Tune and Chromaticity Measurement and Feedback

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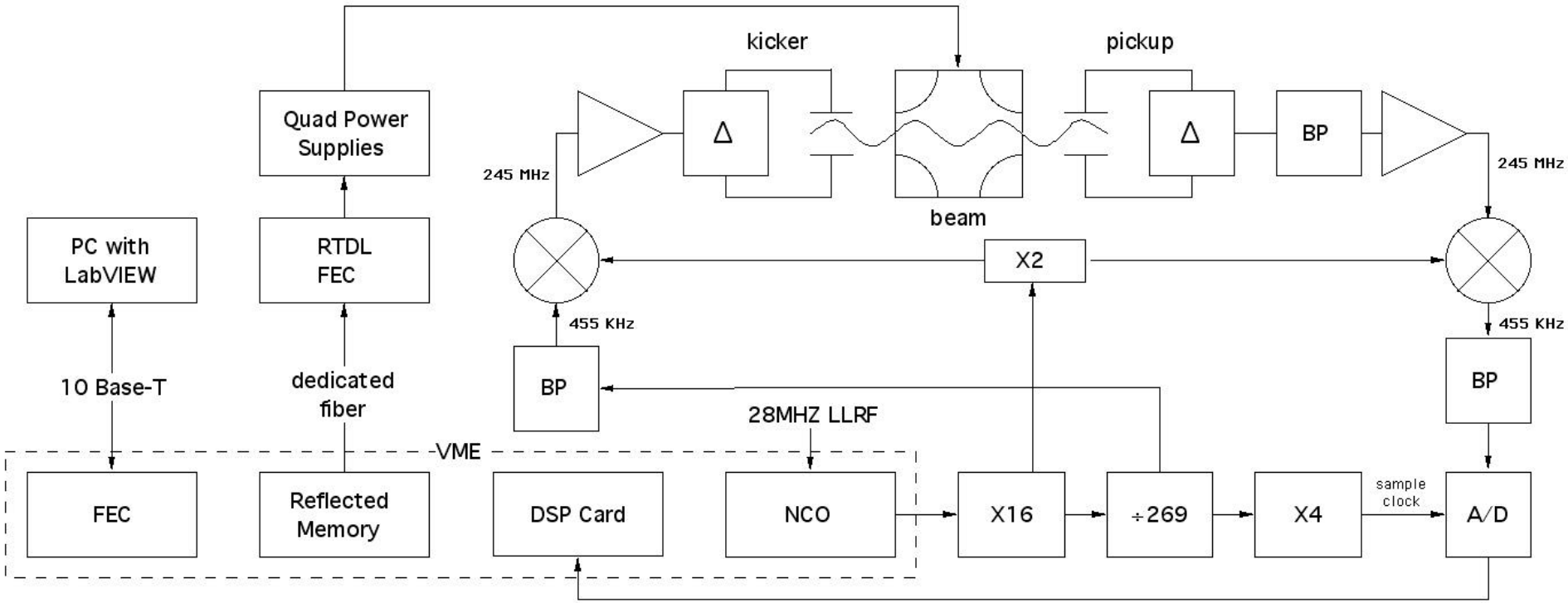
BNL

Outline

- ***PLL Issues***
- LHC specific discussion
  - two systems?
  - pickup specification
  - modeling – include the beam
- Plan for FY04

PLL Block Diagram



PLL Issues – in order?

- ***Signal to Noise***
- Stability and Loop Tuning - modeling
- Coupling
- Anomalous phase shifts
- Chromaticity control (not)

Signal to Noise 1

- Pickup sensitivity – need ‘high’ S/N (~20dB or more)
  - High impedance capacitive (broadband)
  - Resonant striplines – ala RHIC
  - Resonant cavity
  - Traveling wave device – ala FNAL
  - Superconducting? More on this later
- Pickup frequency
  - Linewidth is $N\eta\delta p/p$, at practical resonant pickup frequencies width ~ 1-2KHz ($f_{synchrotron}$ ~ 50Hz to 100Hz)
  - 245MHz in RHIC, ~400MHz in LHC?
  - ‘Landau damping’ more effective with larger linewidth

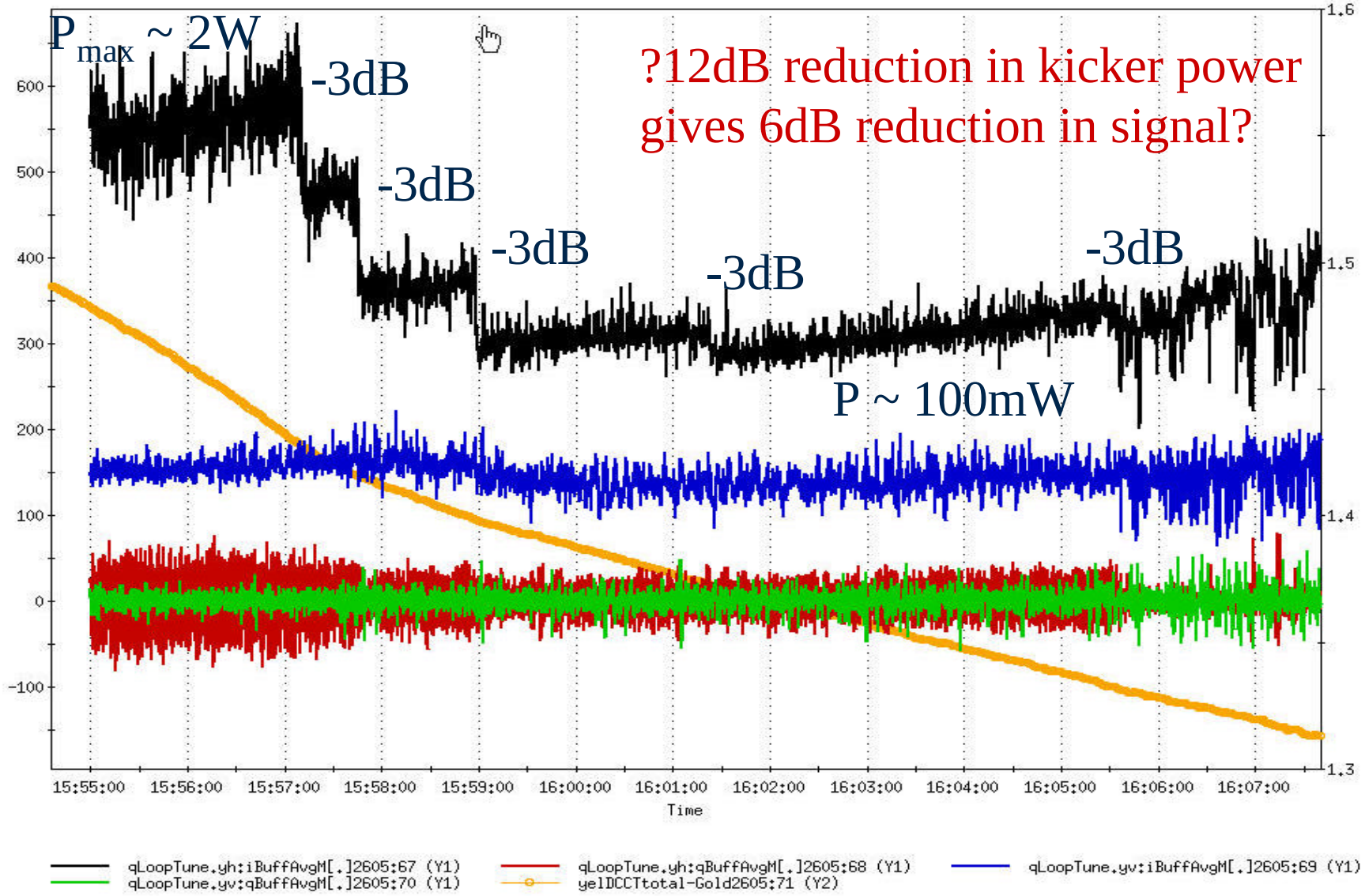
Signal to Noise 2

- Loop bandwidth (and filtering)
  - as low as possible to maximize S/N
    - Implications for chromaticity measurement
  - As high as possible to minimize phase shift, maximize loop stability
  - minimum ~ x10 magnet system BW
- Revolution line - saturation and dynamic range
  - Good filtering in the tunnel – cavity filters?
  - Careful selection of components
  - Moveable BPM, feedback to keep it centered
- Kick strength and emittance growth
  - Kicker power <100mW
  - Sensitive to linewidth
  - Feedback on kicker power essential

Sun Dec 29 15:54:35 - Sun Dec 29 16:07:40

Window Event

PLL amplitude for kick reduced in 3dB steps



qLoopTune.yh:iBuffAvgM[.] successfully displayed
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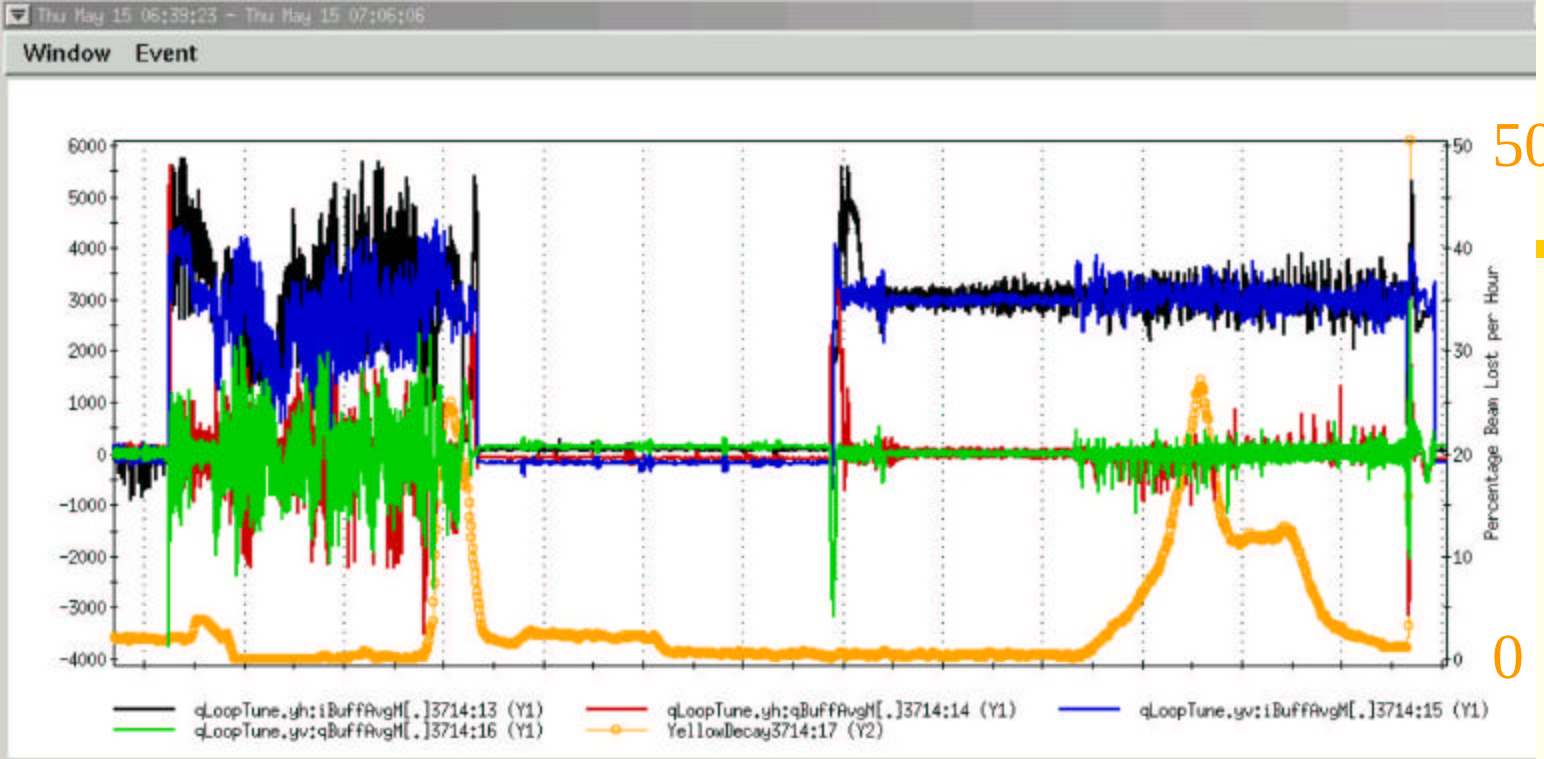


50

Amplitude and phase

Beam decay

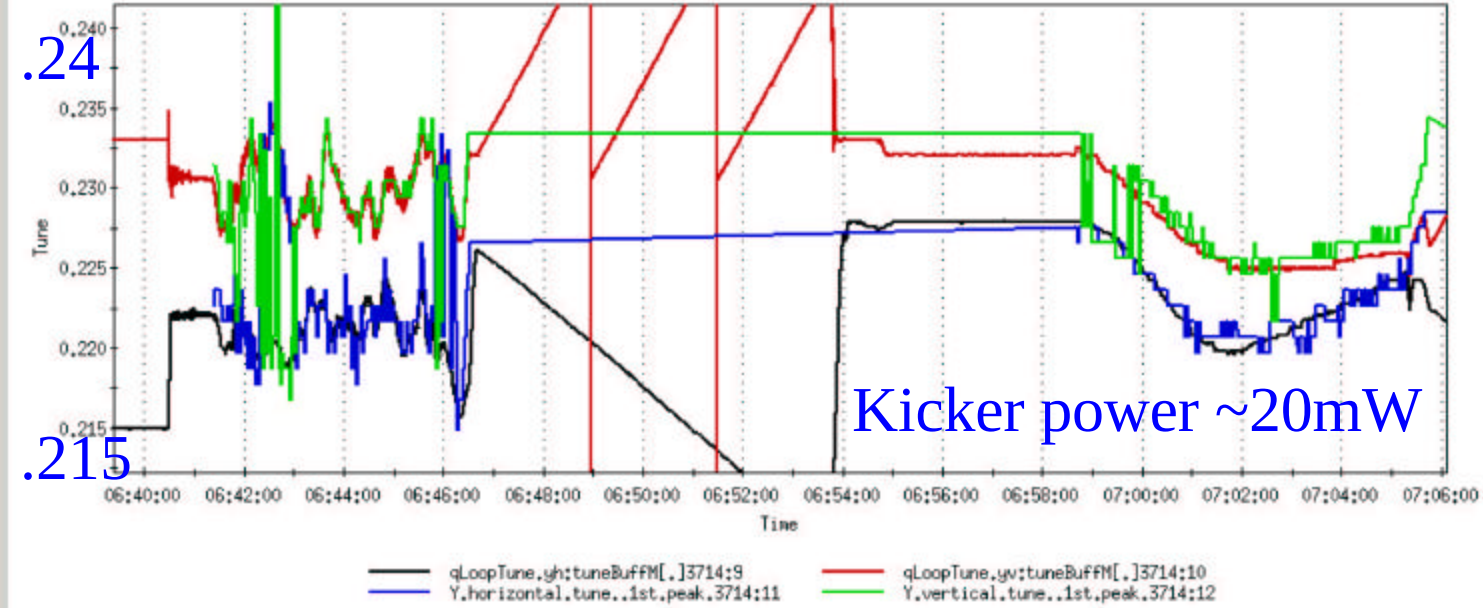
0

Ramp and squeeze

Rotator ramp

.24

.215



PLL and kicked tunes

Kicker power ~20mW

PLL Issues – in order?

- Signal to Noise
- ***Stability and Loop Tuning - modeling***
- Coupling
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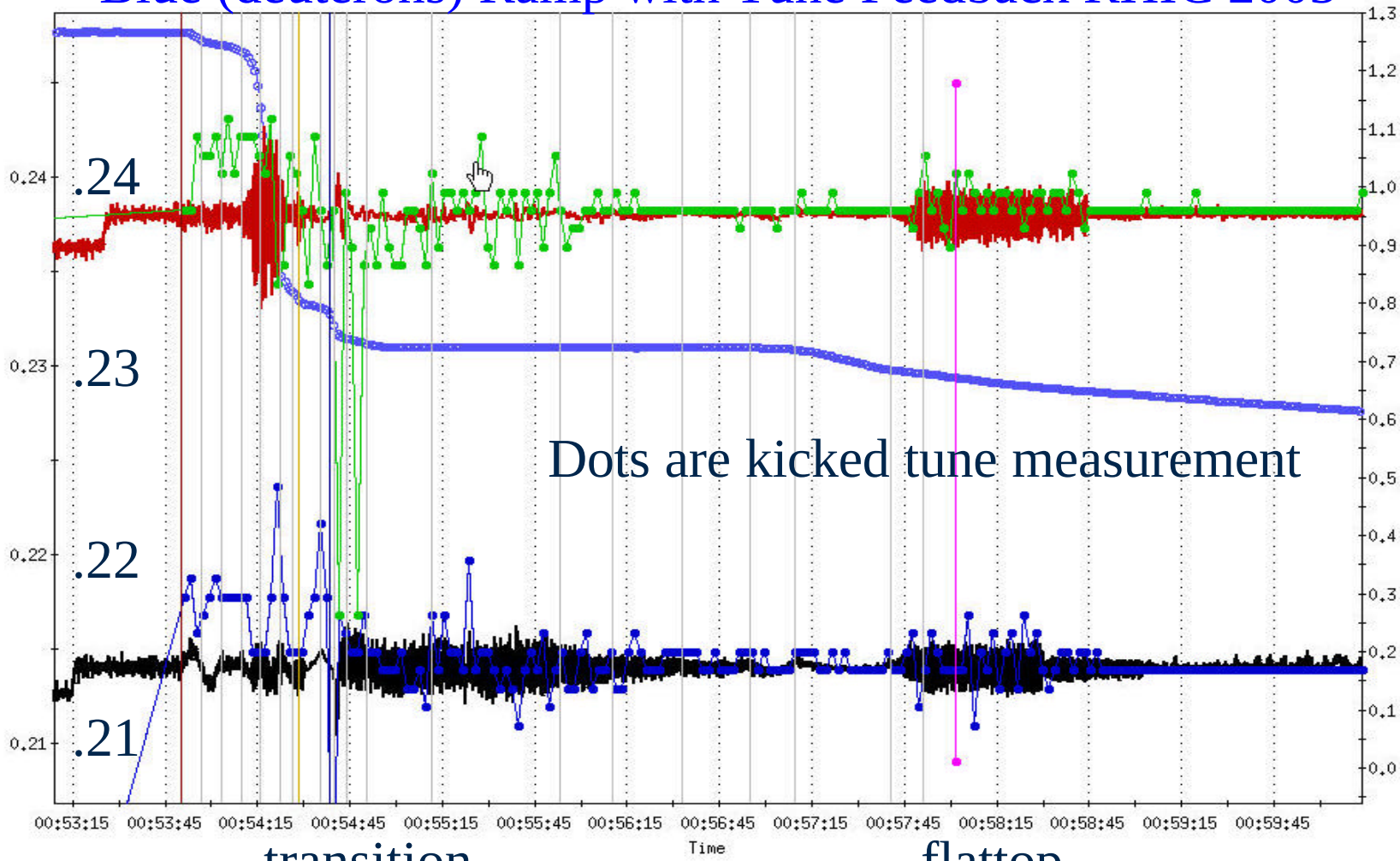
Stability

- Minimize phase shifts – two sources
  - Sampling delay – RHIC 2003 was 4 degrees/Hz with 90Hz update rate
  - BW limiting filter – RHIC 2003 was 40Hz IIR
  - Result was loop was twitchy, always close to instability, efforts went into derivative, auto loop gain,…
- For RHIC 2004
  - Increasing sampling rate to ~ 14KHz
  - Move filter to ~100Hz, switchable digital filters
  - Result is ~x10 improvement in loop bandwith, gain margin,…

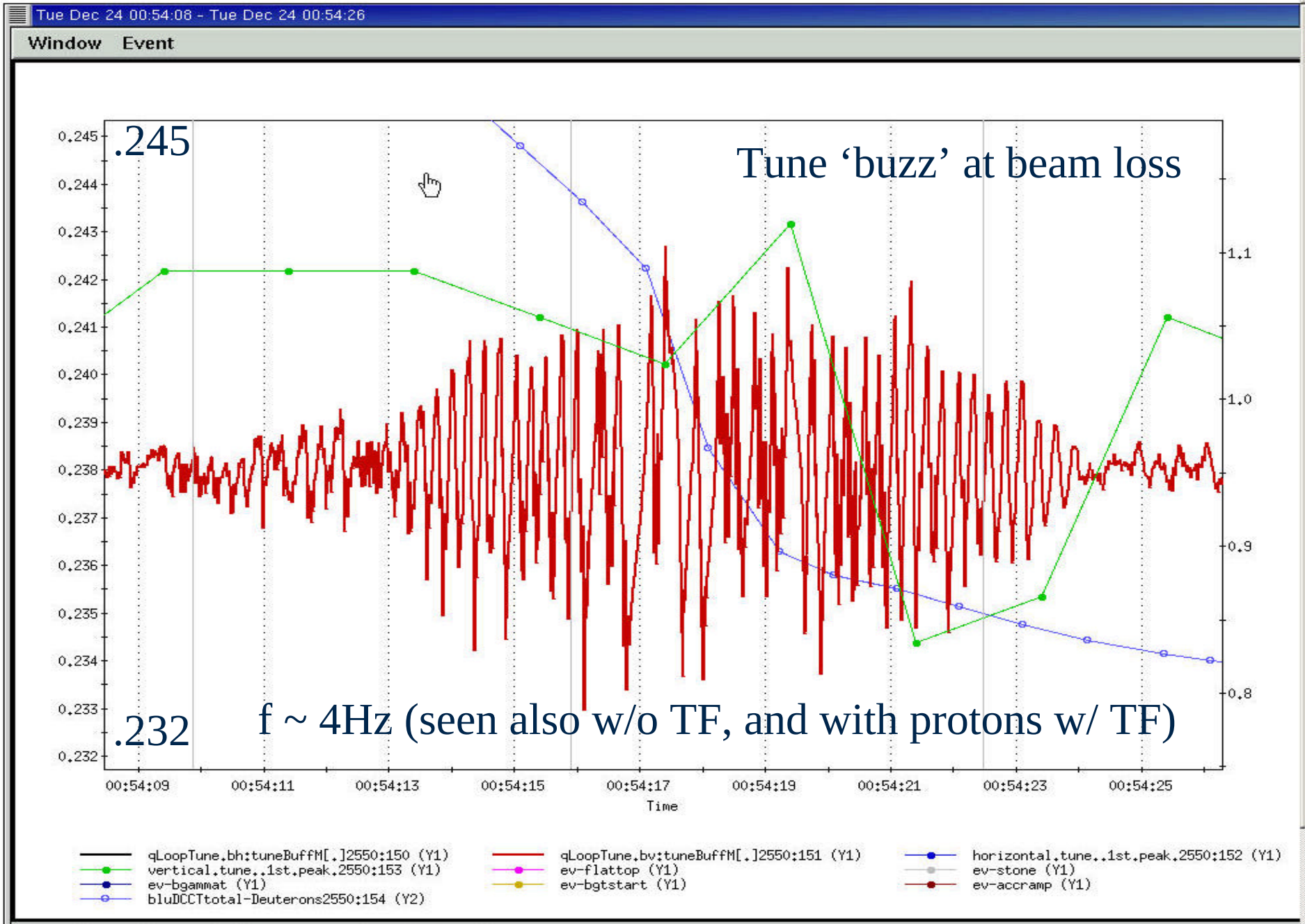
Tue Dec 24 00:53:09 - Tue Dec 24 01:00:13

Window Event

Blue (deuterons) Ramp with Tune Feedback RHIC 2003



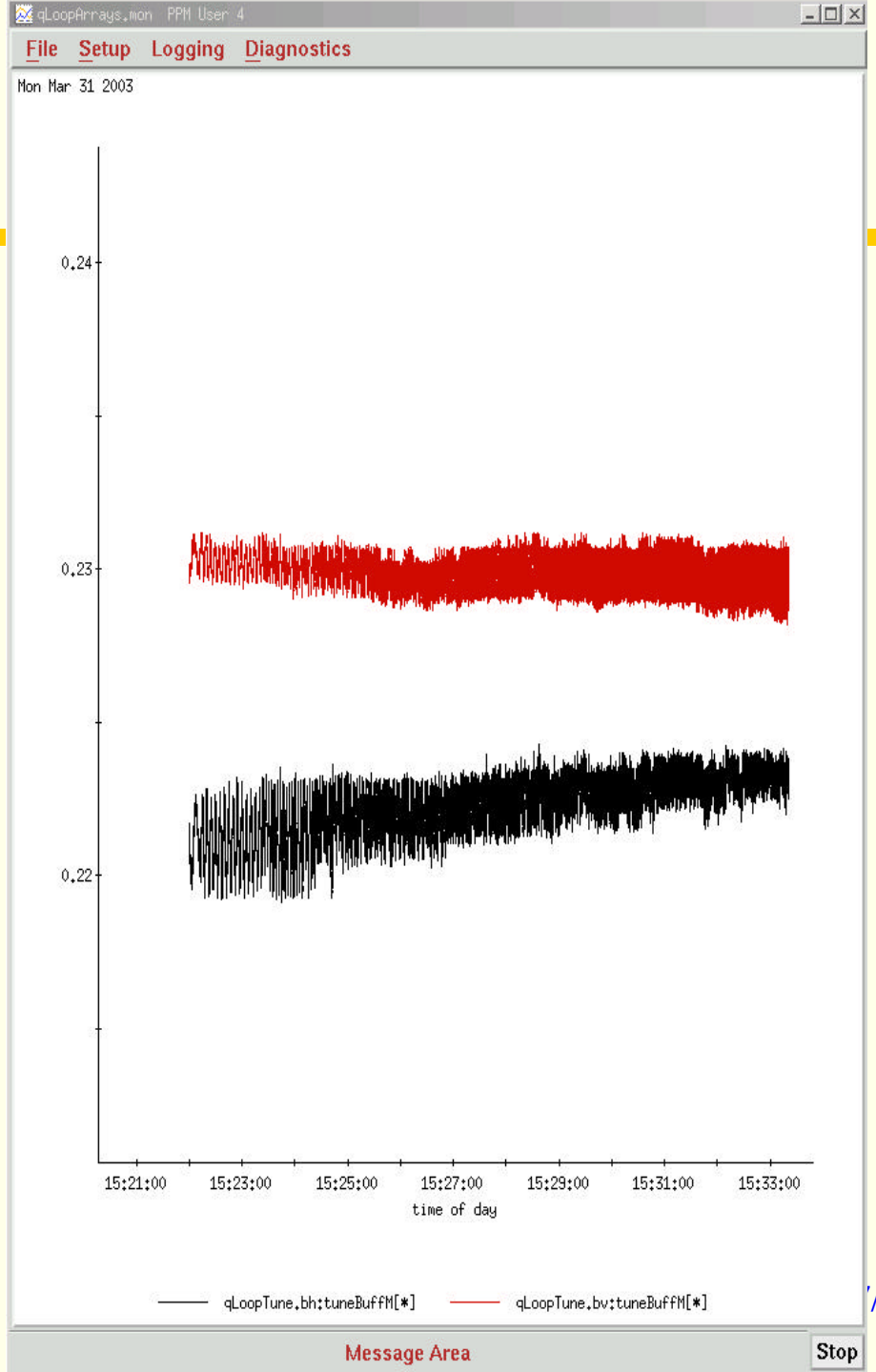
qLoopTune.bh:tuneBuffM[.] successfully displayed
qLoopTune.bv:tuneBuffM[.] successfully displayed


Tue Dec 24 00:54:08 - Tue Dec 24 00:54:26
Window Event
.245
Tune 'buzz' at beam loss
.232
f ~ 4Hz (seen also w/o TF, and with protons w/ TF)
0.245
0.244
0.243
0.242
0.241
0.240
0.239
0.238
0.237
0.236
0.235
0.234
0.233
0.232
1.1
1.0
0.9
0.8
00:54:09
00:54:11
00:54:13
00:54:15
00:54:17
00:54:19
00:54:21
00:54:23
00:54:25
Time
qLoopTune.bh:tuneBuffM[.]2550:150 (Y1)
vertical.tune..1st.peak.2550:153 (Y1)
ev-bgammat (Y1)
bluDCCTtotal-Deuterons2550:154 (Y2)
qLoopTune.bv:tuneBuffM[.]2550:151 (Y1)
ev-flattop (Y1)
ev-bgtstart (Y1)
horizontal.tune..1st.peak.2550:152 (Y1)
ev-stone (Y1)
ev-accramp (Y1)
qLoopTune.bh:tuneBuffM[.] successfully displayed
qLoopTune.bv:tuneBuffM[.] successfully displayed

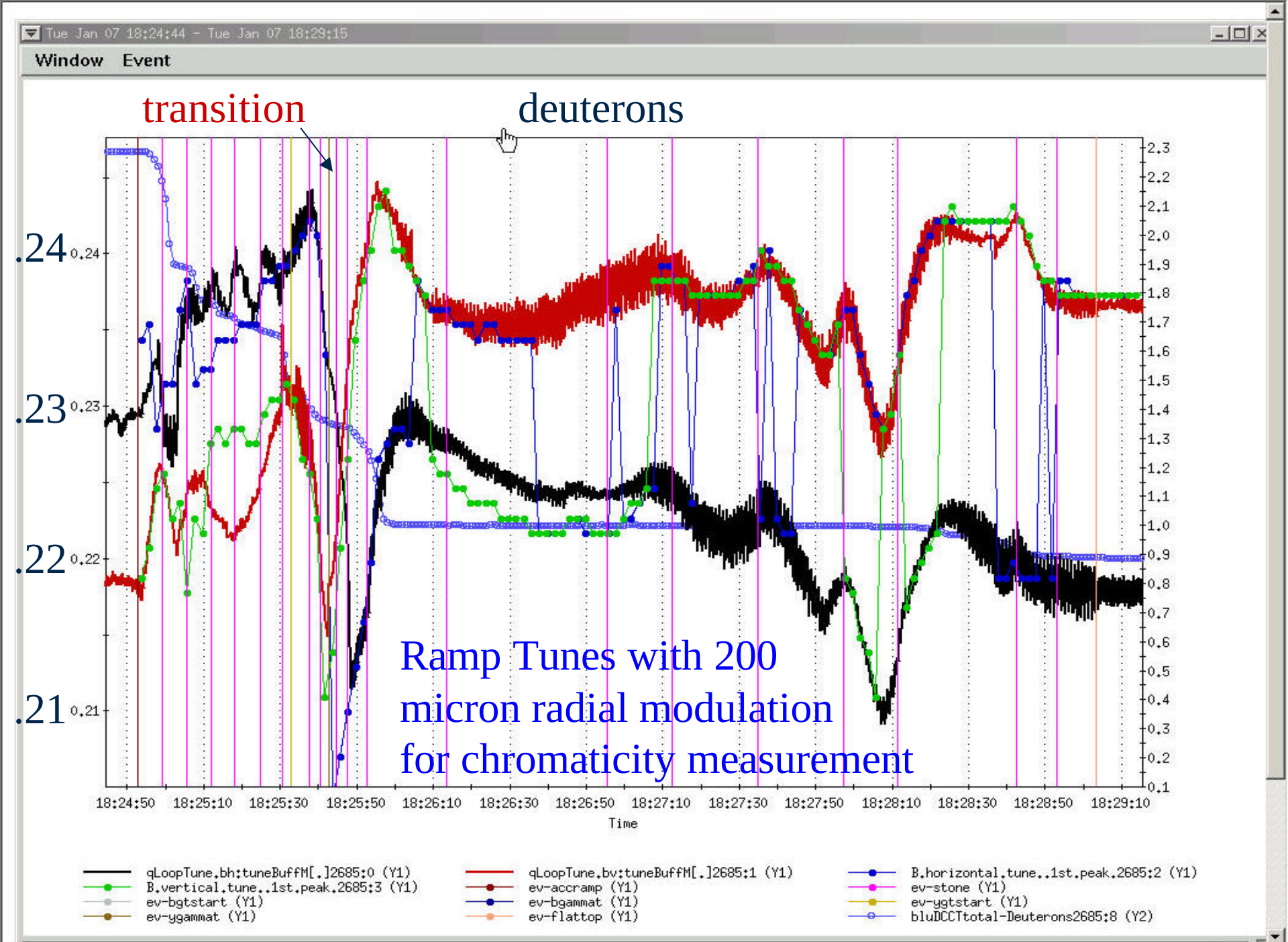
Loop tuning

- PID loop tuning
  - loop is artificially constrained (by maximum dither ~ .001 in RHIC), usual tuning algorithms do not apply
  - the beam transfer function portion of the loop gain varies considerably
- Magnet transfer function uncertainties?

- **extensive studies with modulated test resonator in progress, comparison between results and model**
- **need a model that includes the beam**
- **need dedicated time at start of run for loop tuning**

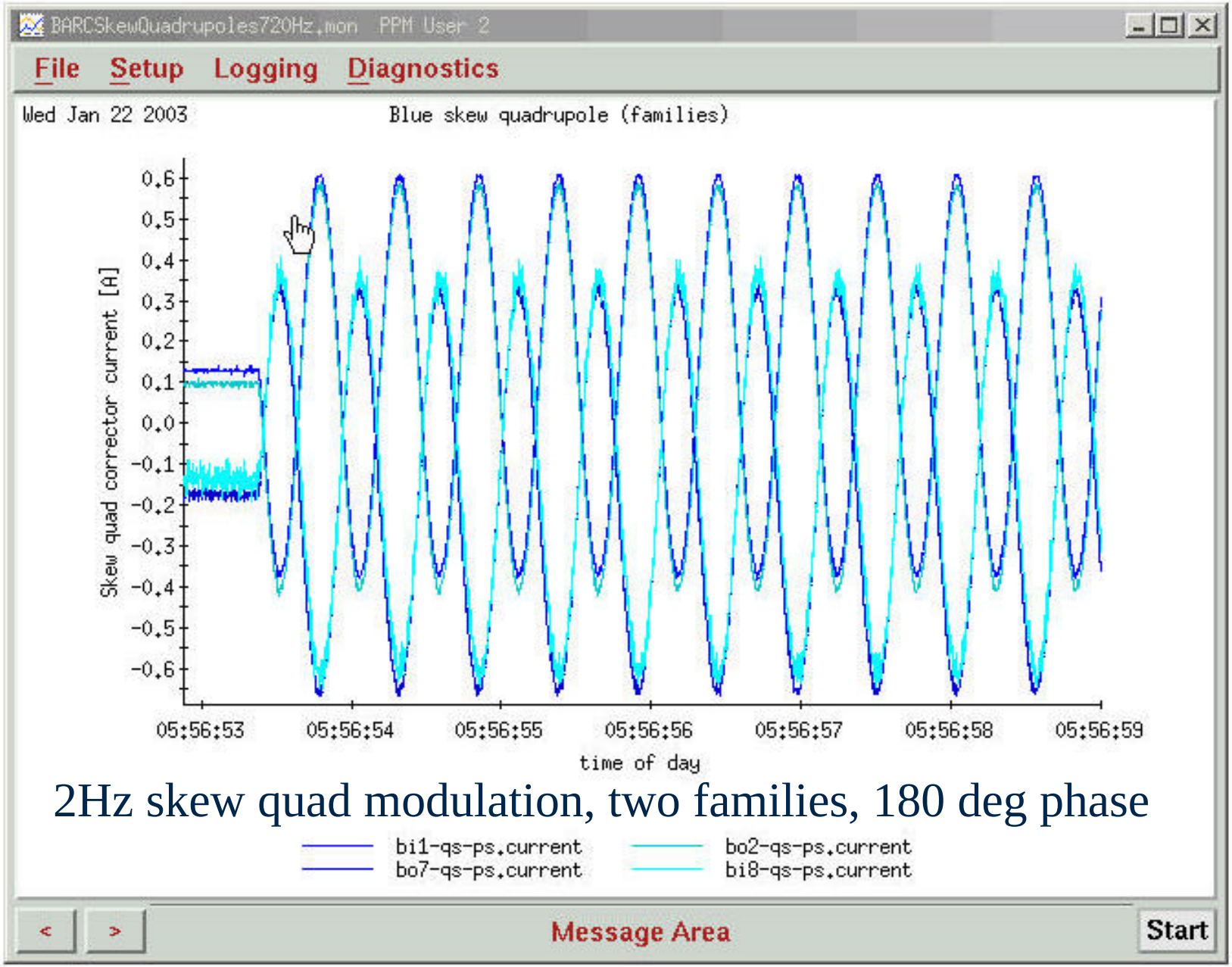


Magnet transfer function uncertainties: ‘constant’ amplitude tune modulation of increasing frequency: measured amplitude increases in vertical, decreases in horizontal, tune shifts.


Tue Jan 07 18:24:44 - Tue Jan 07 18:29:15
Window
Event
transition
deuterons
.24
.23
.22
.21
0.24
0.23
0.22
0.21
2.3
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
Ramp Tunes with 200
micron radial modulation
for chromaticity measurement
18:24:50
18:25:10
18:25:30
18:25:50
18:26:10
18:26:30
18:26:50
18:27:10
18:27:30
18:27:50
18:28:10
18:28:30
18:28:50
18:29:10
Time
qLoopTune.bh:tuneBuffM[.]2685:0 (Y1)
B.vertical.tune..1st.peak.2685:3 (Y1)
ev-bgtstart (Y1)
ev-ygammat (Y1)
qLoopTune.bv:tuneBuffM[.]2685:1 (Y1)
ev-accramp (Y1)
ev-bgammat (Y1)
ev-flattop (Y1)
B.horizontal.tune..1st.peak.2685:2 (Y1)
ev-stone (Y1)
ev-ygtstart (Y1)
bluDCCTtotal-Deuterons2685:8 (Y2)

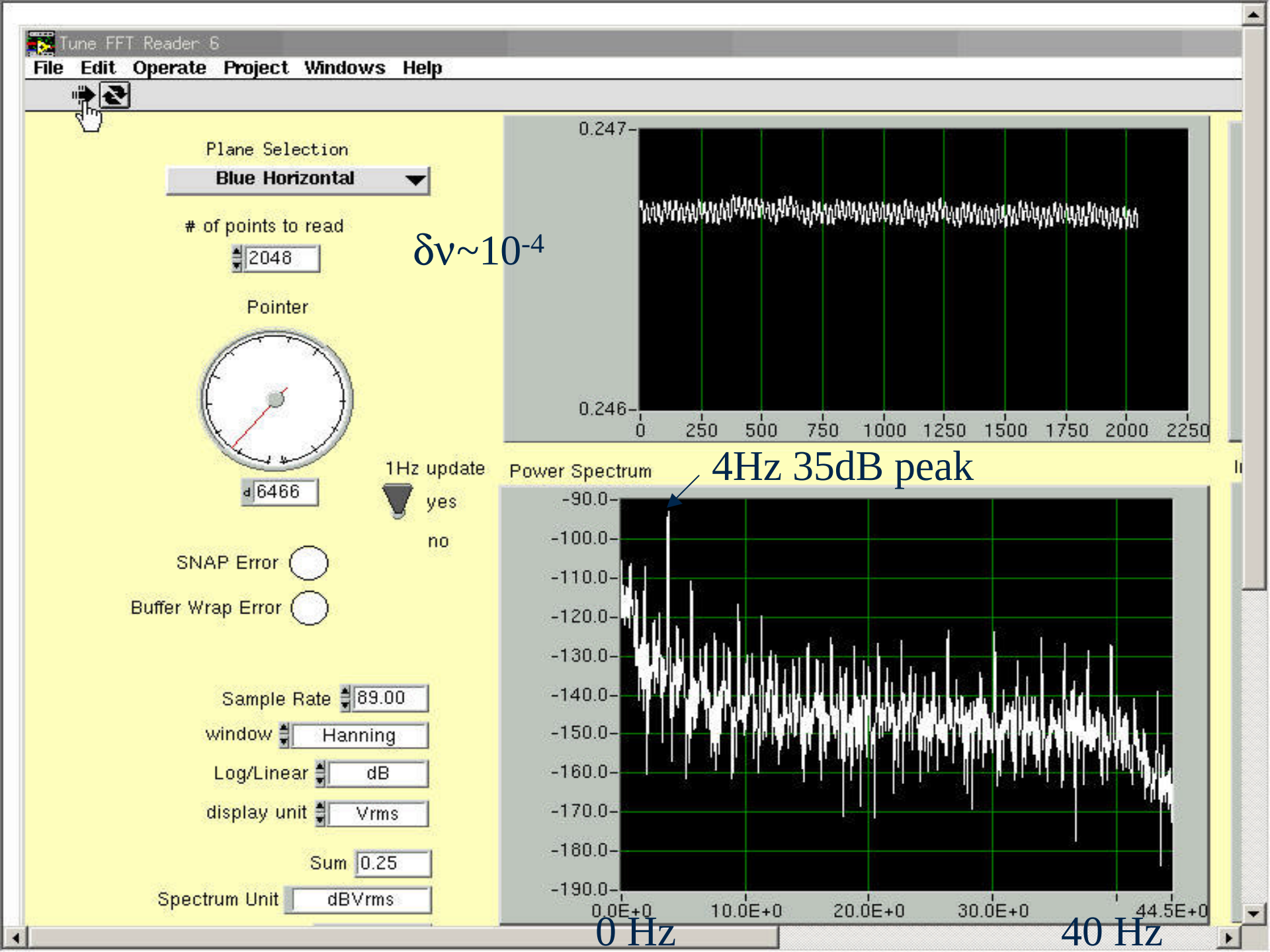
PLL Issues – in order?

- Signal to Noise
- Stability and Loop Tuning - modeling
- ***Coupling***
- Anomalous phase shifts
- Chromaticity control (not)



2Hz skew quad modulation, two families, 180 deg phase

Close Duplicate


Tune FFT Reader 6
File Edit Operate Project Windows Help
Plane Selection
Blue Horizontal
# of points to read
2048
δν~10-4
Pointer
6466
1Hz update
yes
no
SNAP Error
Buffer Wrap Error
Sample Rate 89.00
window Hanning
Log/Linear dB
display unit Vrms
Sum 0.25
Spectrum Unit dBVrms
0.247
0.246
0 250 500 750 1000 1250 1500 1750 2000 2250
Power Spectrum
4Hz 35dB peak
-90.0 -100.0 -110.0 -120.0 -130.0 -140.0 -150.0 -160.0 -170.0 -180.0 -190.0
0.0E+0 10.0E+0 20.0E+0 30.0E+0 44.5E+0
0 Hz
40 Hz

Tune FFT Reader 6

File Edit Operate Project Windows Help

Plane Selection

Blue Horizontal

# of points to read

2048

Pointer

26292

1Hz update

yes

no

SNAP Error

Buffer Wrap Error

Sample Rate 89.00

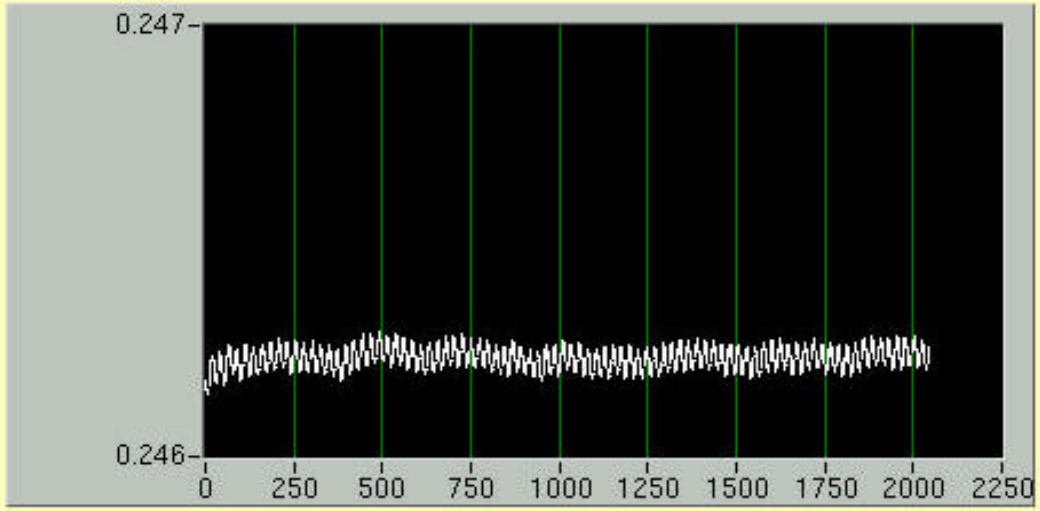
window Hanning

Log/Linear dB

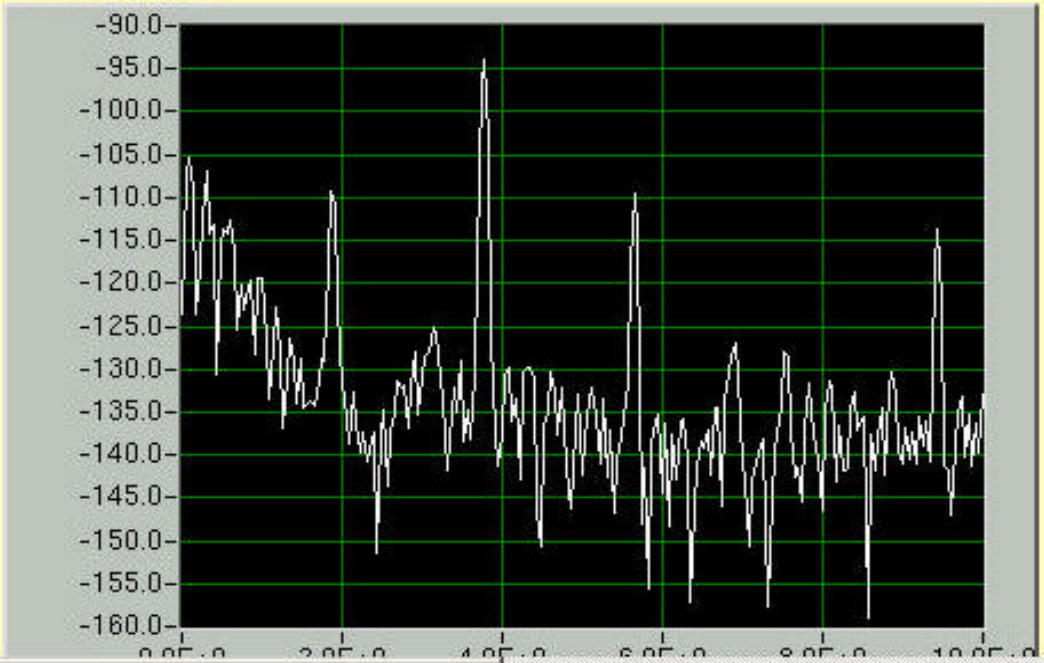
display unit Vrms

Sum 0.25

Spectrum Unit dBVrms



Power Spectrum



Intensi

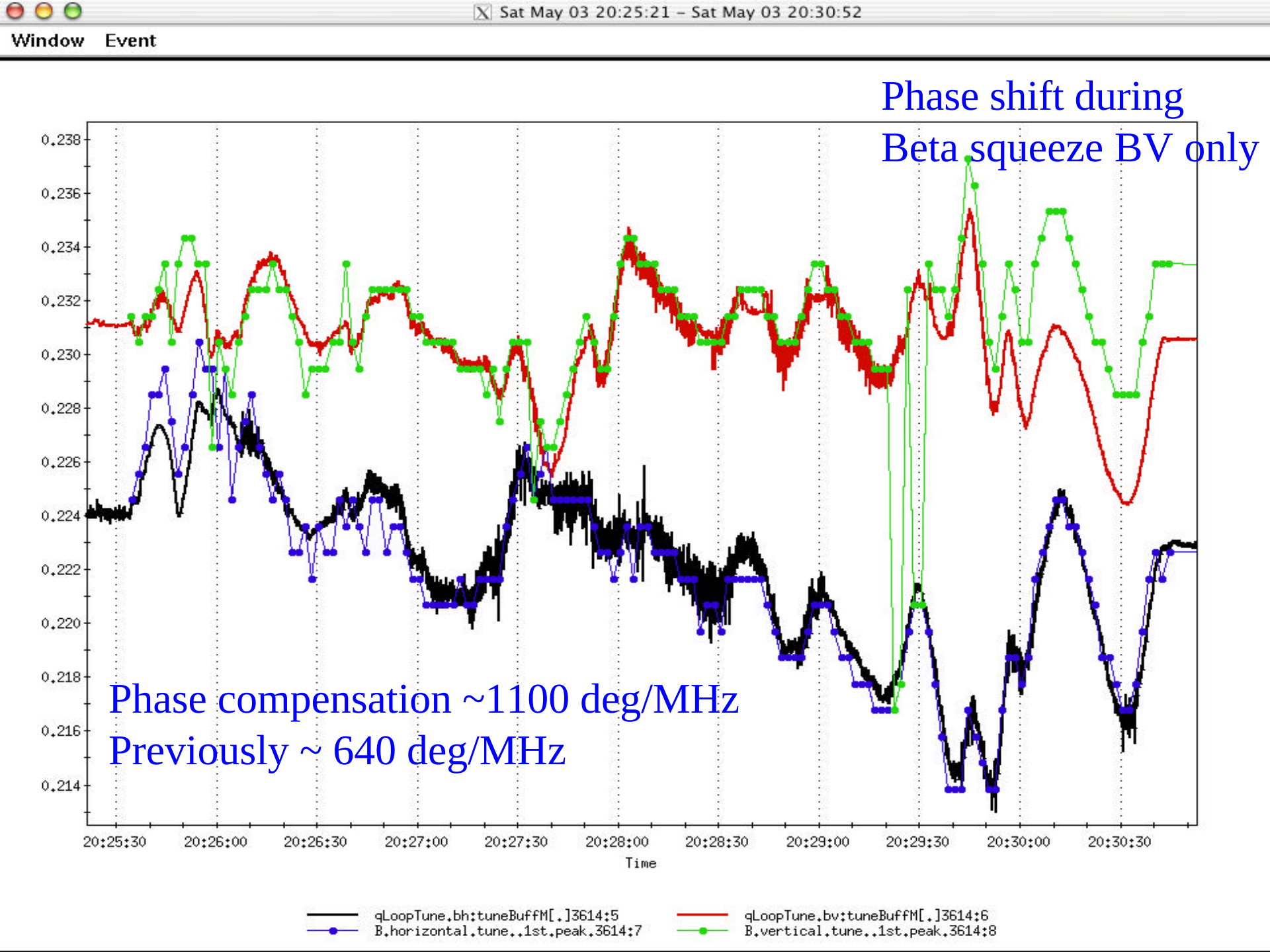
550
500
450
400
350
300
250
200
150
100
50
0

Coupling on the ramp

- Separate excitation in either time or frequency domain
  - Drive first half of bunch train H, last half V
  - Drive H and V at different harmonic numbers – RHIC
  - This may help a bit, but coupling is in the beam
- Potential exists to measure and correct coupling with skew quad modulation and PLL FFT
- This was given some study time, more required to firmly establish the method
- Wolfram's method (analyze BPM data when tune kicker fires) offers another viable approach

PLL Issues – in order?

- Signal to Noise
- Stability and Loop Tuning - modeling
- Coupling
- ***Anomalous phase shifts***
- Chromaticity control (not)


Sat May 03 20:25:21 – Sat May 03 20:30:52
Window
Event
Phase shift during
Beta squeeze BV only
Phase compensation ~1100 deg/MHz
Previously ~ 640 deg/MHz
0.238
0.236
0.234
0.232
0.230
0.228
0.226
0.224
0.222
0.220
0.218
0.216
0.214
20:25:30
20:26:00
20:26:30
20:27:00
20:27:30
20:28:00
20:28:30
20:29:00
20:29:30
20:30:00
20:30:30
Time
qLoopTune.bh:tuneBuffM[.]3614:5
B.horizontal.tune..1st.peak.3614:7
qLoopTune.bv:tuneBuffM[.]3614:6
B.vertical.tune..1st.peak.3614:8

PLL Issues – in order?

- Signal to Noise
- Stability and Loop Tuning - modeling
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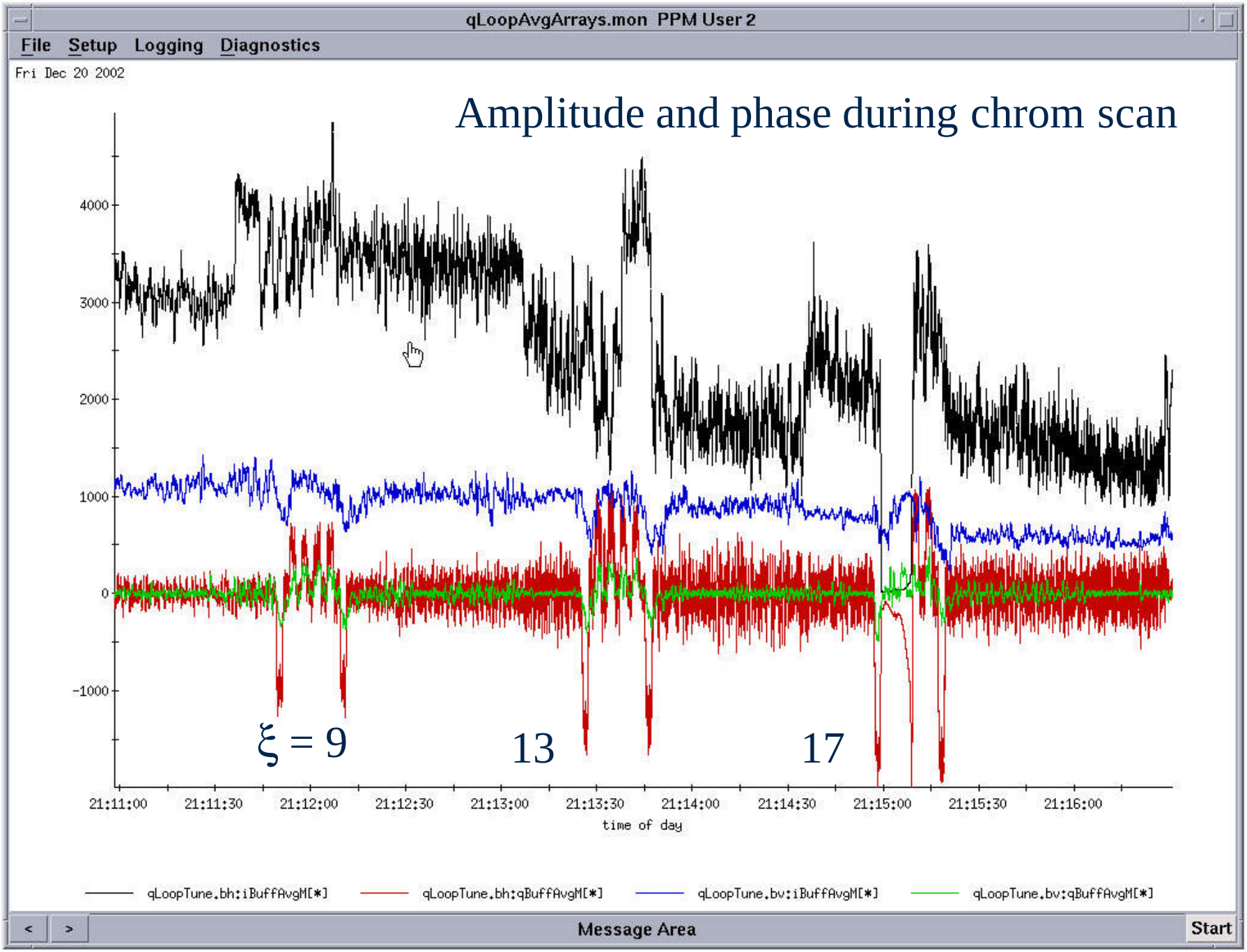
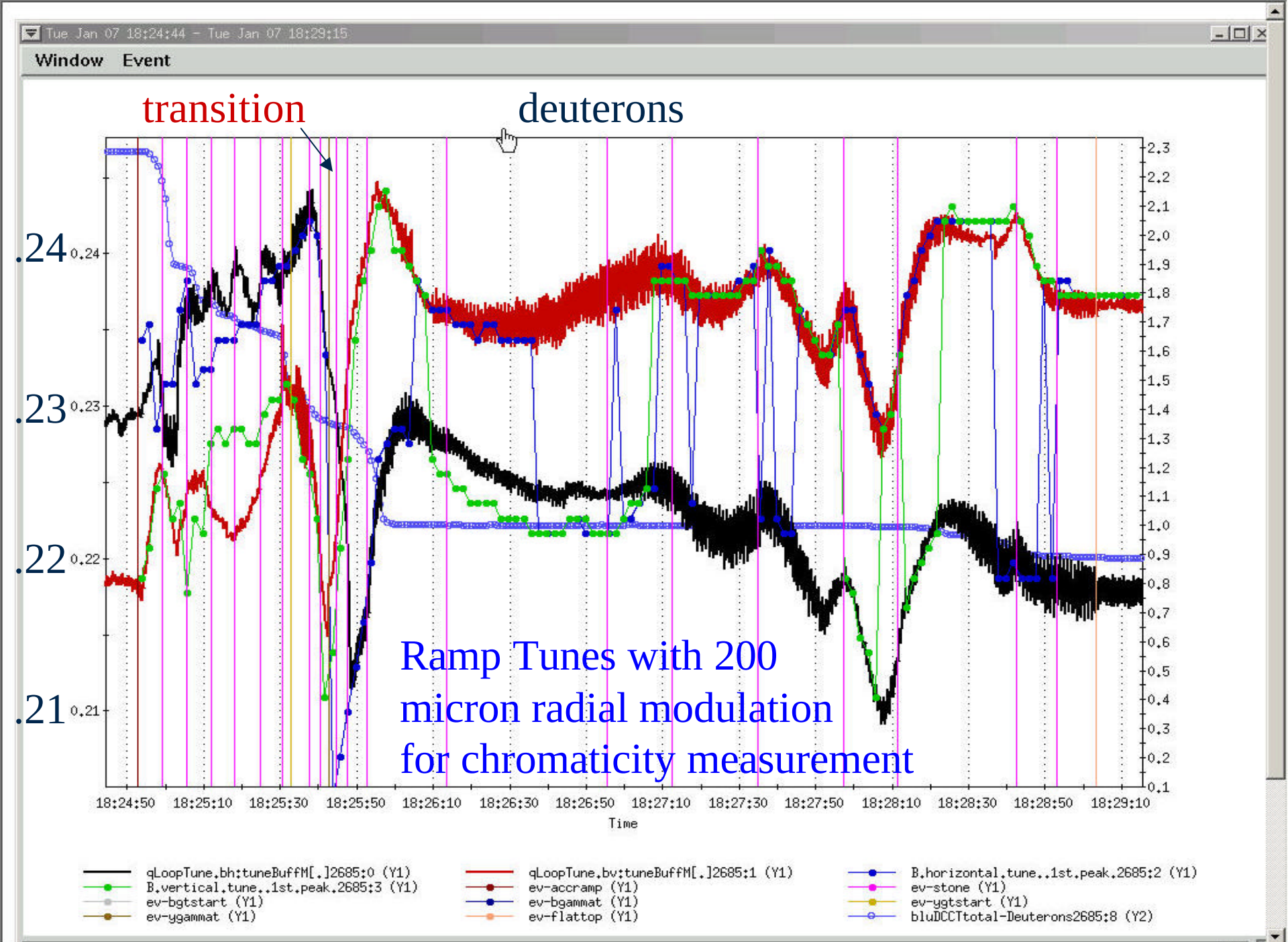
- Anomalous phase shifts
- ***Chromaticity control (not)***

Amplitude and phase during chrom scan



Chromaticity Effect on PLL

- Conclusion from the chromaticity study is that PLL tune measurement can cope with a large range of chromaticity
- Chromaticity control is not a primary issue for PLL tune measurement and tune feedback
- Chromaticity control is an issue primarily in the usual operational sense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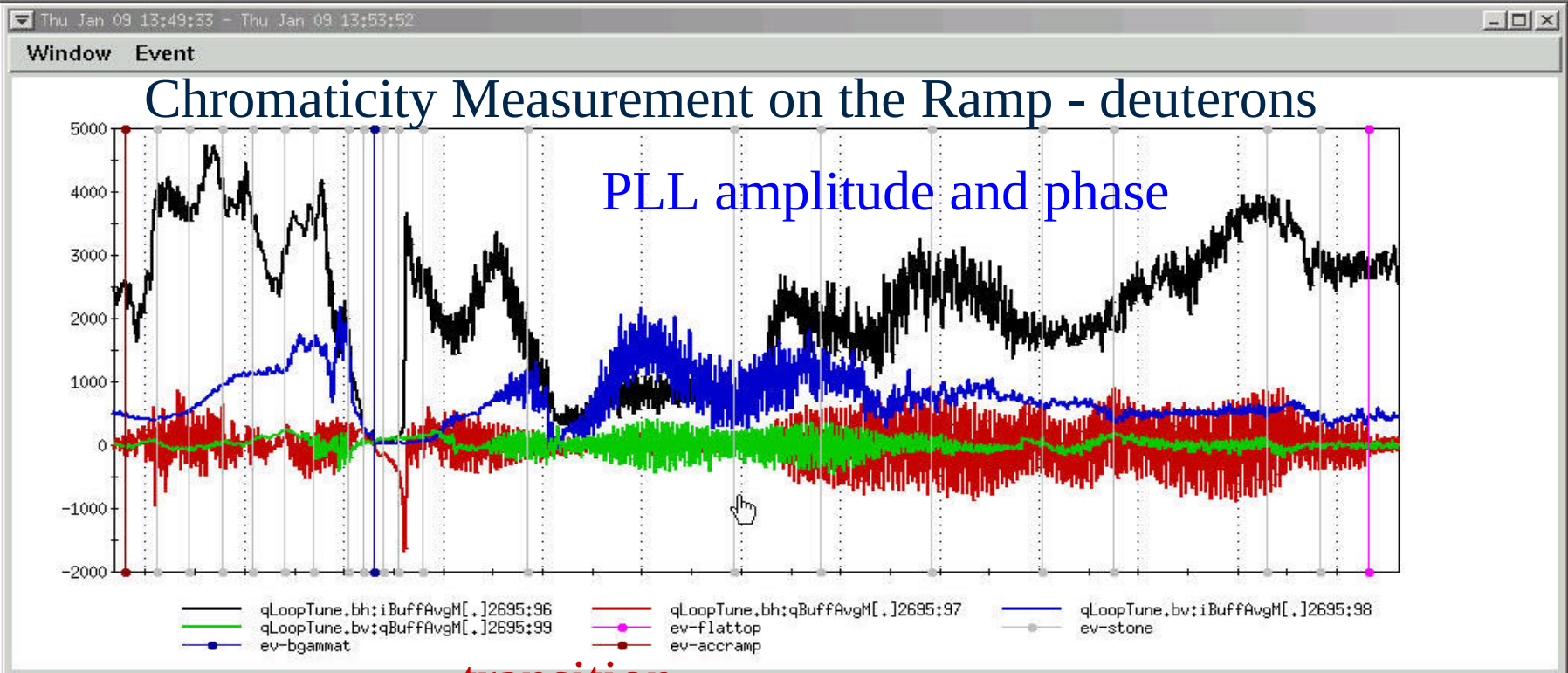
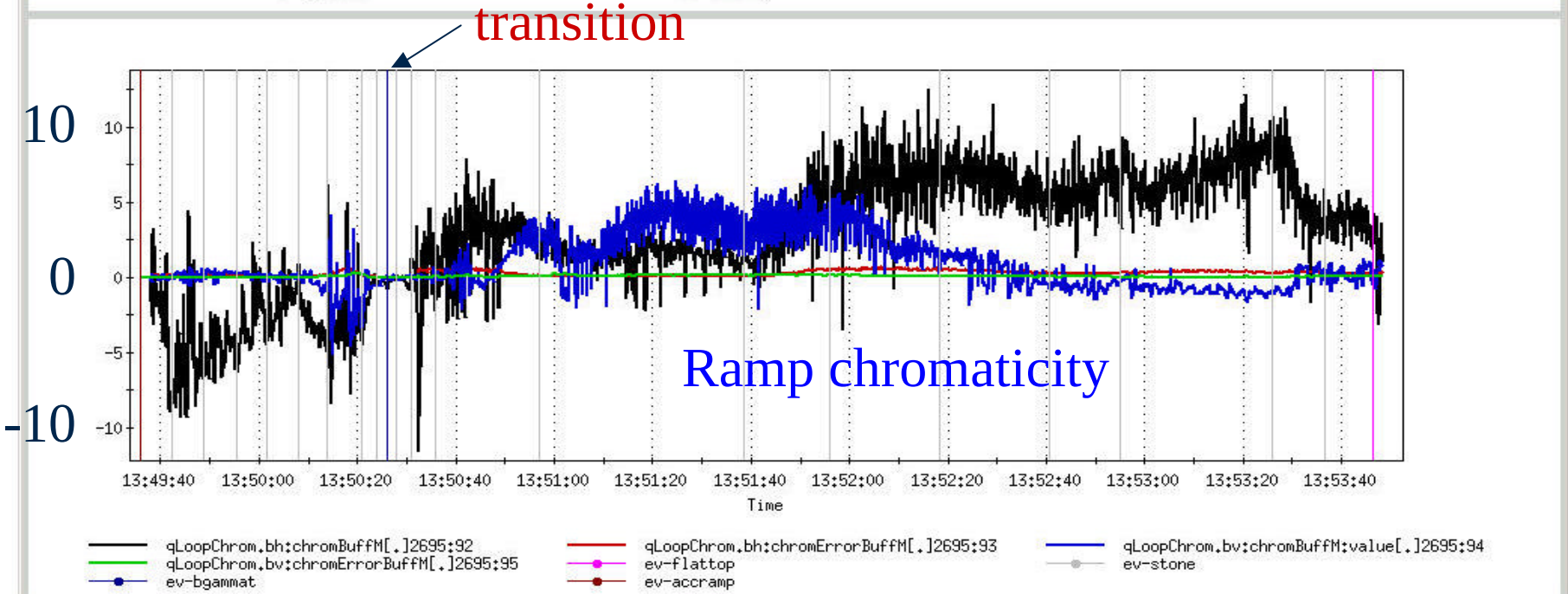
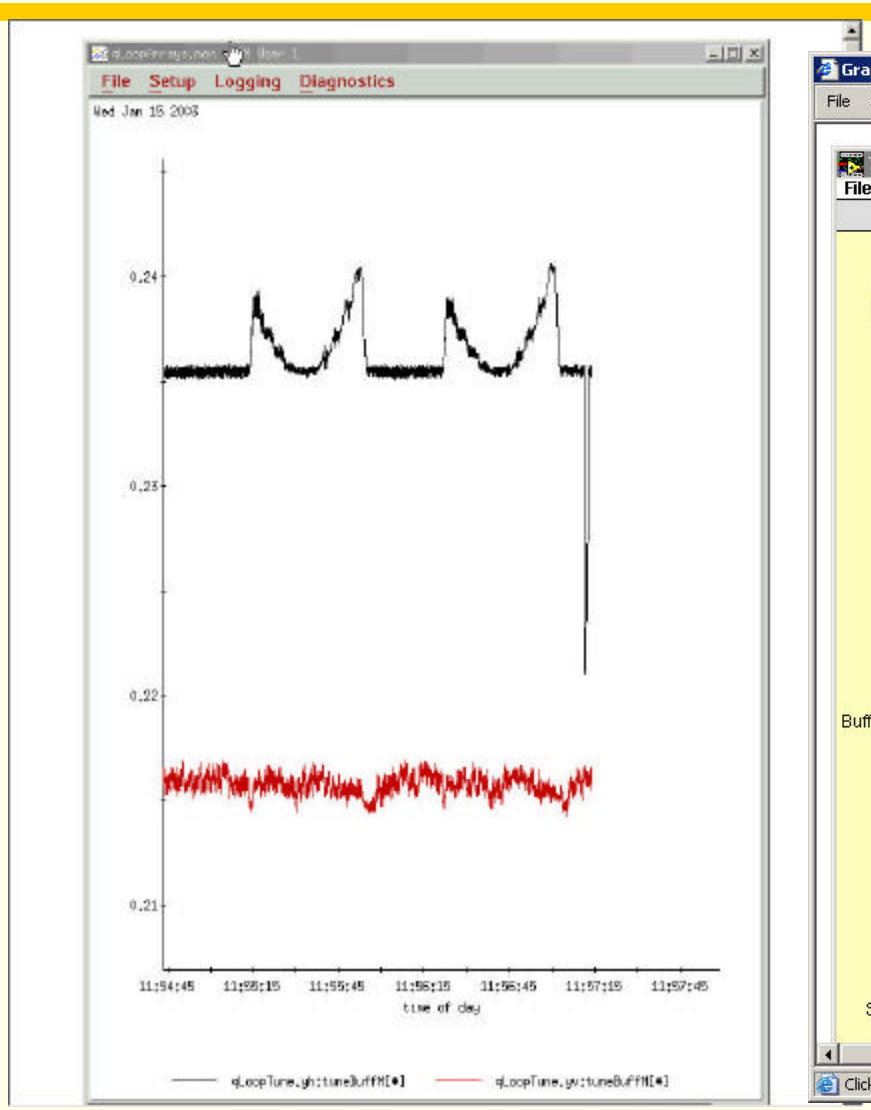
ev-stone (Y1)
ev-ygtstart (Y1)
bluDCCTtotal-Deuterons2685:8 (Y2)

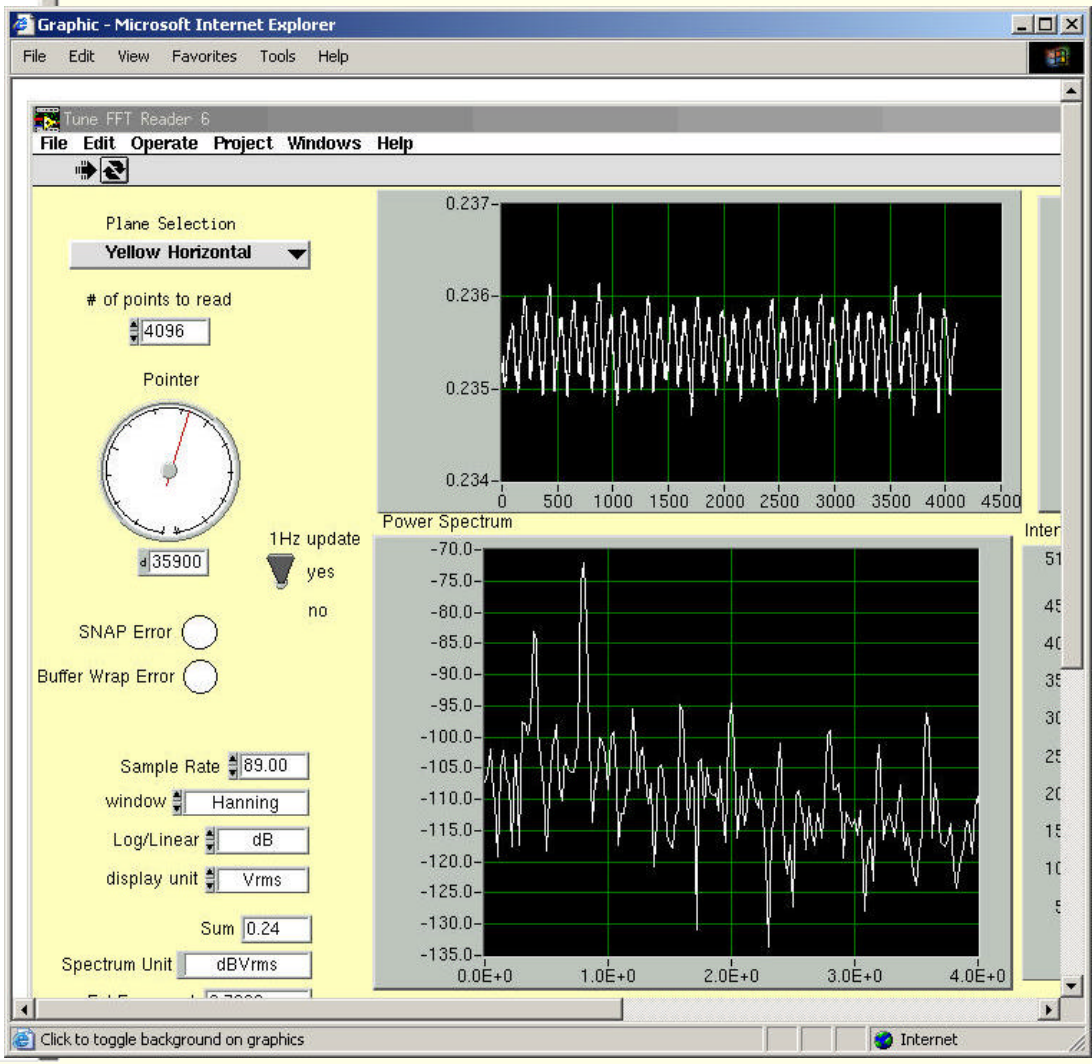
Chromaticity Measurement on the Ramp - deuterons





Non-linear chromaticity – .5Hz, .4mm





Chromaticity Measurement with PLL

- Works well when utilized
- Hesitancy to use on a regular basis because of concern with beam loss due to radial modulation (and it is just more complexity in a complex environment – requires specialists)
- Decoherence of kicked tune excitation is the primary tool used during normal operations
- Non-linear chromaticity measurement possible during ramping with good S/N, good tool at store may be Schottky (Kurt Vetter's presentation)

Outline

- PLL Issues
- ***LHC specific discussion***
  - two systems?
  - pickup specification
  - modeling – include the beam
- Plan for FY04

Two Systems?

- Single bunch commissioning - a useful resonant pickup is difficult, S/N is a serious issue
  - System similar to LEP PLL?
  - Accept emittance blowup during single bunch commissioning
  - Ramp development tool
- Multi bunch commissioning/operations
  - RHIC style system is applicable

Aside – Superconducting Pickup?

- Frequency ~ 400MHz
- Relatively modest Q ~ 10^6
  - Less exotic technologies possible – lead plating?
  - BW ~ 400Hz
  - Single bunch enhancement ~ x30
- Also get filtering on revolution line

Modeling

- PLL without beam – two good models
  - Mathcad frequency domain
  - LabVIEW time domain
- PLL with beam
  - First steps taken by Nikolai Malitsky et al on SNS
  - Other work on UAL completed, this may now be moved higher on priorities list

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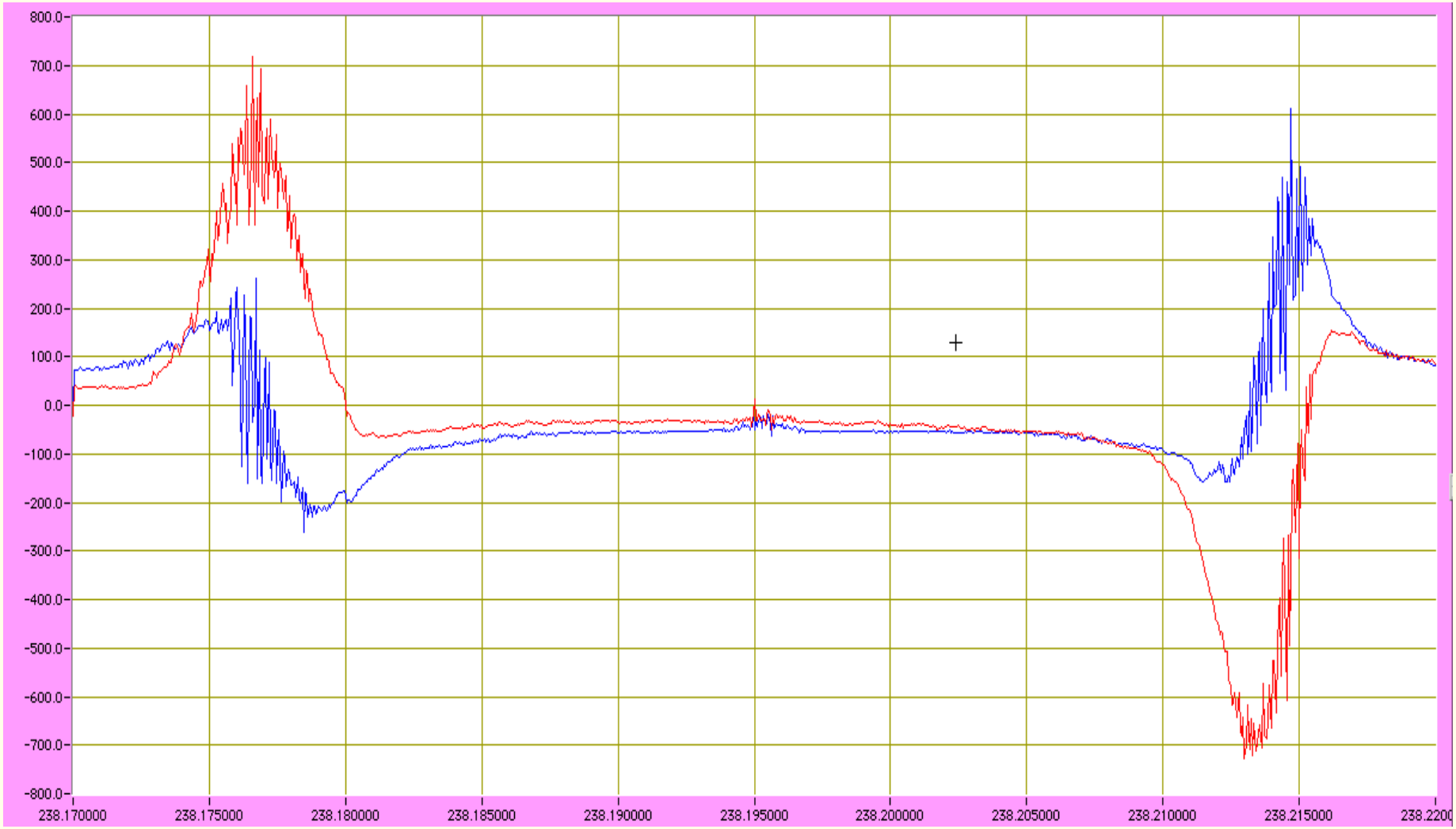
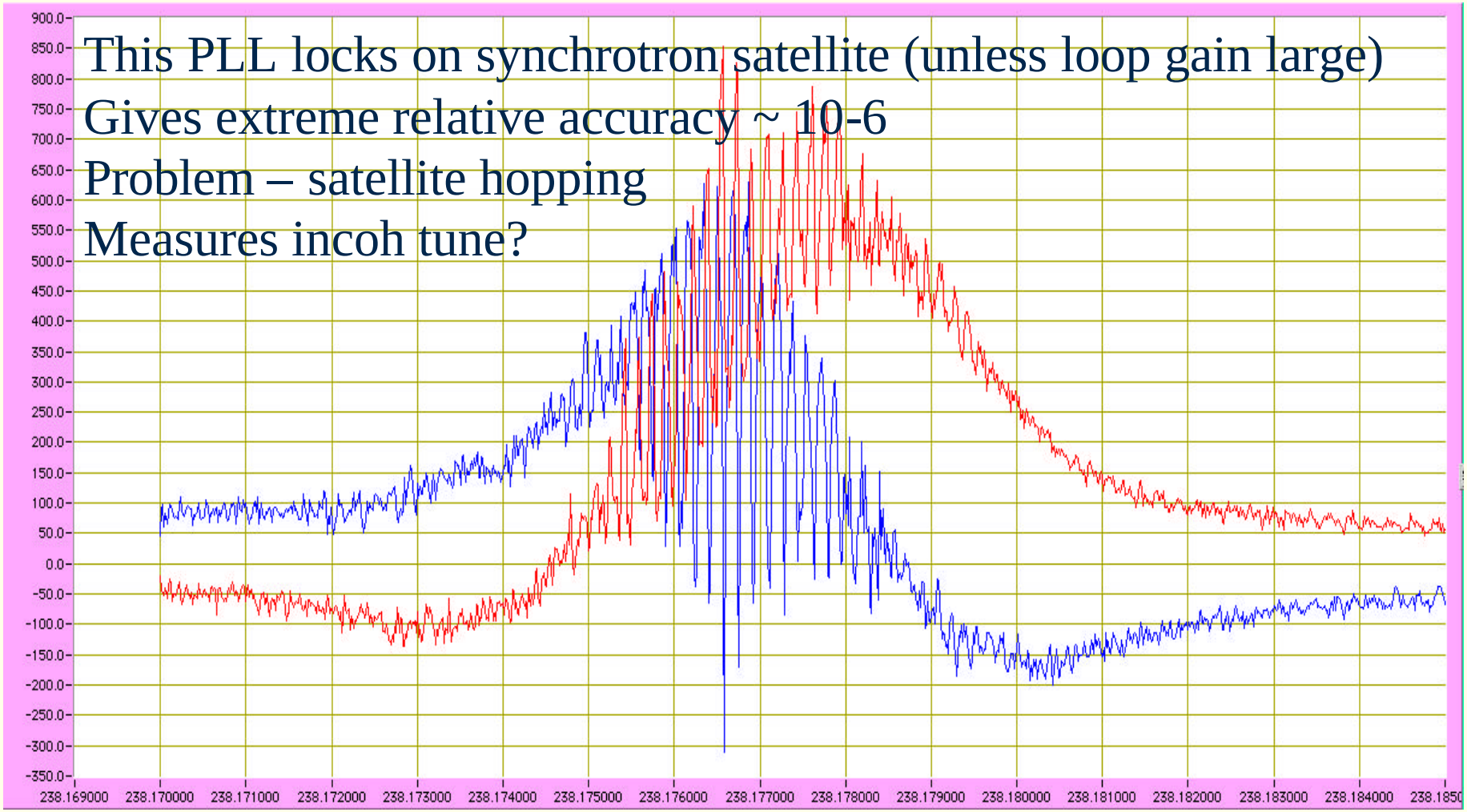
Plan for FY04

- Continue bi-lateral collaboration
  - Groundrule is “work beyond that easily accommodated into normal RHIC operations falls into LARP”
  - Results from RHIC 2004 will clarify ultimate potential
- LARP activities for FY04
  - Progress on LHC pickup specification
  - modeling – include the beam
  - Hardware (DAQ) and support for SPS PLL testing during May-Oct SPS run, possibly in PCI format (requires approval from RHIC management)

Beam Transfer Function



Zoom on Beam Transfer Function