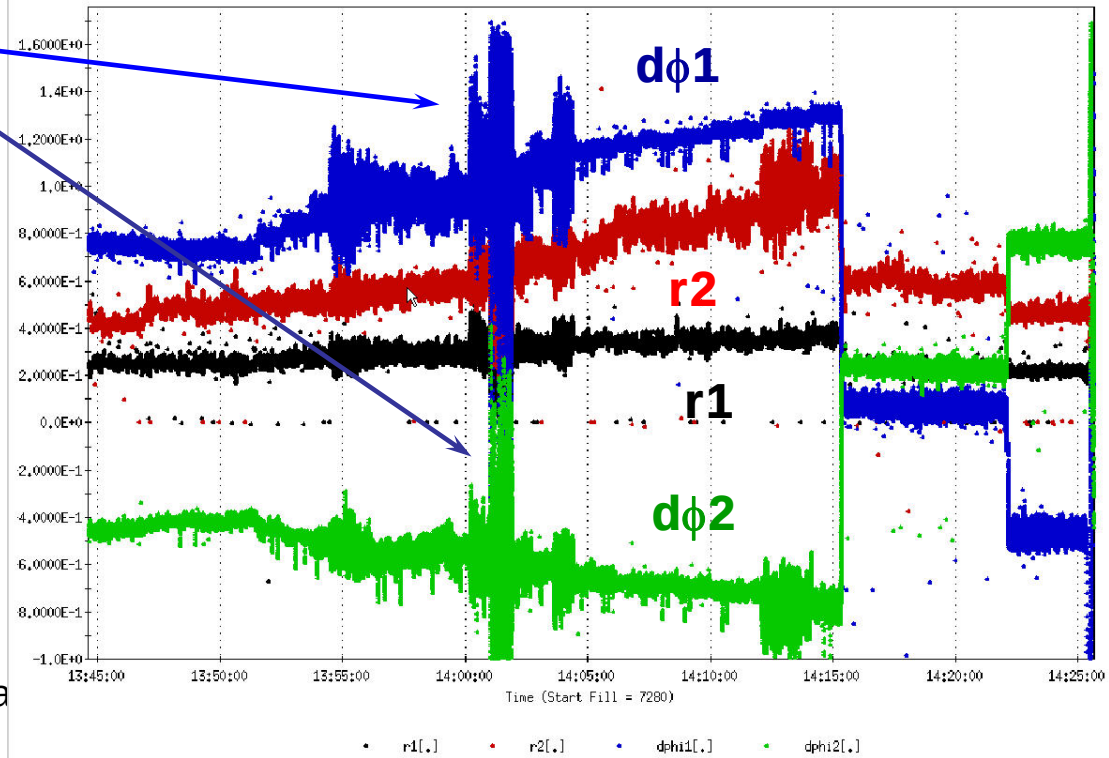
Local Coupling Study

June 13th

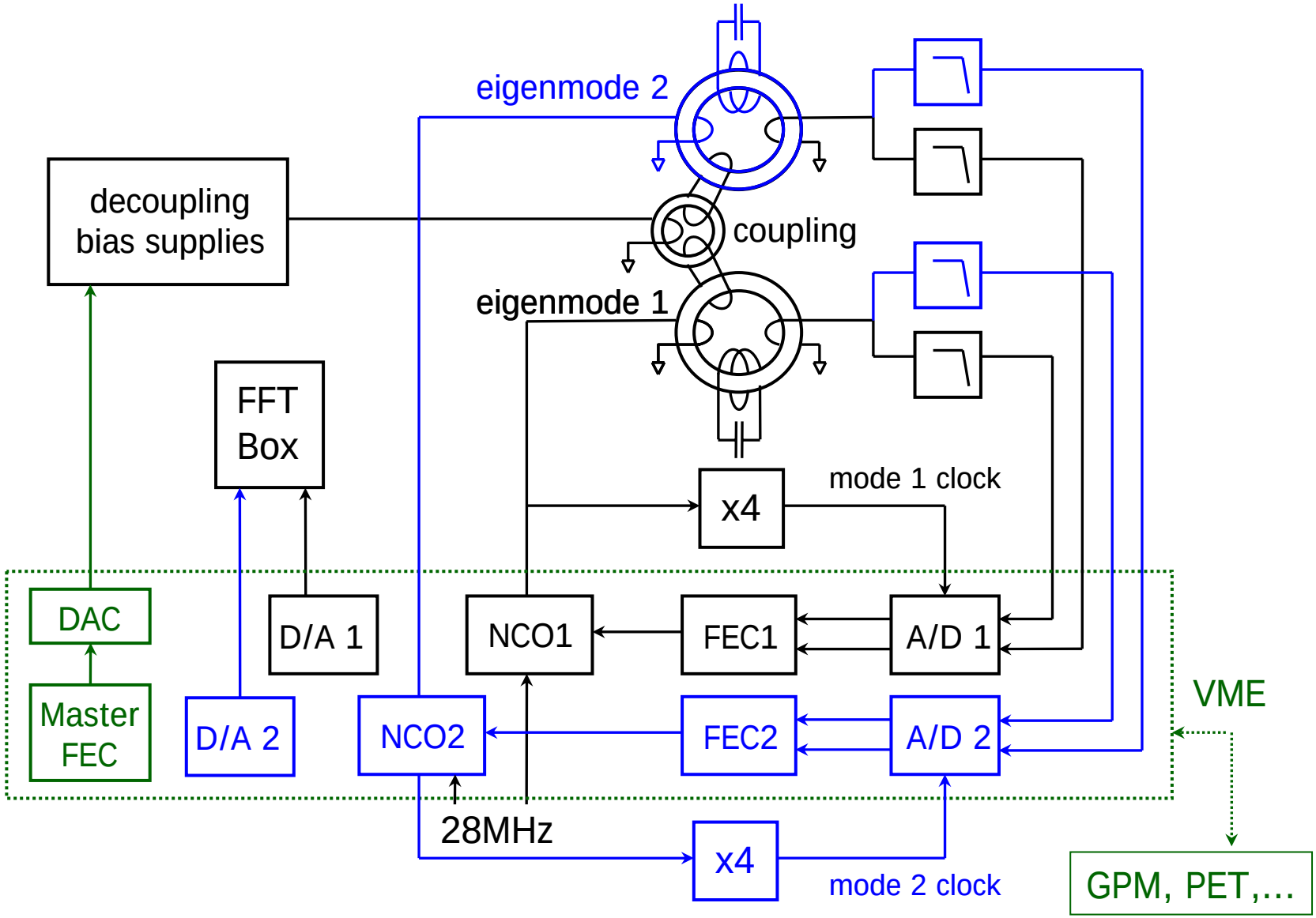
Scanning single skew quad

Implications:

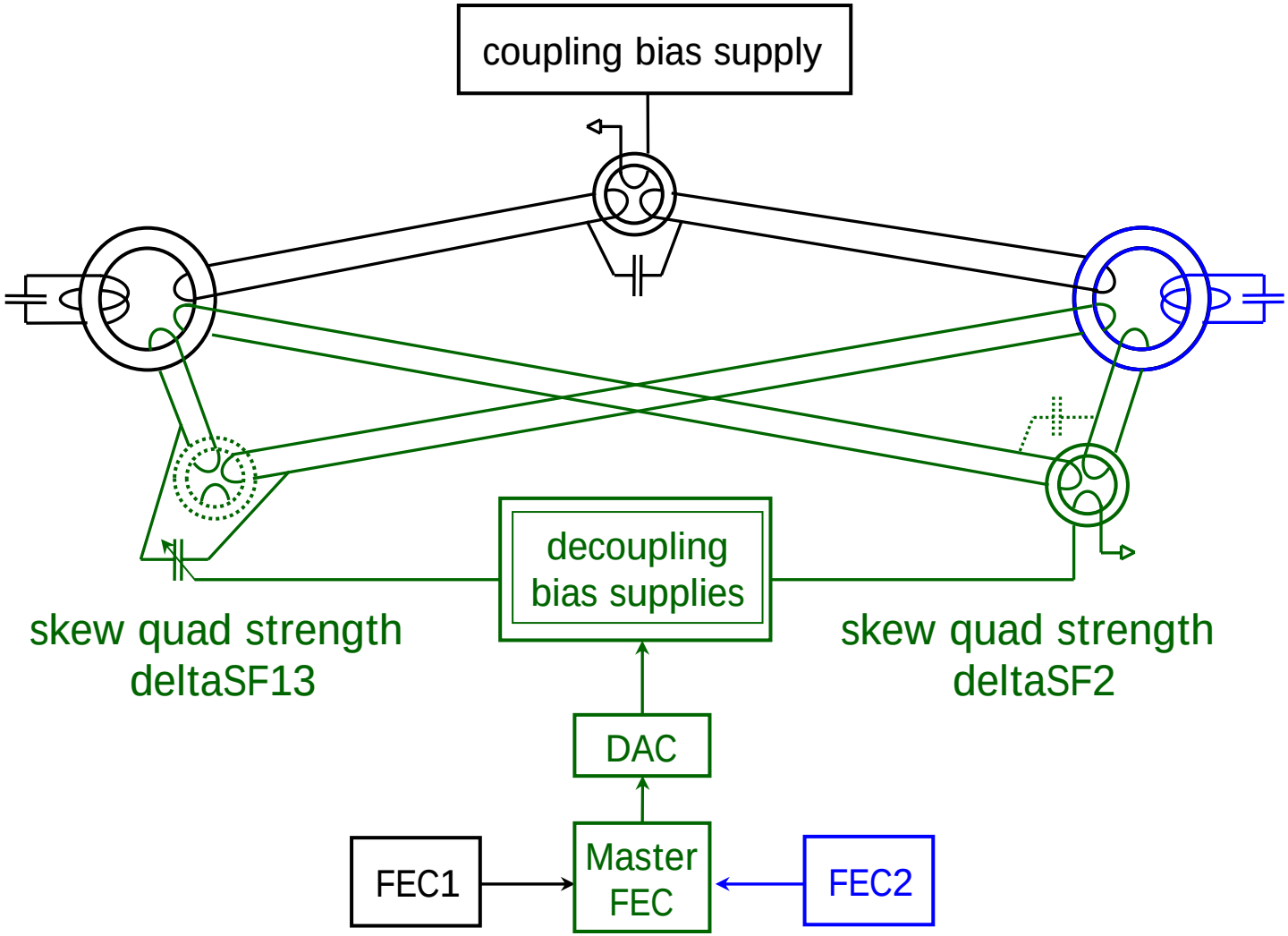
- neg for TF on Qx and Qx
- need for coupling feedback




- noise does not appear in Q1 and Q2
- not affected by loop gain
- appears only at certain settings of skews




# Dual Eigenmode Test Setup for Coupling Correction




# Dual Eigenmode Test Setup for Coupling Correction - more detail

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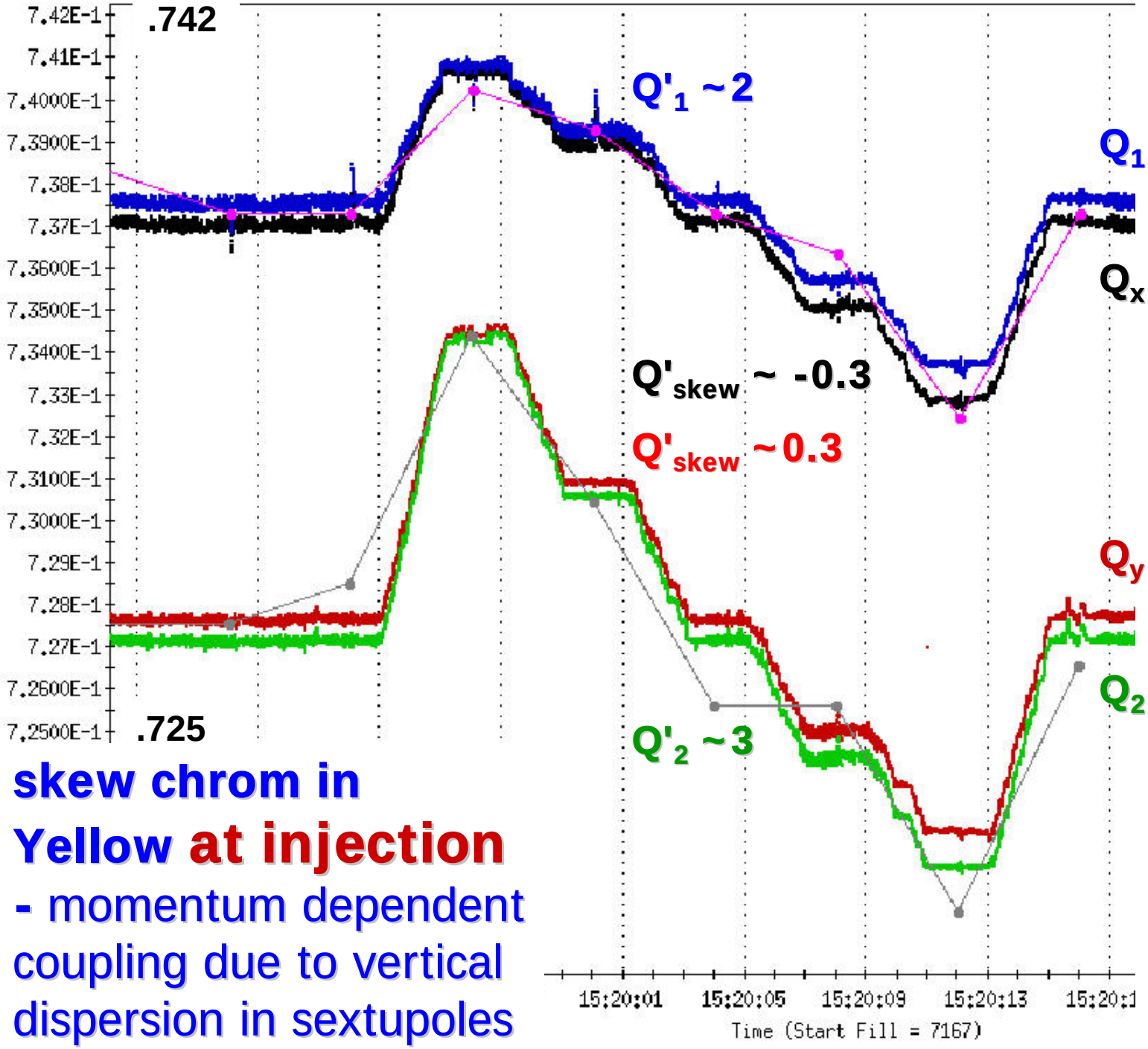
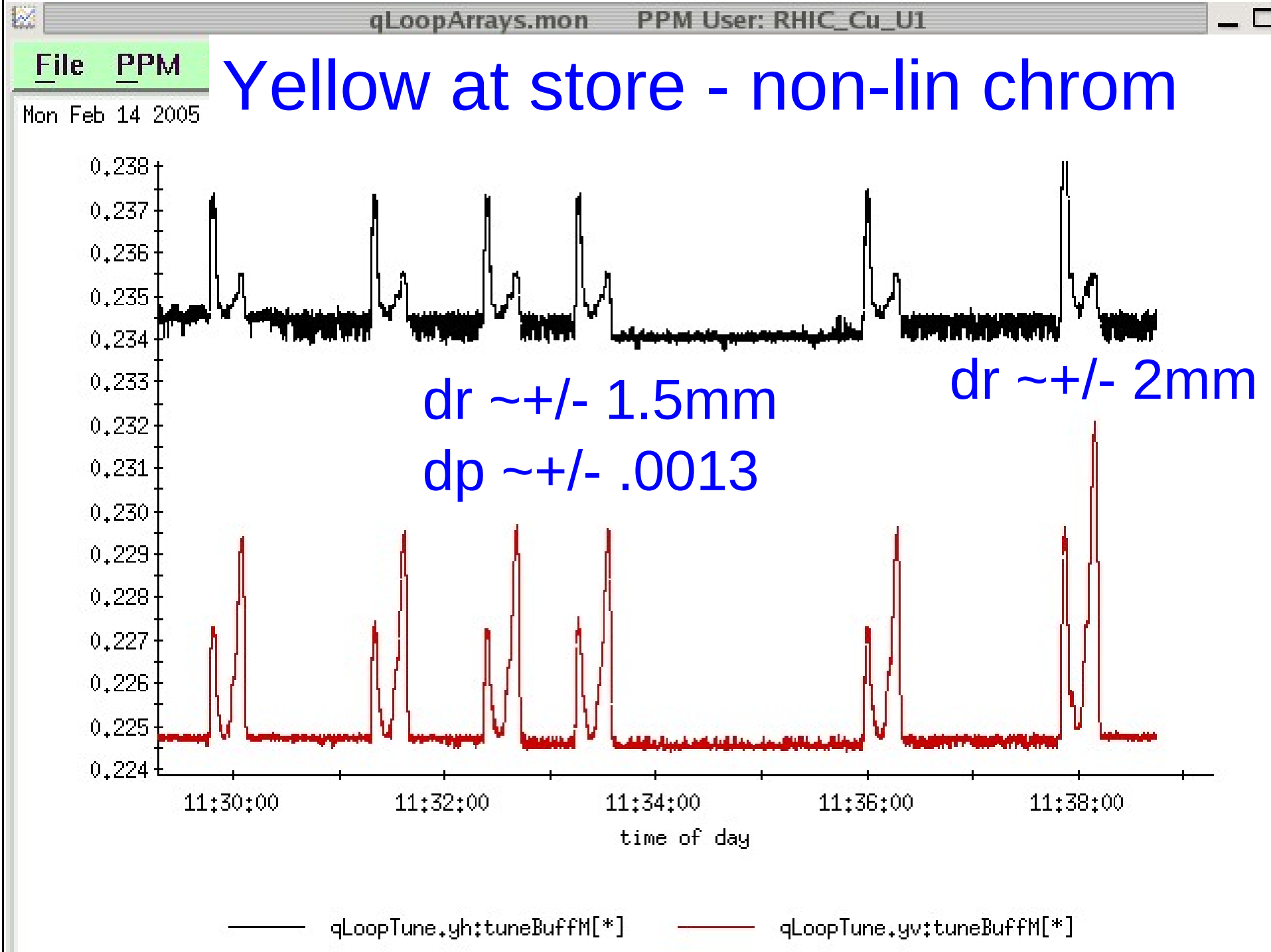
- **skew and non-lin chrom**
- instabilities
- bunch train tune shift

Possible PLL systems Plan for Run06/07




**skew chrom in Yellow at injection**

- momentum dependent coupling due to vertical dispersion in sextupoles


qLoopArrays.mon PPM User: RHIC_Cu_U1
File PPM
Mon Feb 14 2005
Yellow at store - non-lin chrom
dr ~+/- 1.5mm
dp ~+/- .0013
dr ~+/- 2mm
0.238
0.237
0.236
0.235
0.234
0.233
0.232
0.231
0.230
0.229
0.228
0.227
0.226
0.225
0.224
11:30:00
11:32:00
11:34:00
11:36:00
11:38:00
time of day
qLoopTune.yh:tuneBuffM[*]
qLoopTune.yv:tuneBuffM[*]

# Outline

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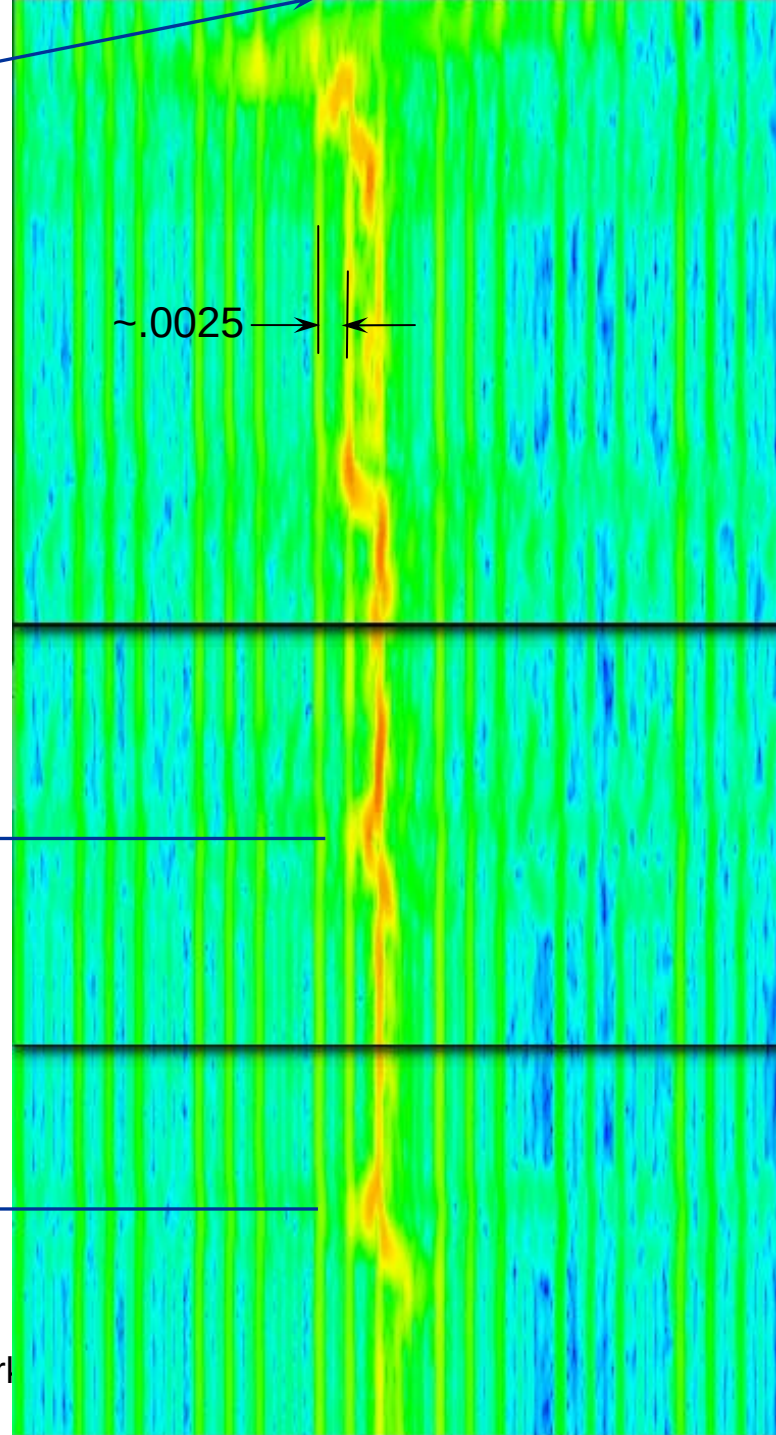
- skew and non-lin chrom
- **instabilities**
- **bunch train tune shift**

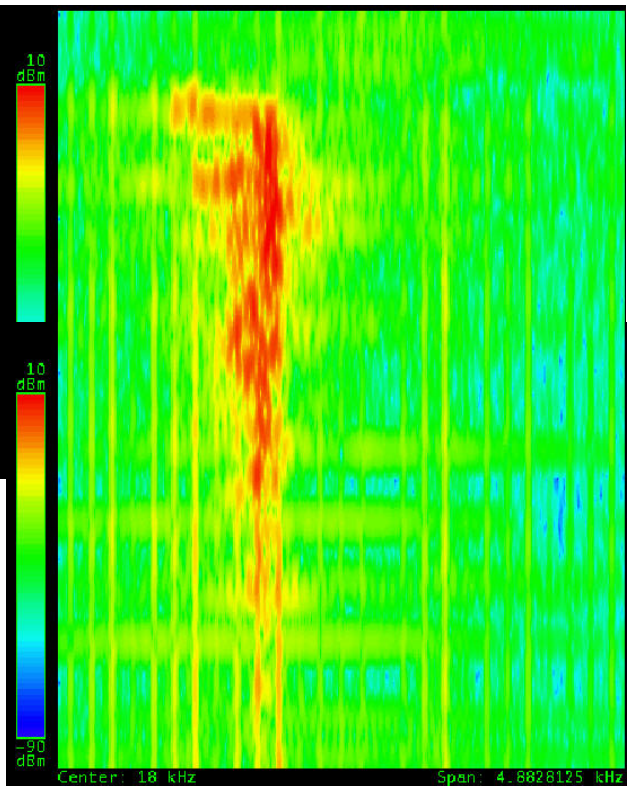
Possible PLL systems Plan for Run06/07

# Transition Instability (weak) as seen by 3D AFE

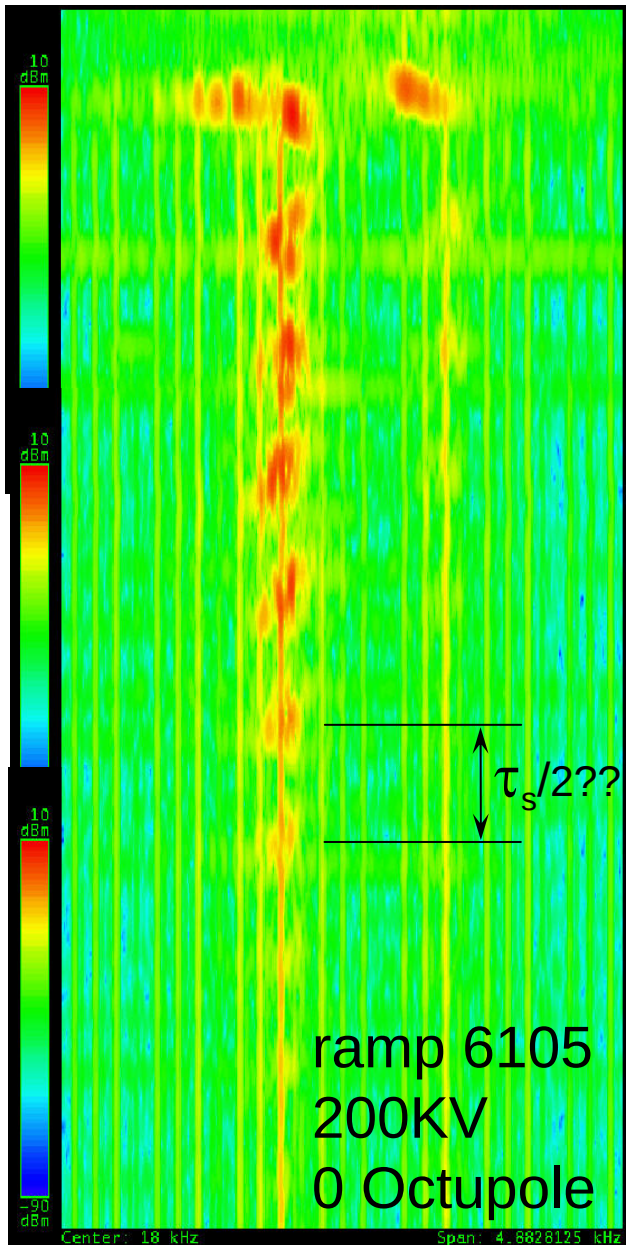
role of mains harmonics in 'seeding' instability?



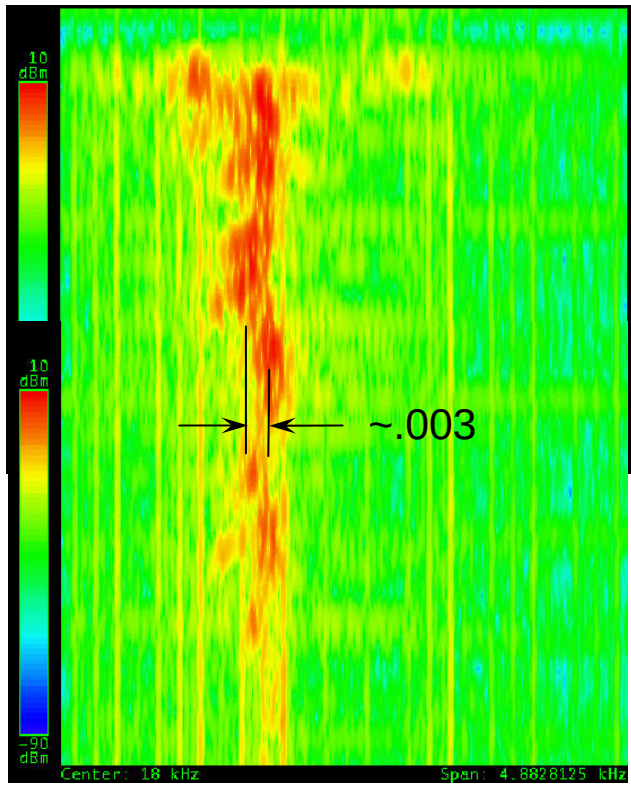
# 3D AFE at $\gamma_t$ - horizontal - 7 Feb 2005




ramp 6103
200KV
-2.5 Octupole

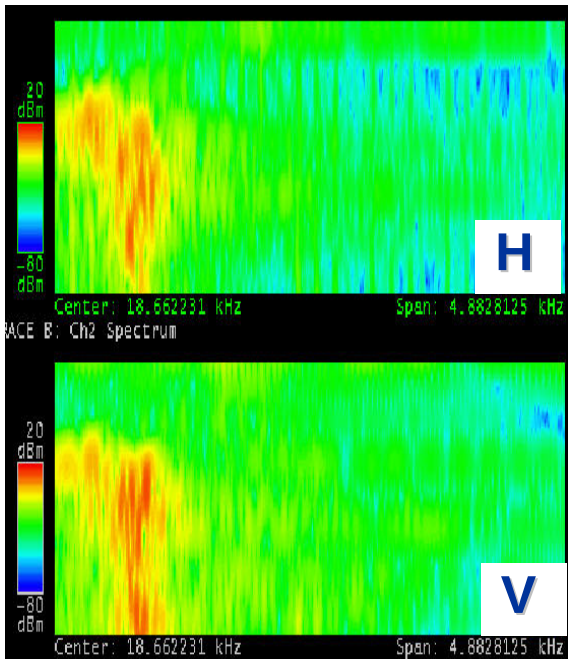



ramp 6105
200KV
0 Octupole

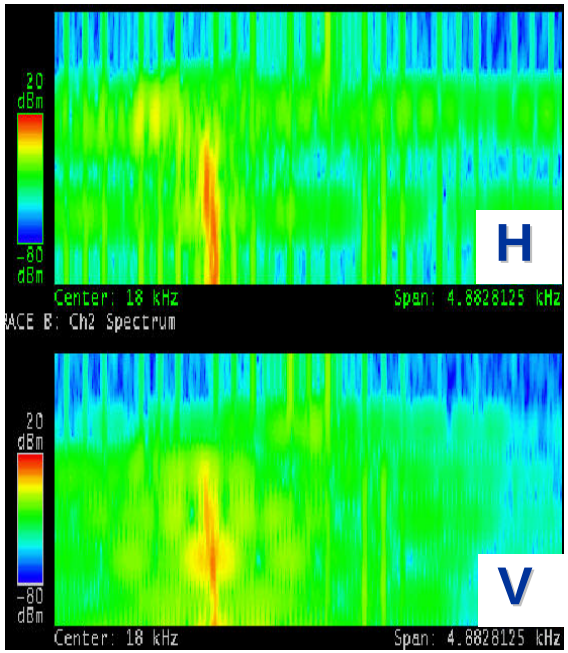



ramp 6106
100KV
-2.5 Octupole
best???

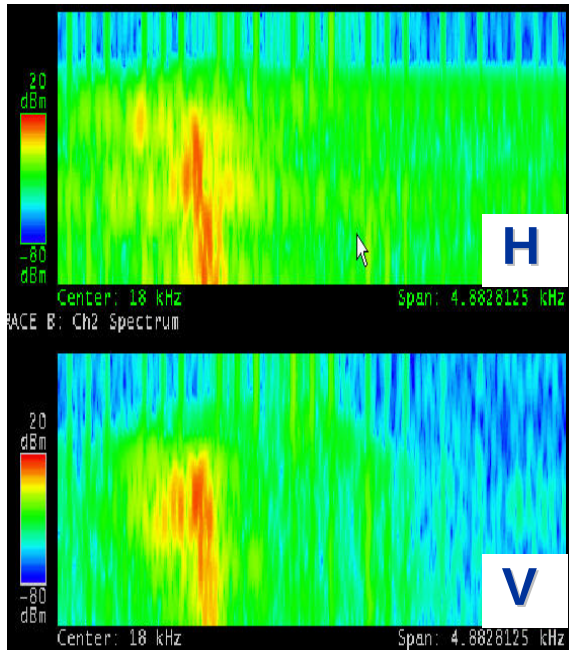
ramp 6248 3D AFE
150KV, $4.7 \times 10^9$



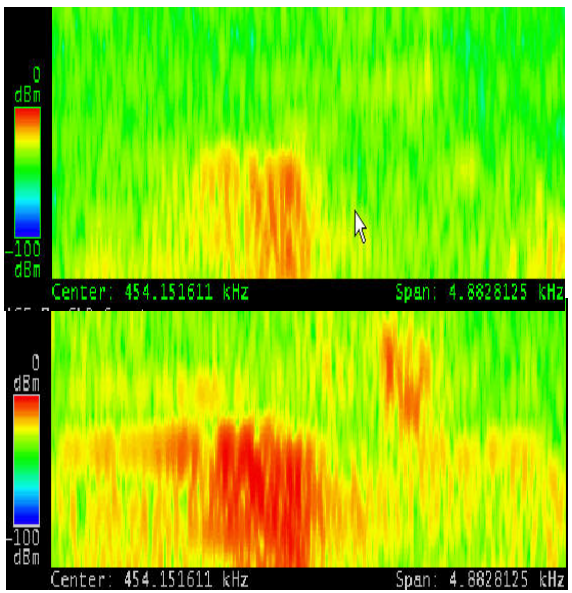

ramp 6249 3D AFE
100KV, $2.3 \times 10^9$




ramp 6250 3D AFE
100KV, $4.5 \times 10^9$




"no instability"




front 1usec of bunch train

ramp 6248 245MHz PLL

rear 1usec of bunch train

features:

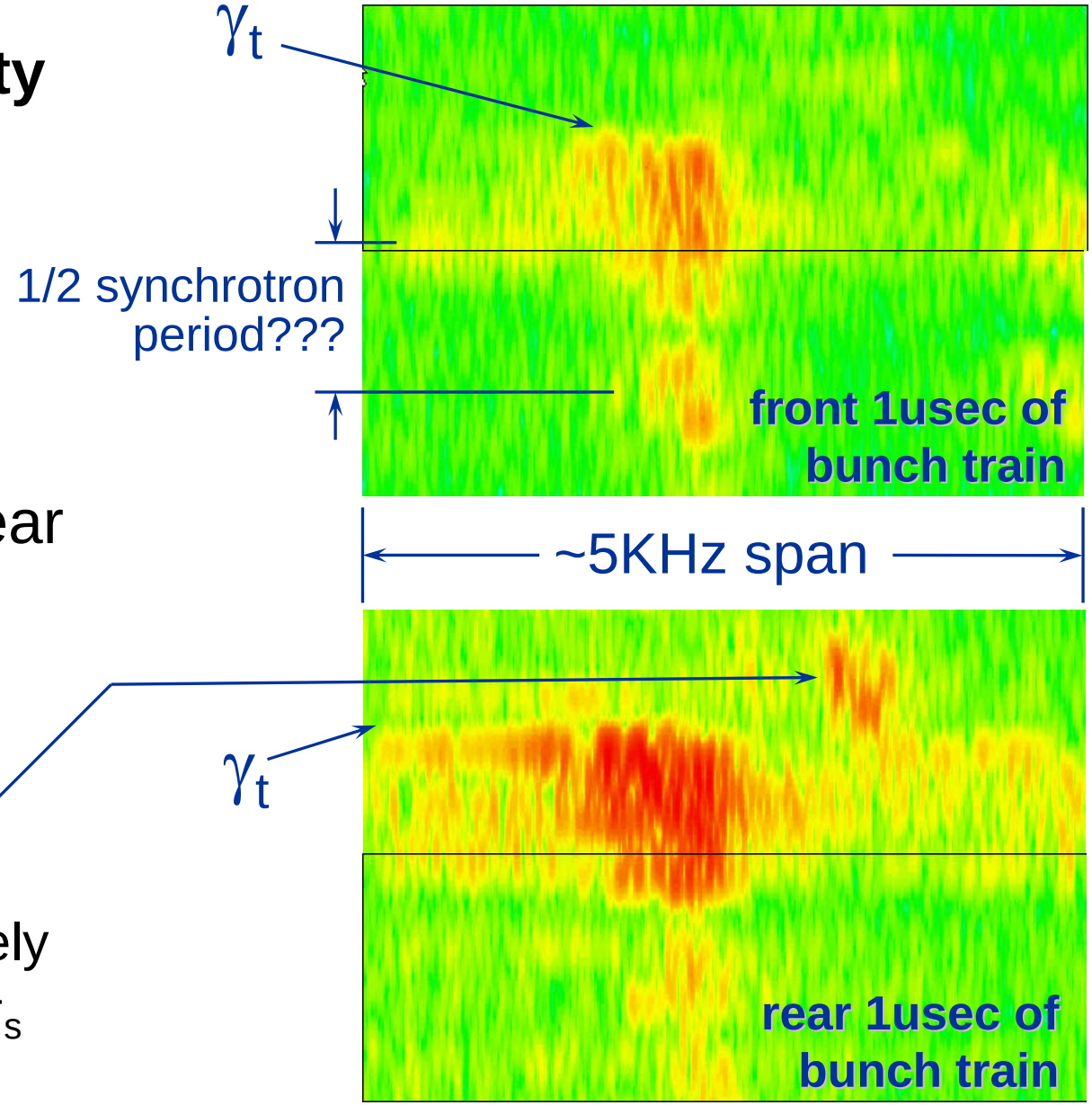
1. braiding - momentum dependent coherence
2. different pattern in BBQ and PLL
3. BBQ more similar to front of train

**Transition Instability as seen by gated 245MHz PLL ramp 6248**

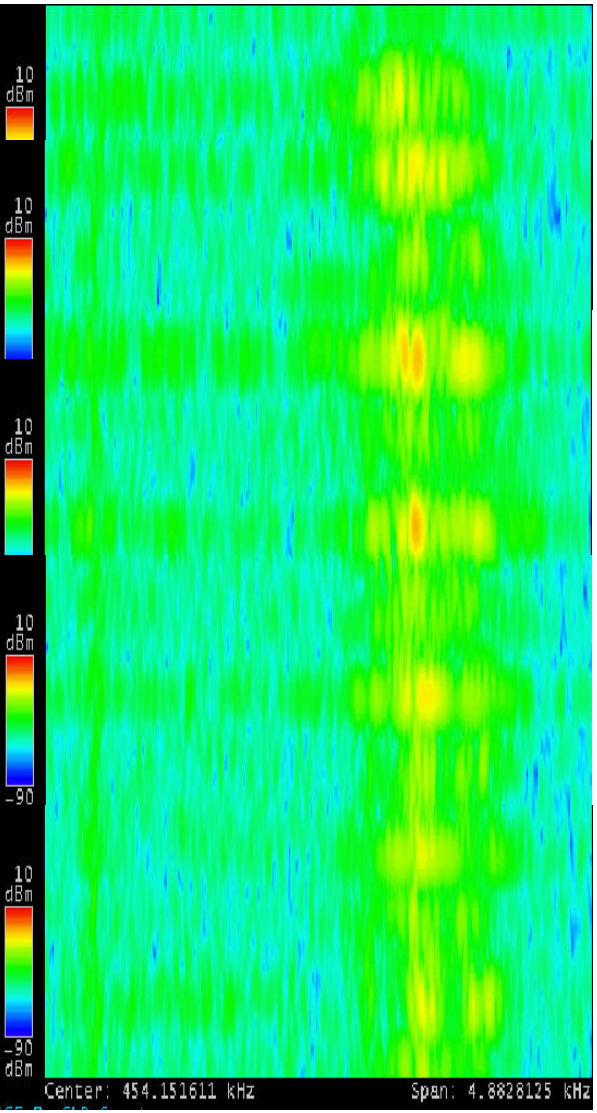
objective: to see $\delta q$ between front and rear of bunch train.

notable features:

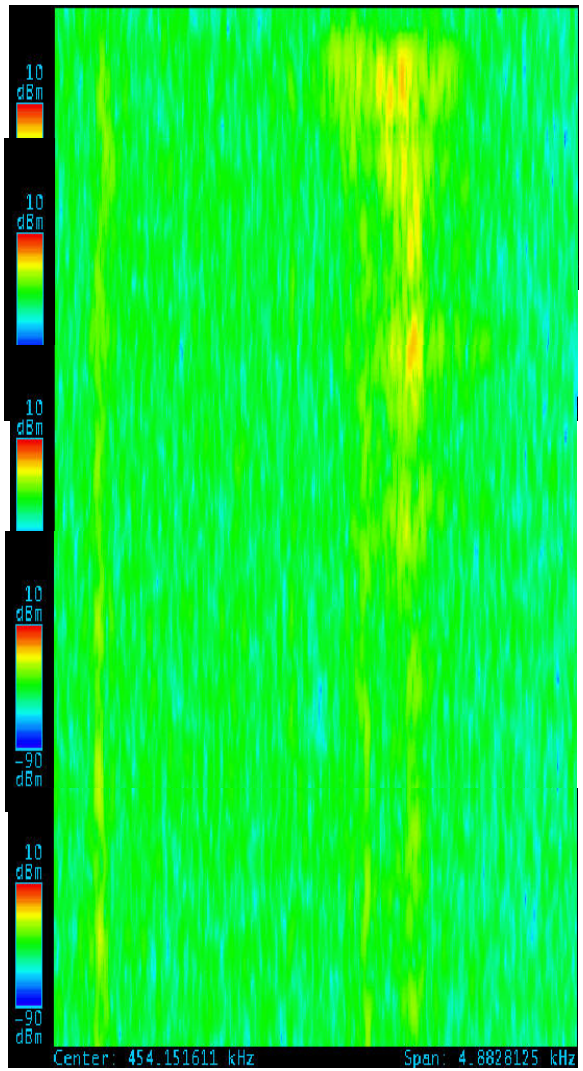
1. coherence before $\gamma_t$
2. very broad coherence
3. front becomes relatively stronger after 1 $\tau_s$
4. 'braiding'



front 1usec of bunch train




rear 1usec of bunch train

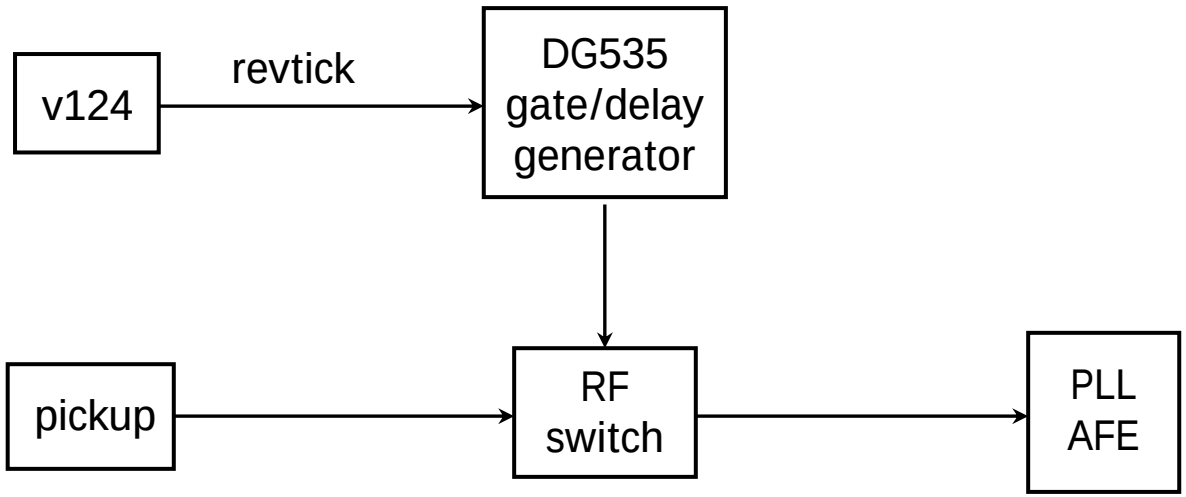



**Transition Instability as seen by gated 245MHz PLL ramp 6250**

notable features:

1. initially stronger at rear
2. front becomes relatively stronger after 1 $\tau_s$
3. persistence of coherence at quadrupole frequency(??) at front

# 245MHz PLL - Gated Measurement Setup




Procedure:

1. set gate width to ~1usec (minimum as determined by resonant pickup time constant)
2. adjust delay to move gate along ~12usec bunch train as needed

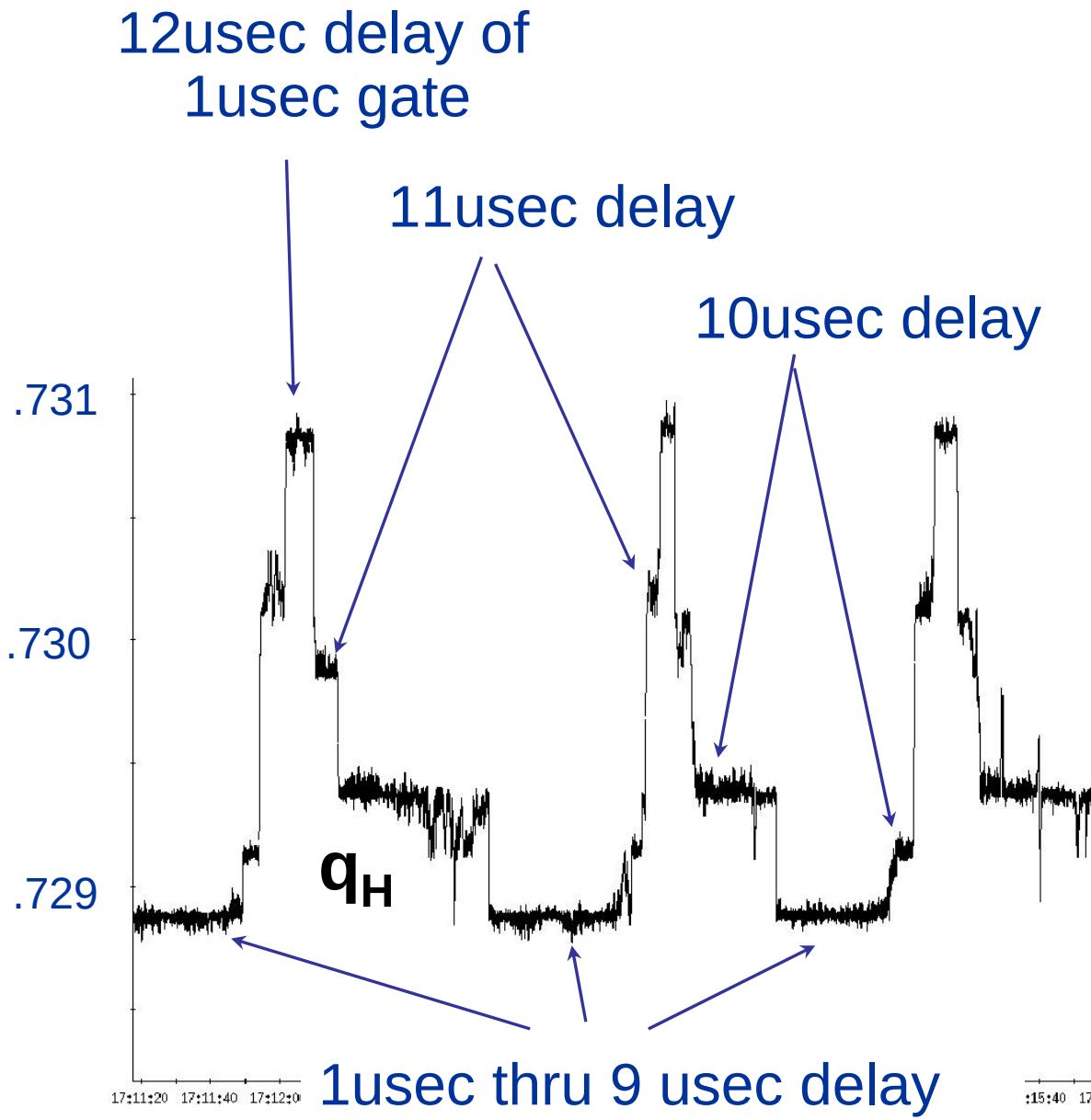
# Notes from bunch train study:

1. PLL measurement of tune shift along bunch train is repeatable
2. amount of tune shift 'saturated' before fill was complete
3. 'saturation' appeared to take place earlier in vert than horiz
4. maximum observed shifts were .004 in horiz, .007 in vert
5. amount of tune shift diminishes with time after filling
6. with 130 x $10^{11}$, 30 min after filling tune shift along bunch train was still .002
7. with 130 x $10^{11}$, 30 min after filling tune shift of first bunch relative to low current was .002
8. ratio of vertical shift to horizontal tune shift increased over the 2 hour time span of the study

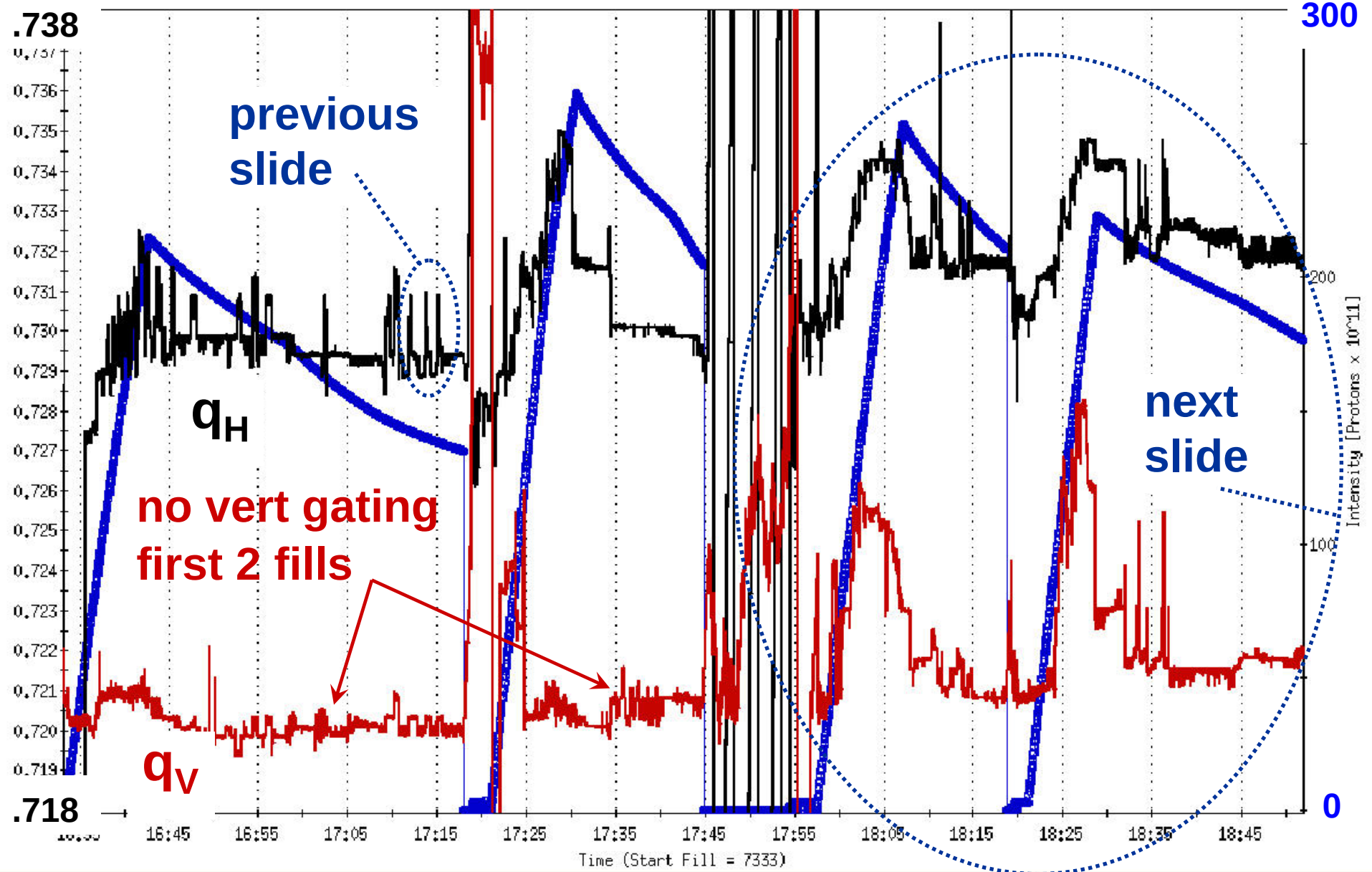
Three gate scans over an interval of ~5 minutes show

1. repeatability
2. tune shift is in last 3usec of bunch train only
3. greatest shift is at end of bunch train

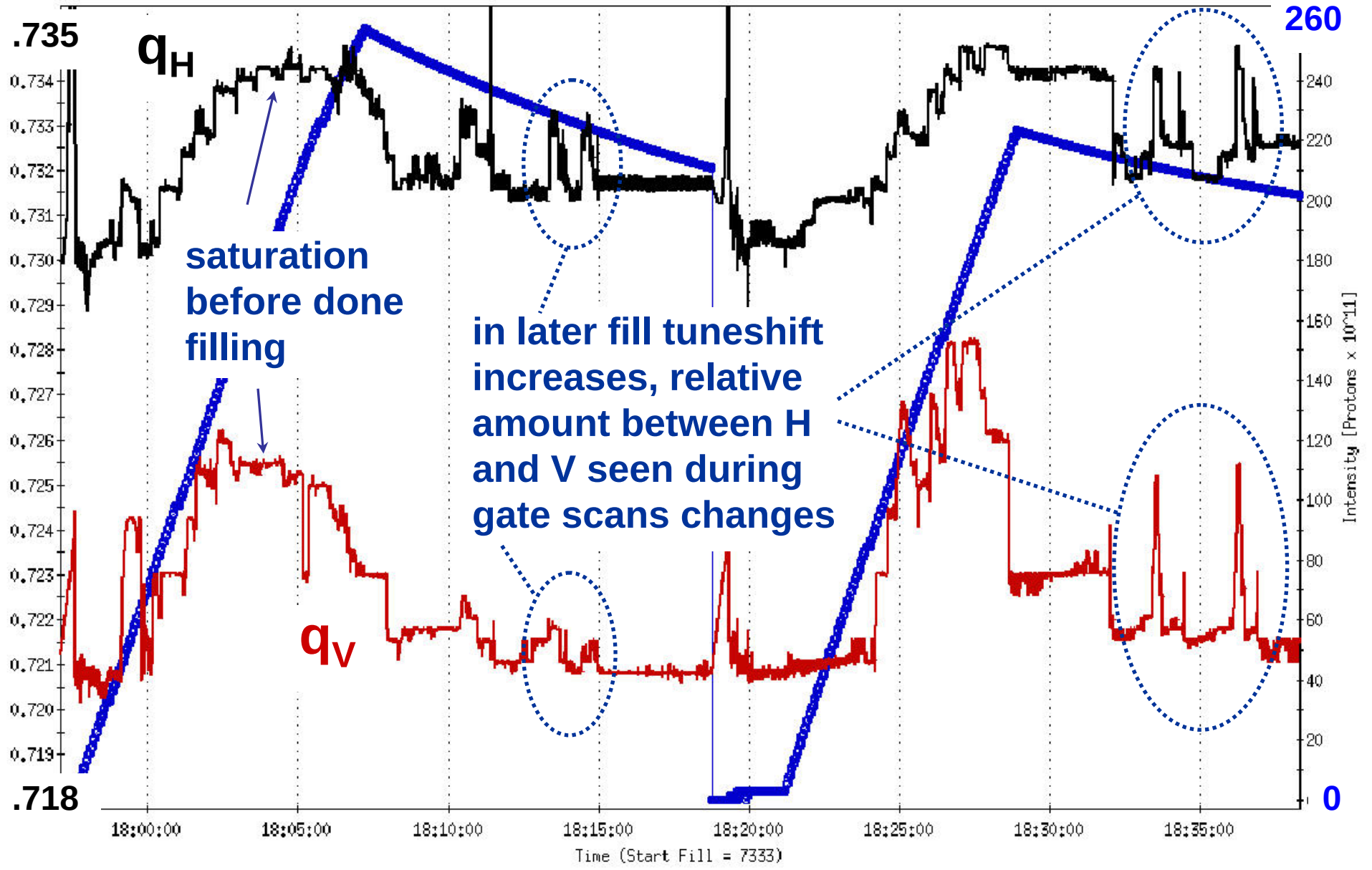
these scans were ~30min after filling, tune shift is comparatively small



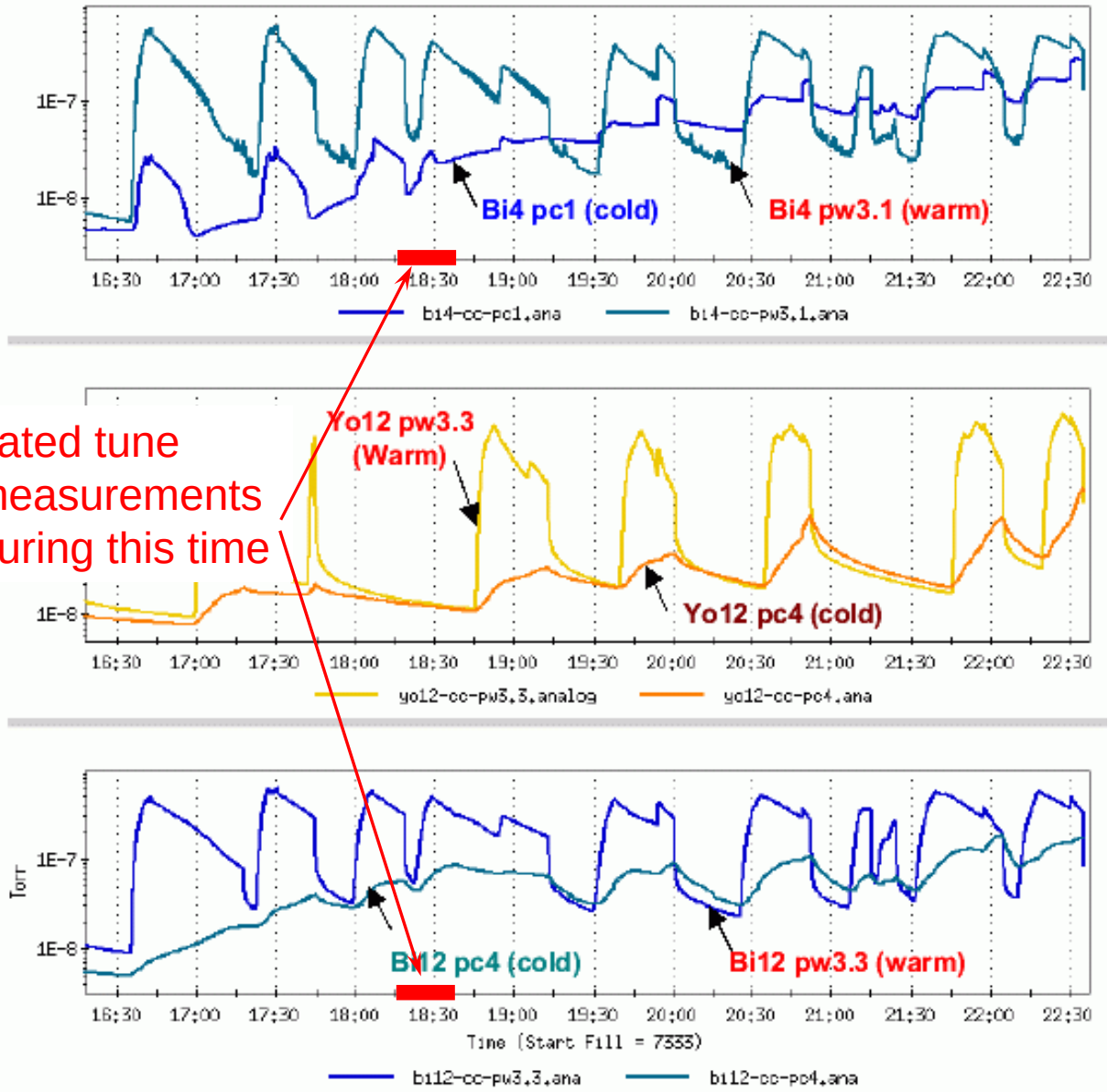
# Blue DCCT and tunes during ~2hrs of study



# Blue DCCT and tunes during ~40 minutes of study gate follows most recently injected 1usec of beam



# Pressure Rise in Cold Sections (2)




- **Total six locations with highest pressure rise of $5*10^{-8}$ to $2*10^{-7}$ Torr at Q3 and Q4. All look like due to ($H_2$) migration from nearby warm section pressure rise.**

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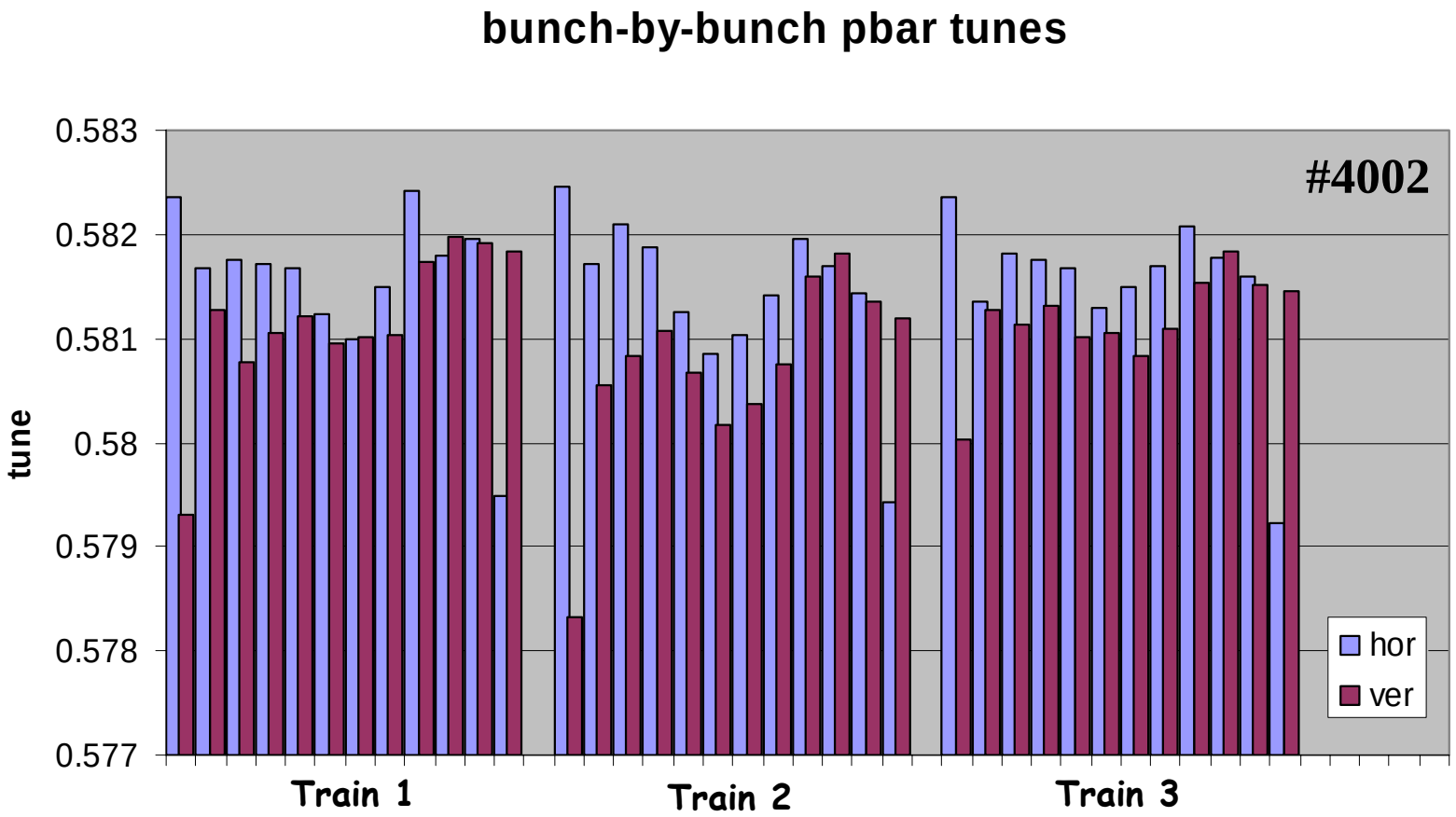
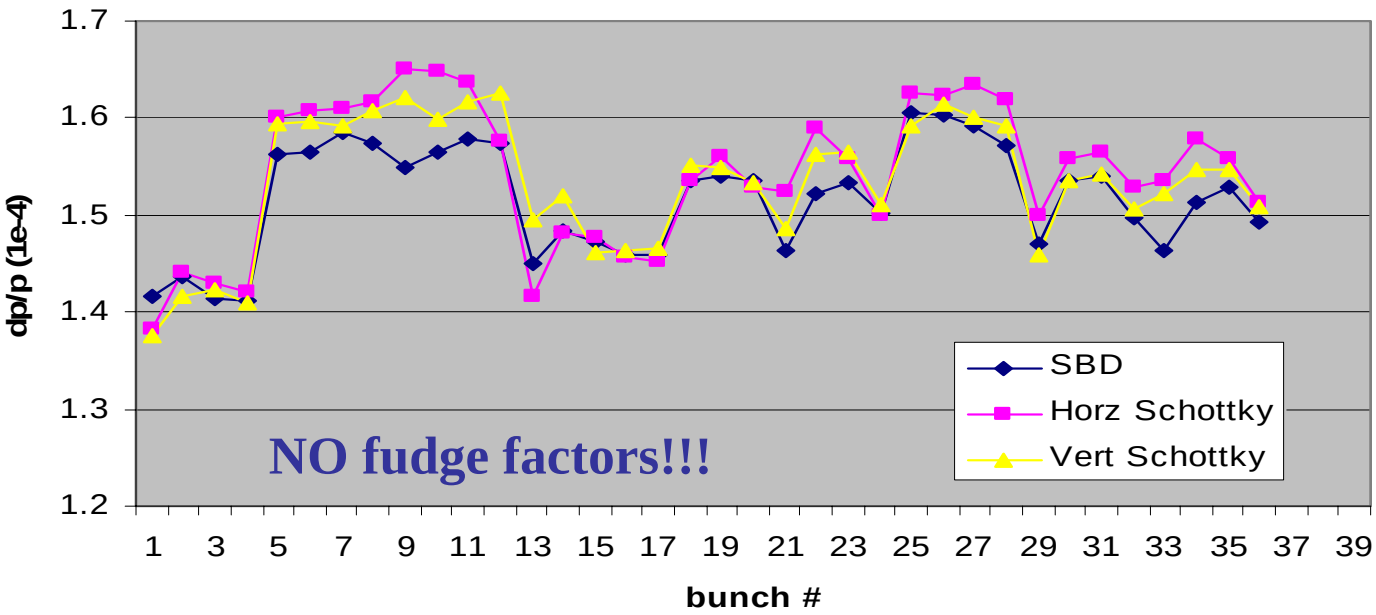
# Tevatron Single bunch tunes

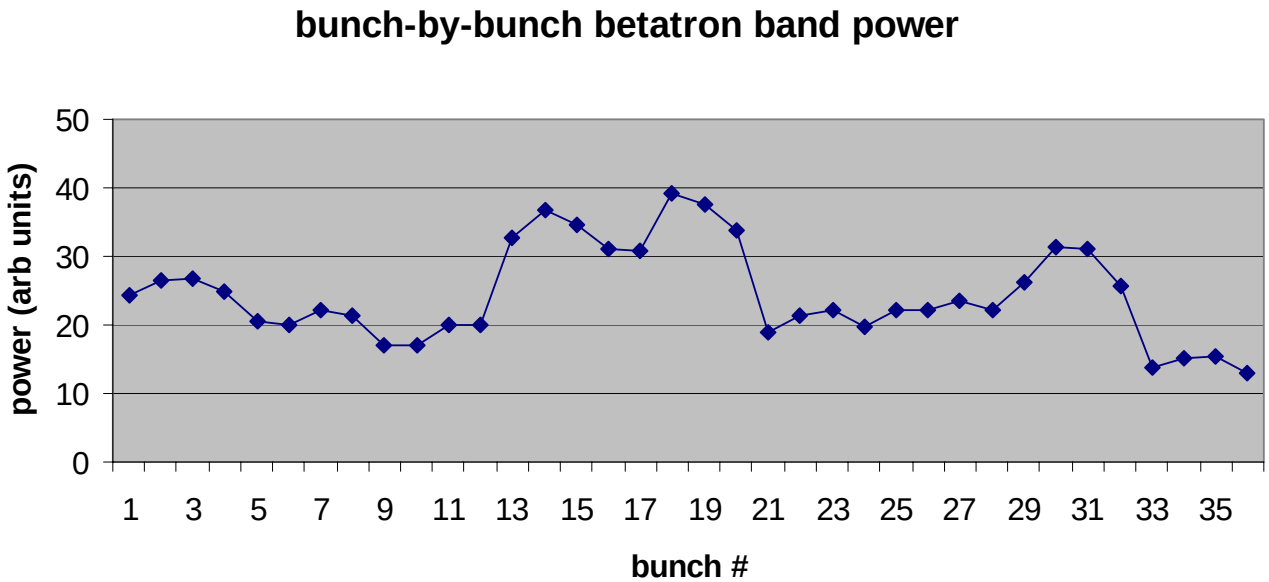



Bunch intensities: 15-40 $10^9$ Emittances: 7-17 $\pi$ mm mrad

Note characteristic beam-beam signature on first and last bunches in each train!

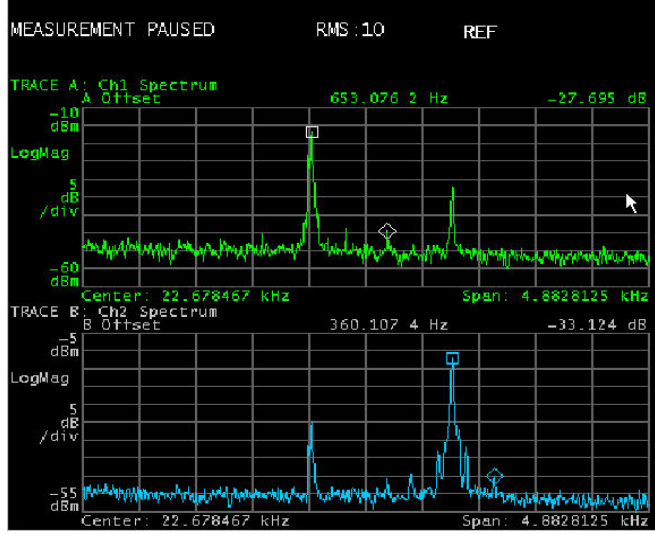
# Andreas Jansson




**longitudinal and transverse emittances are anti-correlated?**

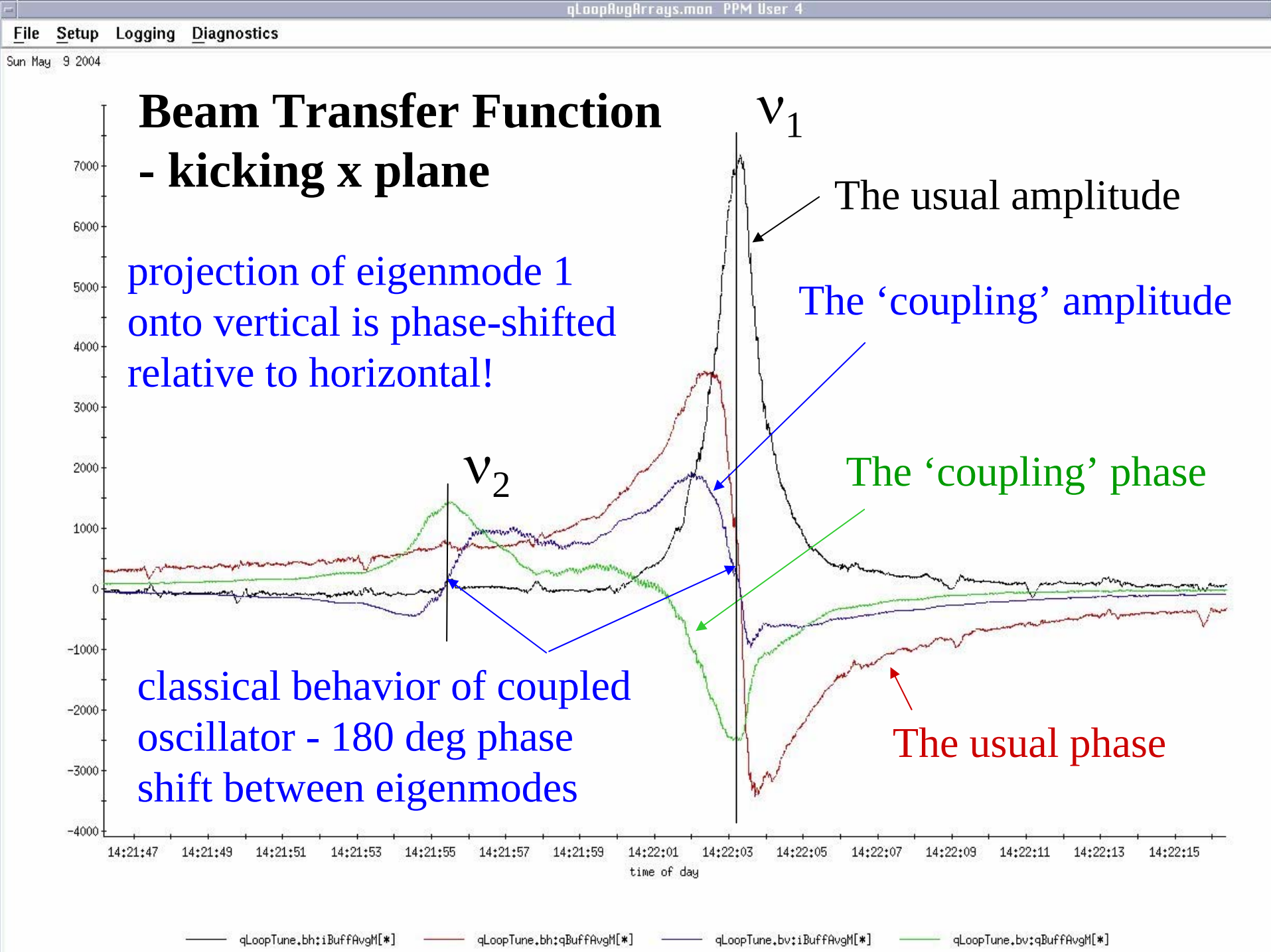
# For next run




- BBQ - FFT of data all 4 planes will be available from DAB FPGA
  - gating along bunch train not possible (?)
  - transition captures will be available with ~10msec time resolution
- 245MHz PLL (do both options?)
  - Option 1 - Run the four planes thru four 4-to-1 muxes, followed by gate generators/RF switches
    - FFT in LabVIEW
    - gated measurements available from MCR as desired on all four planes
    - front/back available as desired on two planes
  - Option 2 - Duplicate TW Schotty DAB system
- TW Schottky - leverage on LARP TW DAQ
  - gated bunch-by-bunch acquisition and FFT on DAB board
- Build another TW pickup for Horizontal?

# Other possibilities

- 3D in AGS - using FFT box for DAQ
- BBQ in AGS - vert only, would get coupling ampl and phase
- BTF measurements with BBQ and PLL
  - supplement Schottky with weak excitation
  - variable cutoff prefilter for BBQ
    - tune footprint as a function of frequency
    - transverse impedance (amplitude and phase relative to kicker) as a function of frequency
  - other usefulness?
- Resonance locking for resonance compensation?


qLoopAvgArrays.mon PPM User 4
File Setup Logging Diagnostics
Sun May 9 2004
Beam Transfer Function
- kicking x plane
$\nu_1$
$\nu_2$
The usual amplitude
projection of eigenmode 1
onto vertical is phase-shifted
relative to horizontal!
The 'coupling' amplitude
The 'coupling' phase
classical behavior of coupled
oscillator - 180 deg phase
shift between eigenmodes
The usual phase
7000
6000
5000
4000
3000
2000
1000
0
-1000
-2000
-3000
-4000
14:21:47
14:21:49
14:21:51
14:21:53
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14:22:03
14:22:05
14:22:07
14:22:09
14:22:11
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14:22:15
time of day
qLoopTune.bh:iBuffAvgM[*]
qLoopTune.bh:qBuffAvgM[*]
qLoopTune.bv:iBuffAvgM[*]
qLoopTune.bv:qBuffAvgM[*]

# BMX needed for Run 5

Tune feedback related beam experiments which need to be done during Run 5 are:

- 04-07 - chromaticity feedback priority 1
  - LHC concerns - effect of NL and skew chrom on feedback
  - LHC concerns - how to extract this info from radial modulation data
- **05-33 - reduction of 60Hz harmonics on main dipole bus by 12 phase balancing** priority 1
- effect of chrom on BBQ operation