



3D Results from FNAL and BNL

Peter Cameron

Outline



- Why Baseband/3D?
- Results from FNAL
 - beam spectra, comparison w/ 21.4MHz Schottky
 - the 60Hz problem
- Results from BNL
 - beam spectra
 - PLL tune tracking
 - emittance growth
 - the 60Hz problem

Why Baseband/3D?



Why Baseband?

- **Dynamic Range** - γ_t and 400MHz RF solution is to live always in the coherent spectrum
- Filters much easier (dynamic range/rev line problem)
- 24 bit digitizers - 144dB (better than available preamps!)
- Improved CMRR possible at audio frequencies
- Synchrotron satellites/linewidth - less of an issue
- Eliminates need for phase compensation - of more interest at RHIC (~700 degrees during ramp)
- Possibility of many cheap receivers scattered throughout ring (**local coupling!**)

Why 3D? clever spectral translation, improved S/N

Comparing BBQ, 21.4MHz and 1.7GHz Schottkys

C.Y. Tan
Tune Tracker Workshop
09 March 2005

Thanks to the following people

- M. Gasior for building the hardware.
- P. Cameron, M. Gasior and F. Caspers for discussions.
- Tevatron group for BBQ support.

Goals

- _ Install the BBQ in the Tevatron.
- _ Compare the BBQ with the existing tune measurement systems in the Tevatron.

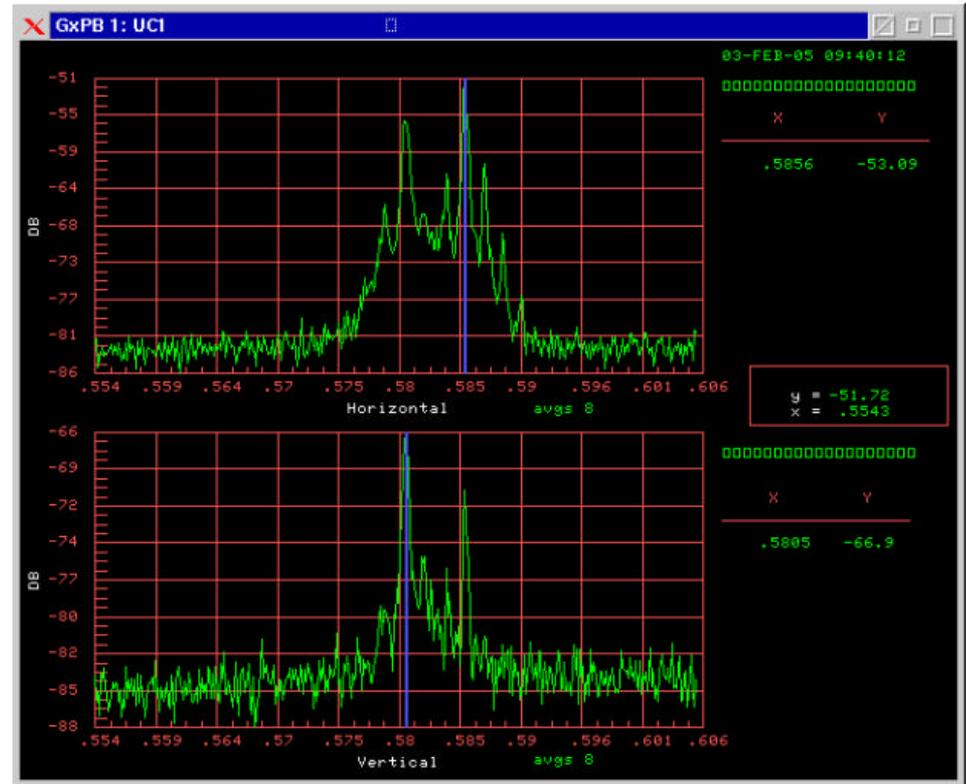
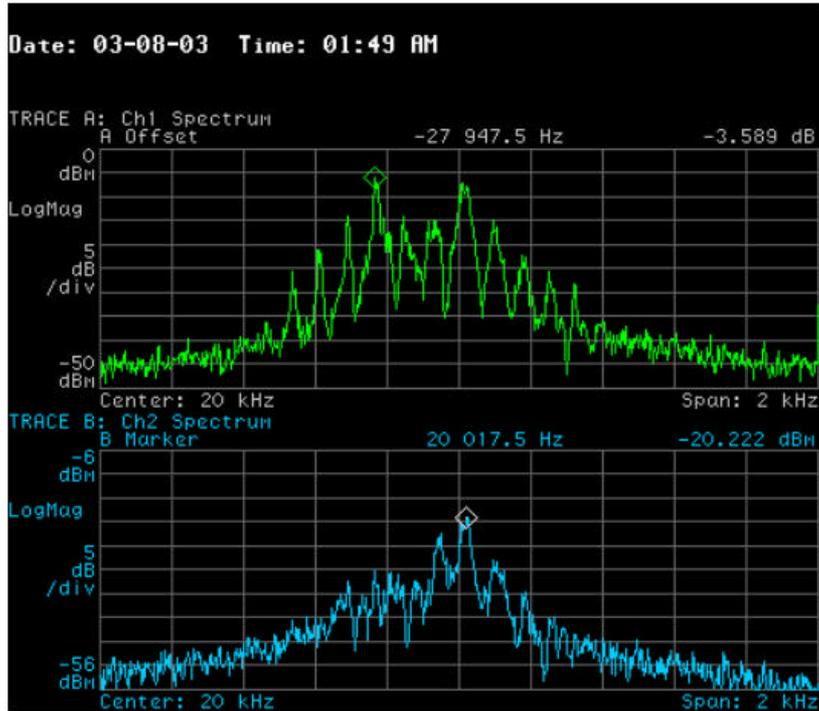
Different Bunch Types

- _ There are 2 different bunch types in the Tevatron
 - Uncoalesced bunch. Approx $200e9$ protons spread out in 30 adjacent buckets. Mainly used for tuning in the Tevatron.
 - Coalesced bunch. Can range from $150e9$ to $280e9$ of protons in one bucket. Used for HEP. At HEP there are 36 bunches of protons and 36 bunches of pbars in 3 trains of 12 bunches separated by 21 buckets.

Comparison Experiments

- _ Comparison experiments between the BBQ and 21.4 Mhz Schottky.
 - 150GeV with uncoalesced beam. VTICK on/off.
 - _ VTICK is a vertical kicker connected to a noise source. Centre is around tune frequency bw is 5kHz, power 5W.
 - 980GeV with 4x0 coalesced bunches.
 - 980GeV with 36x36 during HEP.
- _ Note BBQ measures tunes BELOW 1/2 integer while 21.4MHz measures tunes above 1/2 integer.

Uncoalesced Beam (VTICK on) 150GeV favorable condition for resonant pickup



BBQ $Q_h = 0.5855$, S/N ~40dB

BBQ $Q_v = 0.5804$, S/N ~30dB

Schottky $Q_h = 0.5856$, S/N ~30dB

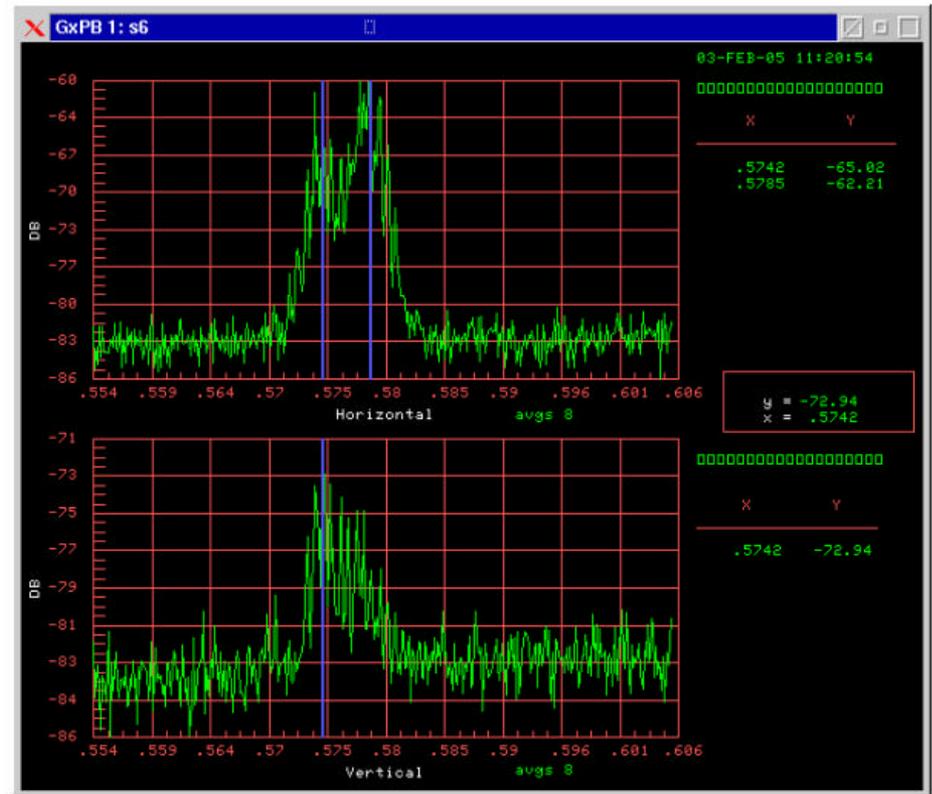
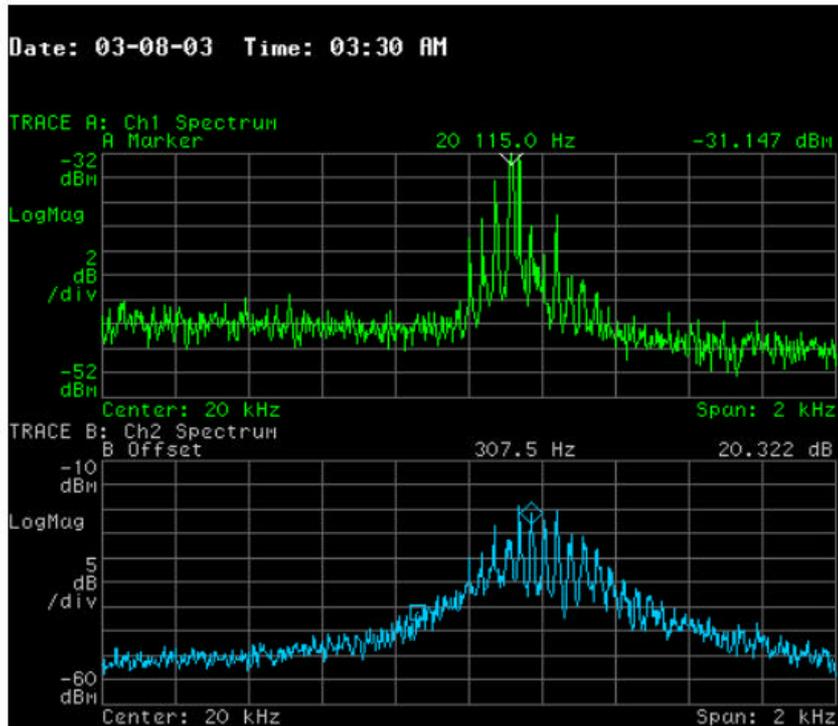
Schottky $Q_v = 0.5805$, S/N ~20dB

Cheng-Yang Tan 08 Mar 2005

note: blue font indicates comments added by P. Cameron

favorable condition for BBQ

4x0 low beta (VTICK on)



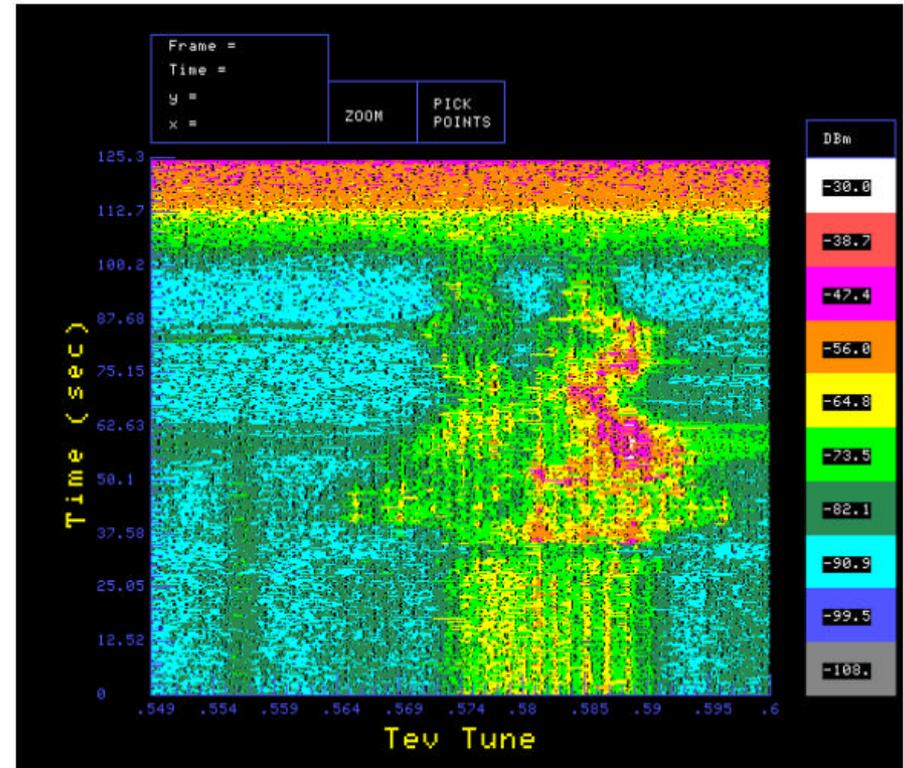
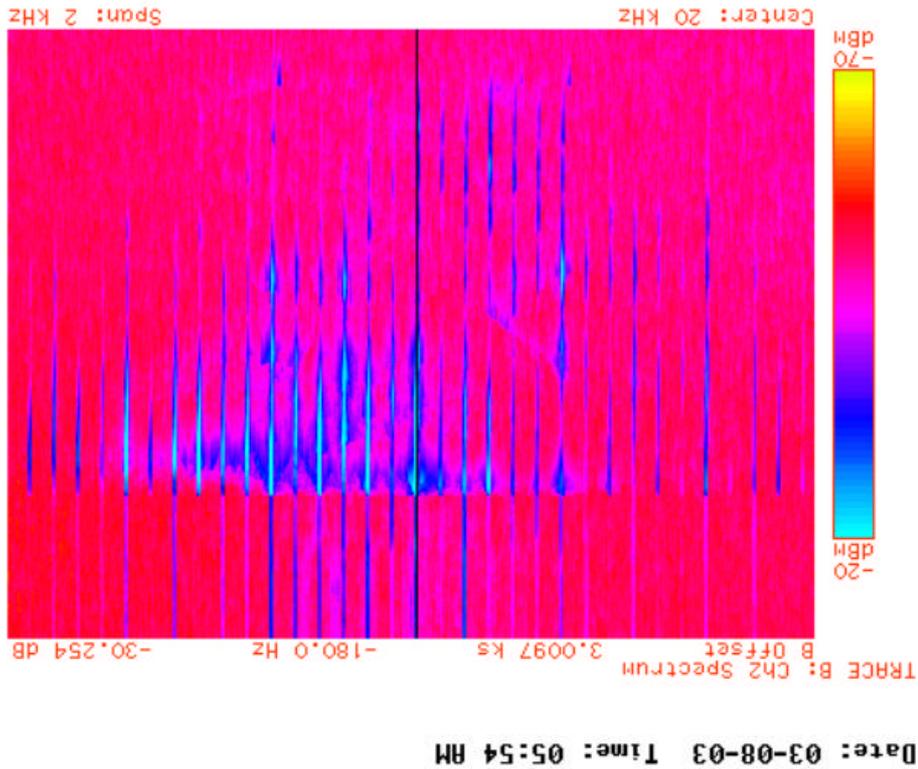
BBQ $Q_v=0.5784$, S/N ~30dB
Note differences in shape.

Schottky $Q_v=0.5785$, S/N ~10dB

BBQ

36x36 going up the ramp

21.4 pickup



Going up the ramp, BBQ dominated by 60Hz lines,
also present in 21.4 pickup

Summary of FNAL 3D Results



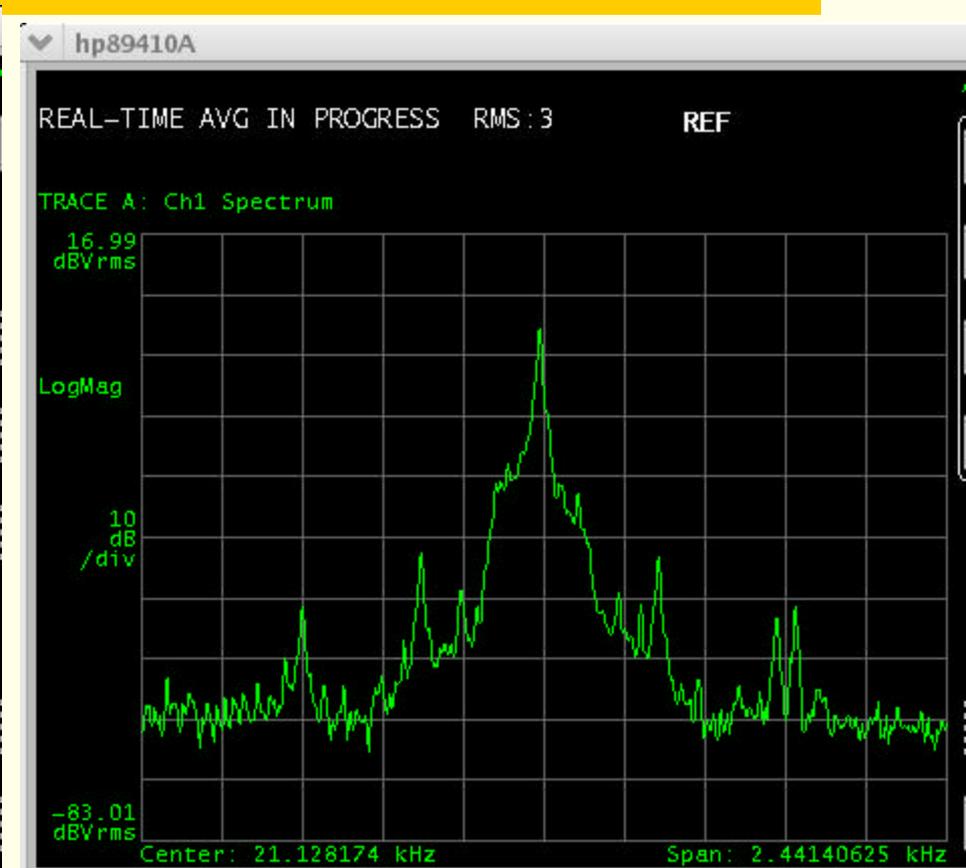
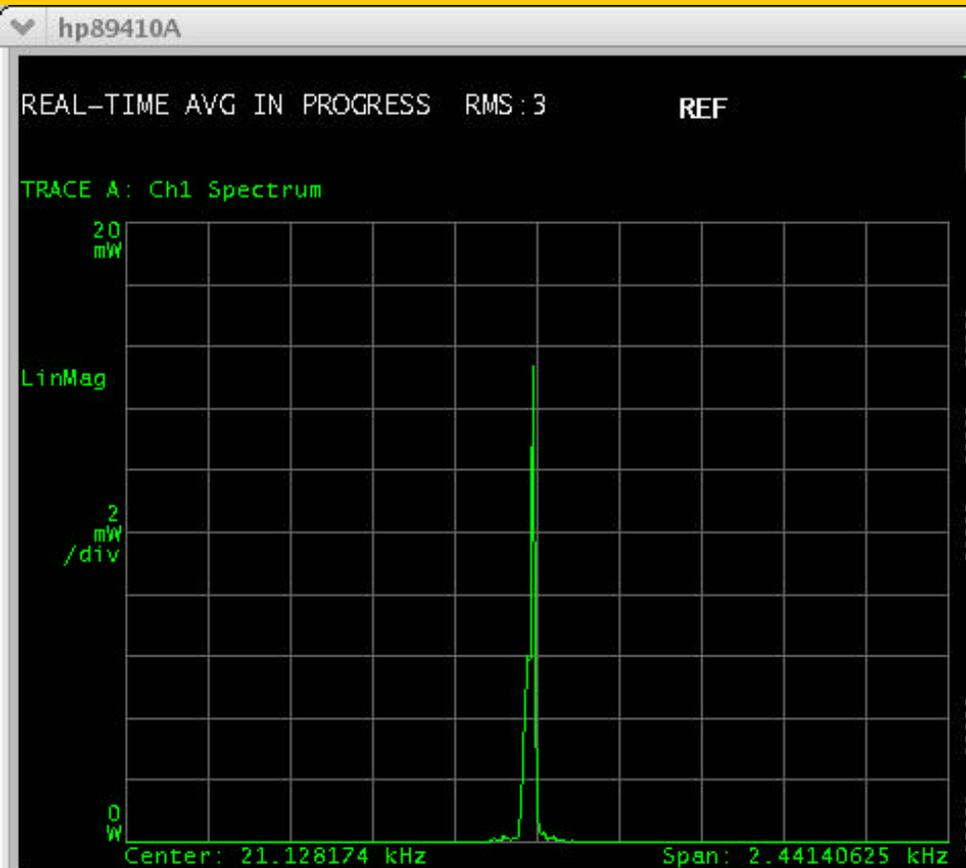
- betatron lines are observed with good S/N relative to the 21.4MHz Schottky pickup, and in good agreement with measured tune values
- 60Hz lines are a dominant feature of 3D spectra, especially on ramp, and are also present in 21.4
- More data from FNAL will be shown in the presentation on the 60Hz problem. That data was extremely valuable in arriving at the conclusive demonstration that 60Hz harmonics are on the beam.

Status at BNL



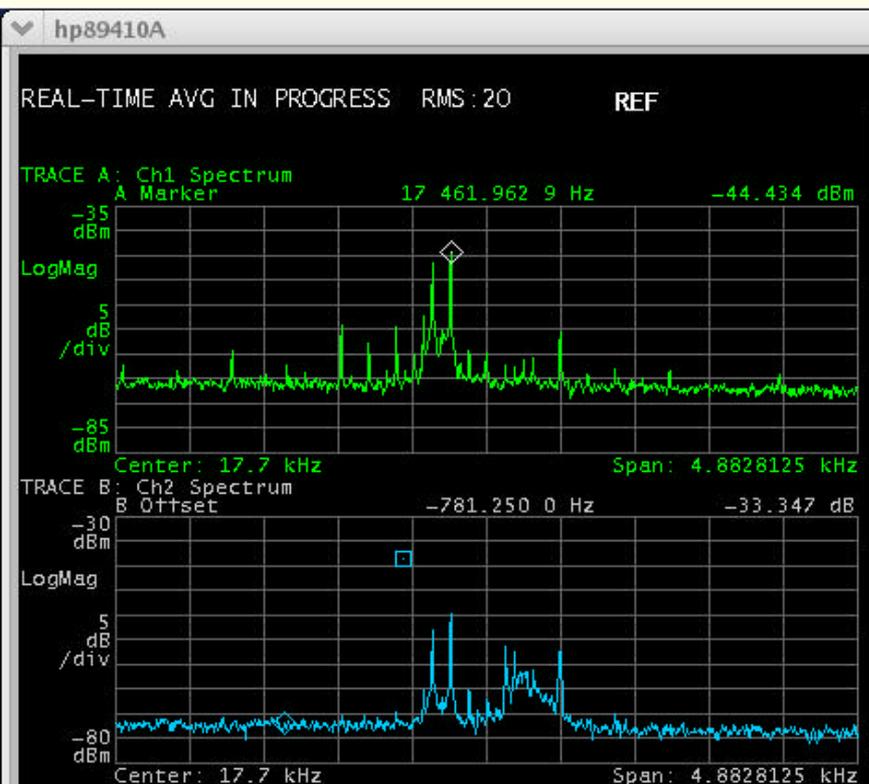
- 1m long pickups installed w/ motion control (not needed?!), both planes, both rings
- 1m long kickers installed
- In blue, 3D on both planes
- homodyne available both rings, both planes
- Tune evident without excitation - monitor at store
- Transition captures are easy - dynamic range no problem
- PLL tracking - equal or superior to 245MHz system, both in tracking and emittance growth
- **60Hz at the betatron line - has taken precedence in 3D evaluation**

same signal, linear and log scales



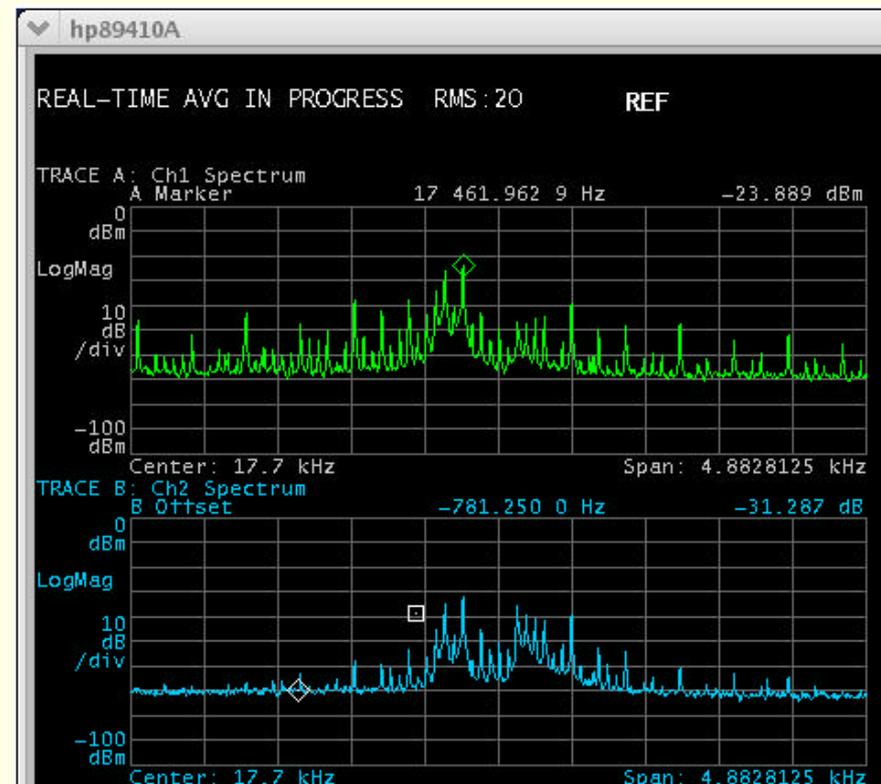
just a reminder

single and 37 bunches on BBQ



H

V



single bunch, 5dB/div,
no kick, ~10dB S/N

37 bunches, 10dB/div,
no kick, ~20dB S/N

noise floor ~2dB higher in 37 bunch traces



REAL-TIME AVG IN PROGRESS RMS:10

REF

FREQUENCY

center
17.5 kHz

span
2.4414062 kHz

full span

start
16.2792969 kHz

stop
18.7207031 kHz

time data
zoom
baseband

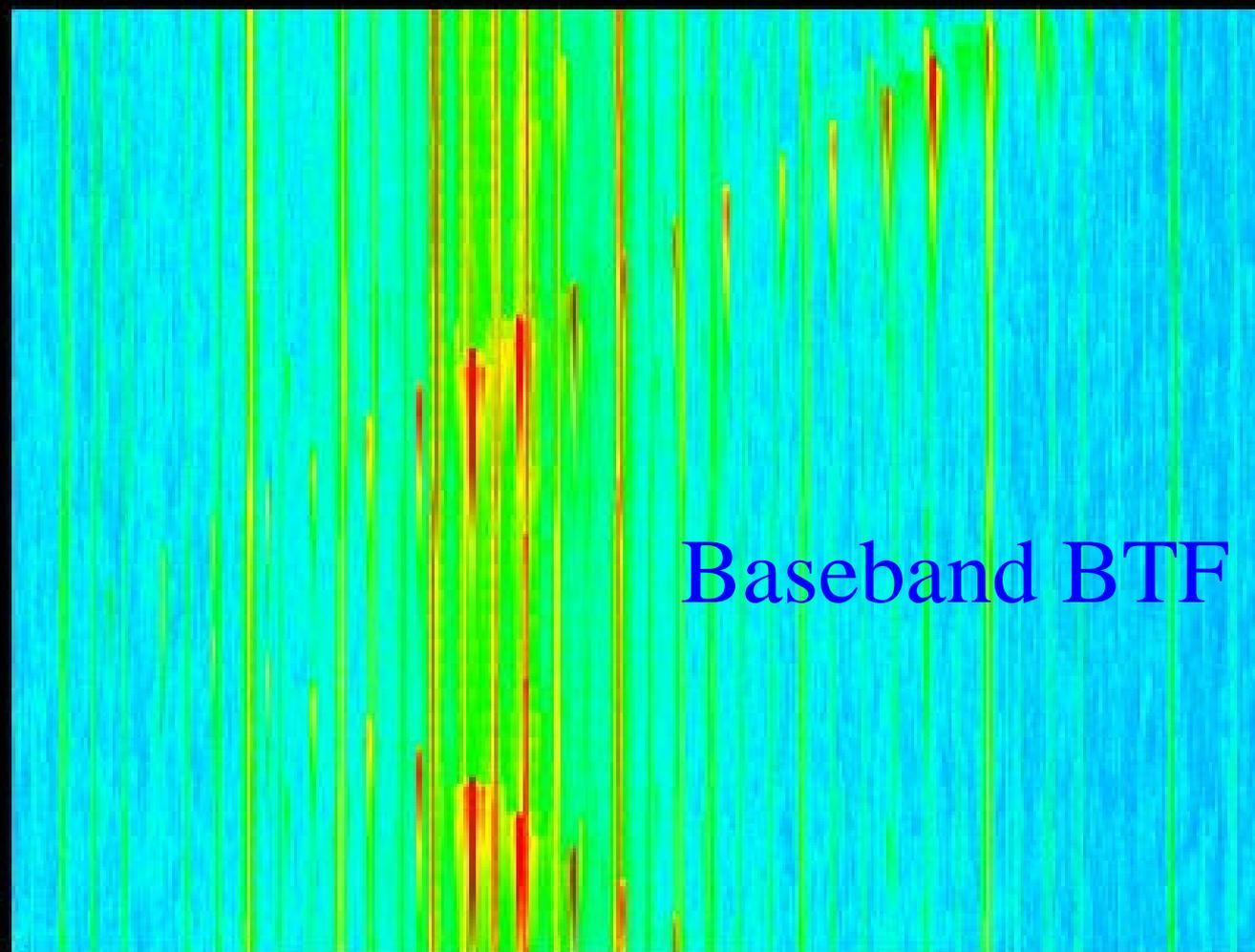
more →

TRACE A: Ch1 Spectrum

-45 dBm



-95 dBm



Baseband BTF

Center: 17.5 kHz

Span: 2.44140625 kHz

Closing the Loop



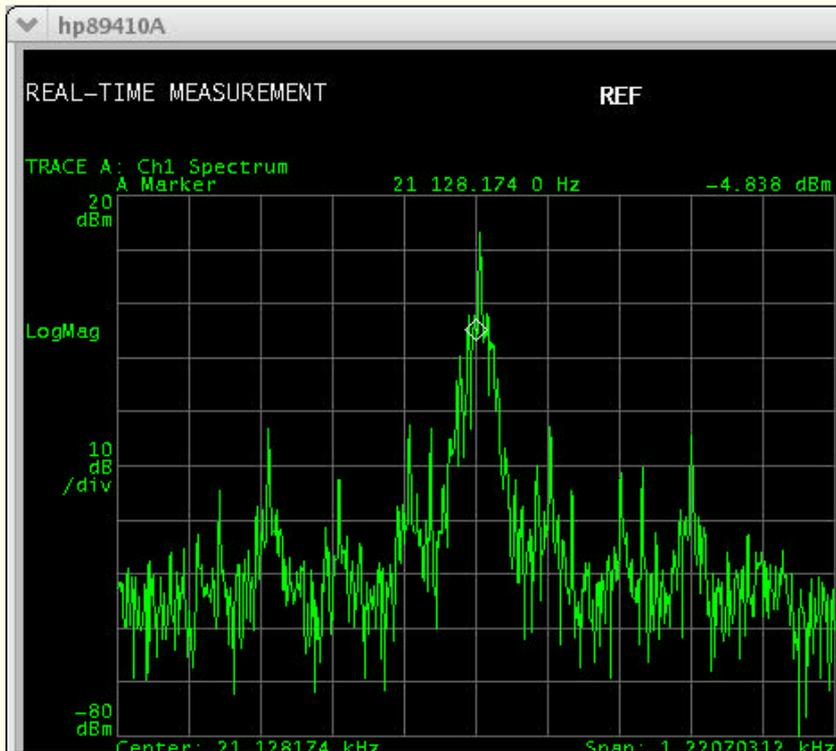
The setup

- SRI 830 lockin amplifier
- Wavetek Model 81 generator w/VCO input
 - VCO transfer function not well matched to the system
- Krohn-Hite model 3343 filter as kicker amplifier, driving balanced into the tunnel on twisted pair, ~20mW typical
- 3D AFE in the tunnel, with gain before cabling signals out

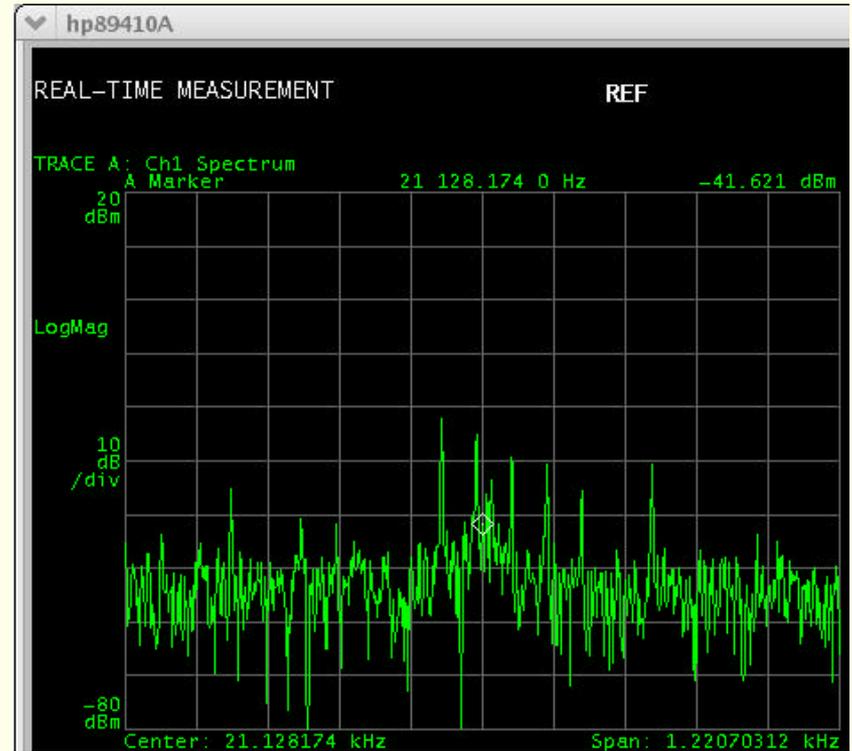
No Bleedthru!

- 245MHz system has been plagued by bleedthru - connectors
- signals at ~-140dBm, kick at ~+10dBm
- conventional shielding almost useless at audio freq

kick (PLL locked) and no kick



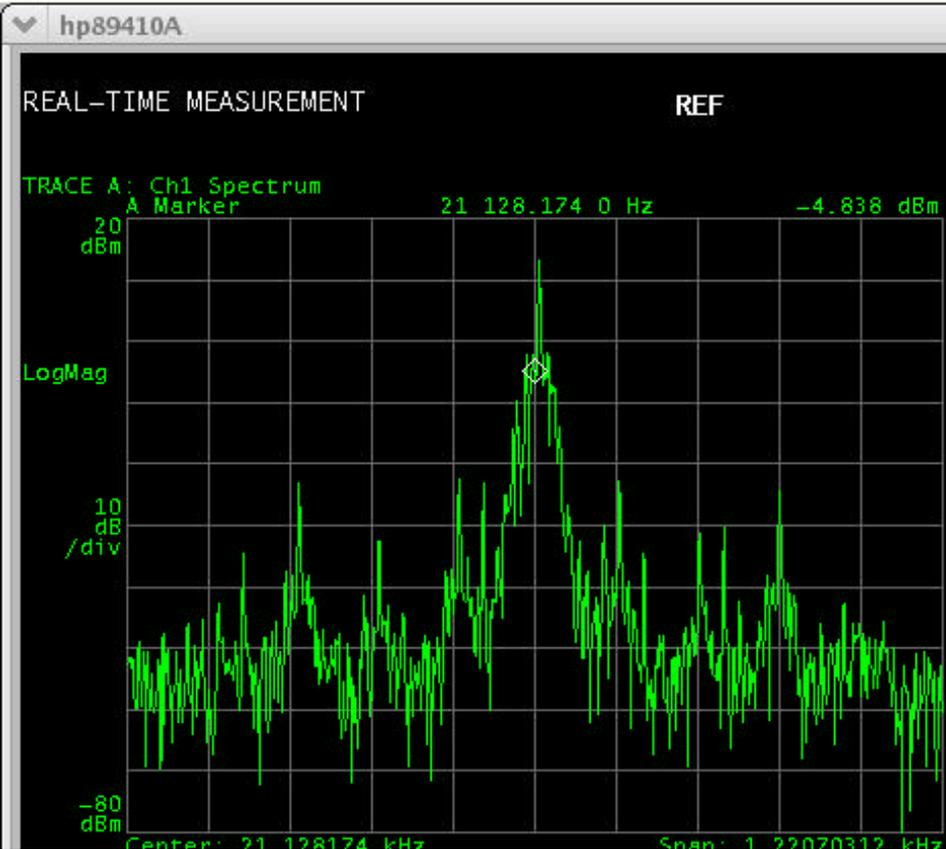
10dB/div, ~20mW kick,
PLL locked, ~70dB S/N



10dB/div, no kick,
~10dB S/N

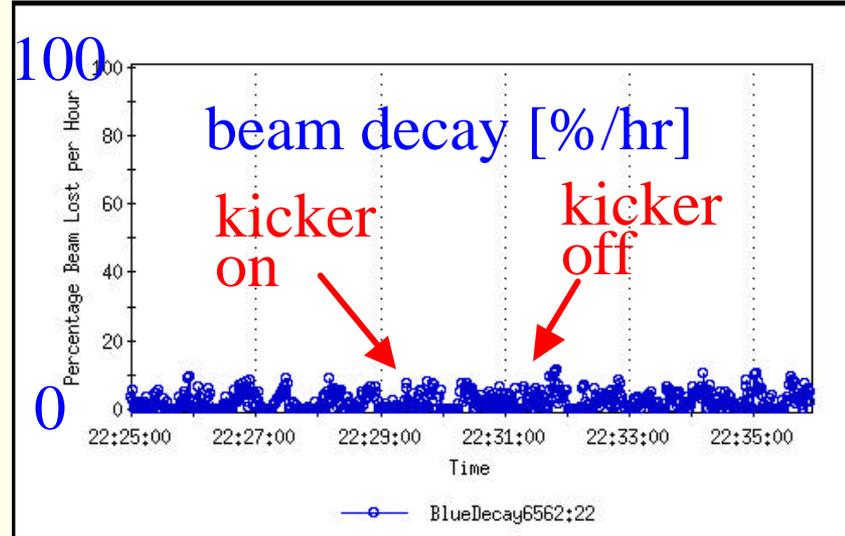
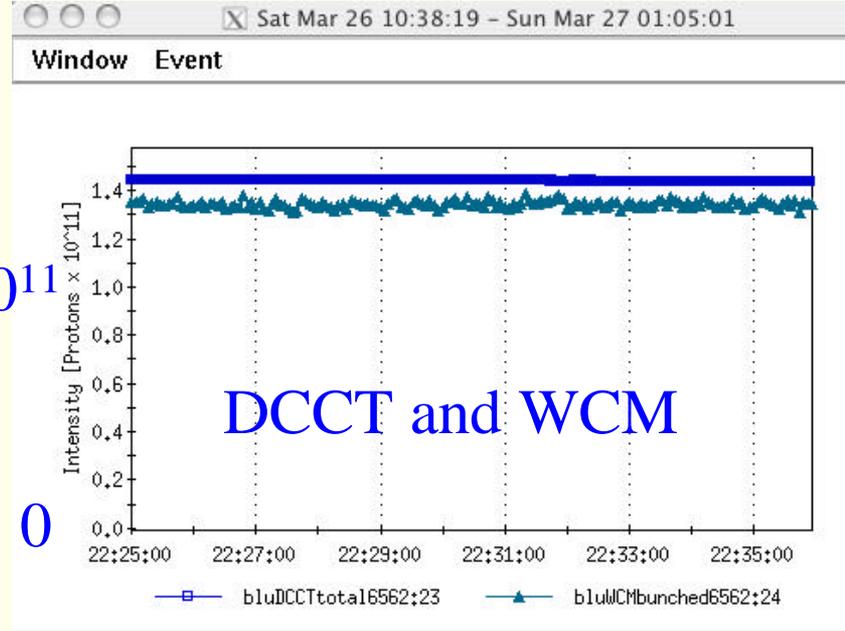
2×10^{11} circulating in 6 bunches, span 1.2KHz

No Measureable Beam Decay!

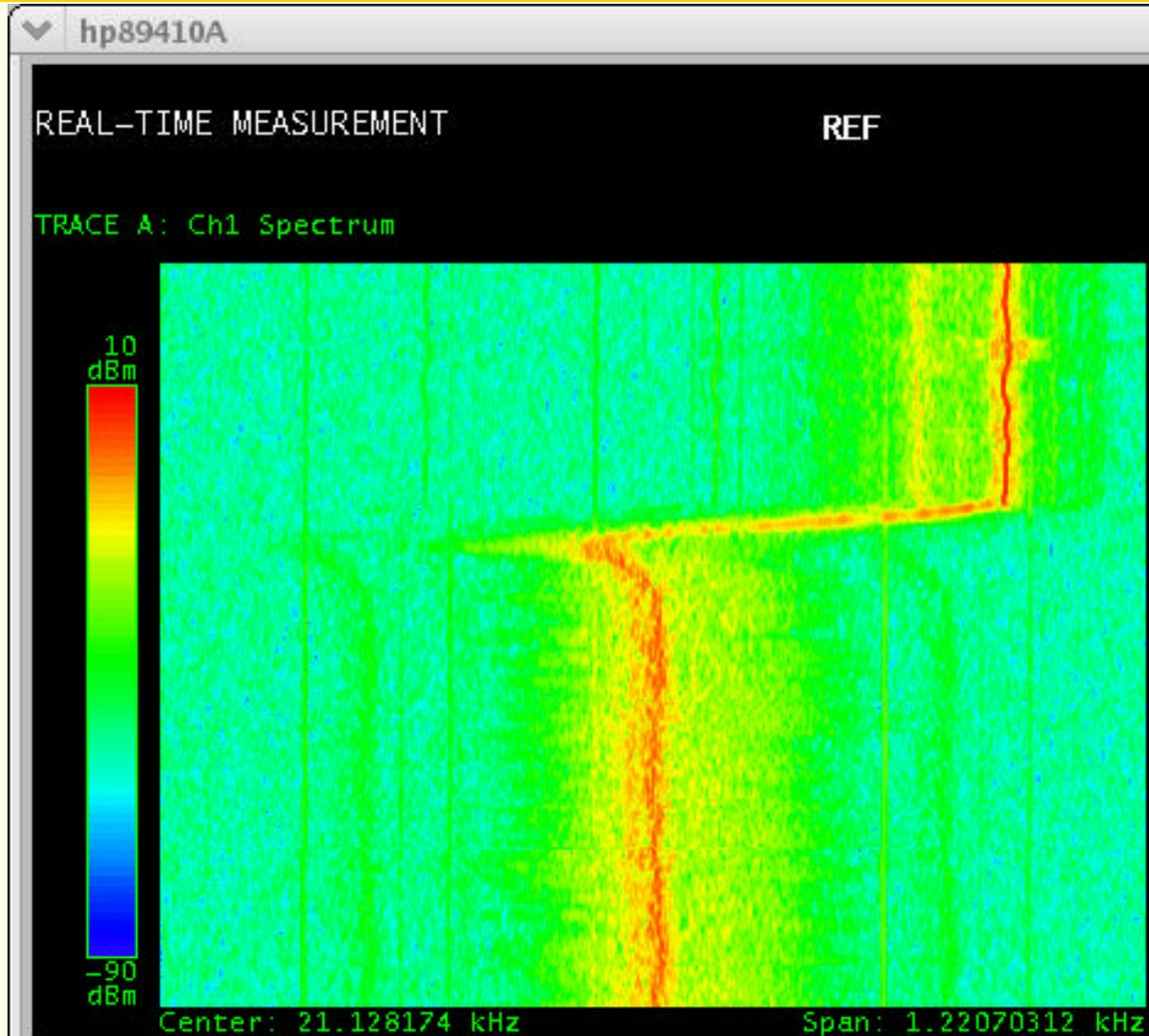


10dB/div, ~20mW kick,
PLL locked, ~70dB S/N

TF Design Review 4-5 April 2005

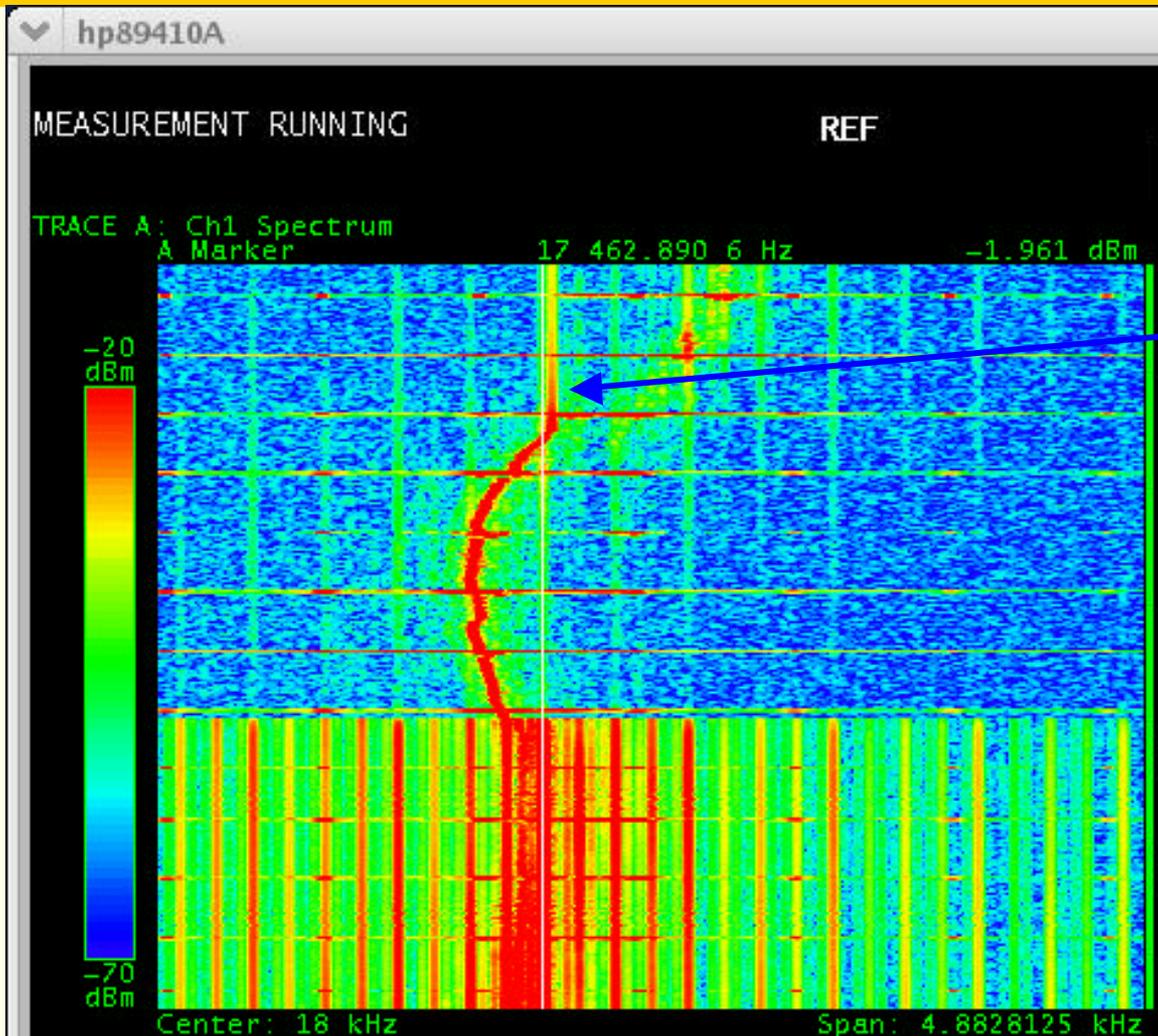


Tracking at Injection



span 1.2KHz,
slew rate $\sim .005/\text{sec}$
overshoot is real?
change in linewidth
with tune change is
non-linear transfer
function of VCO

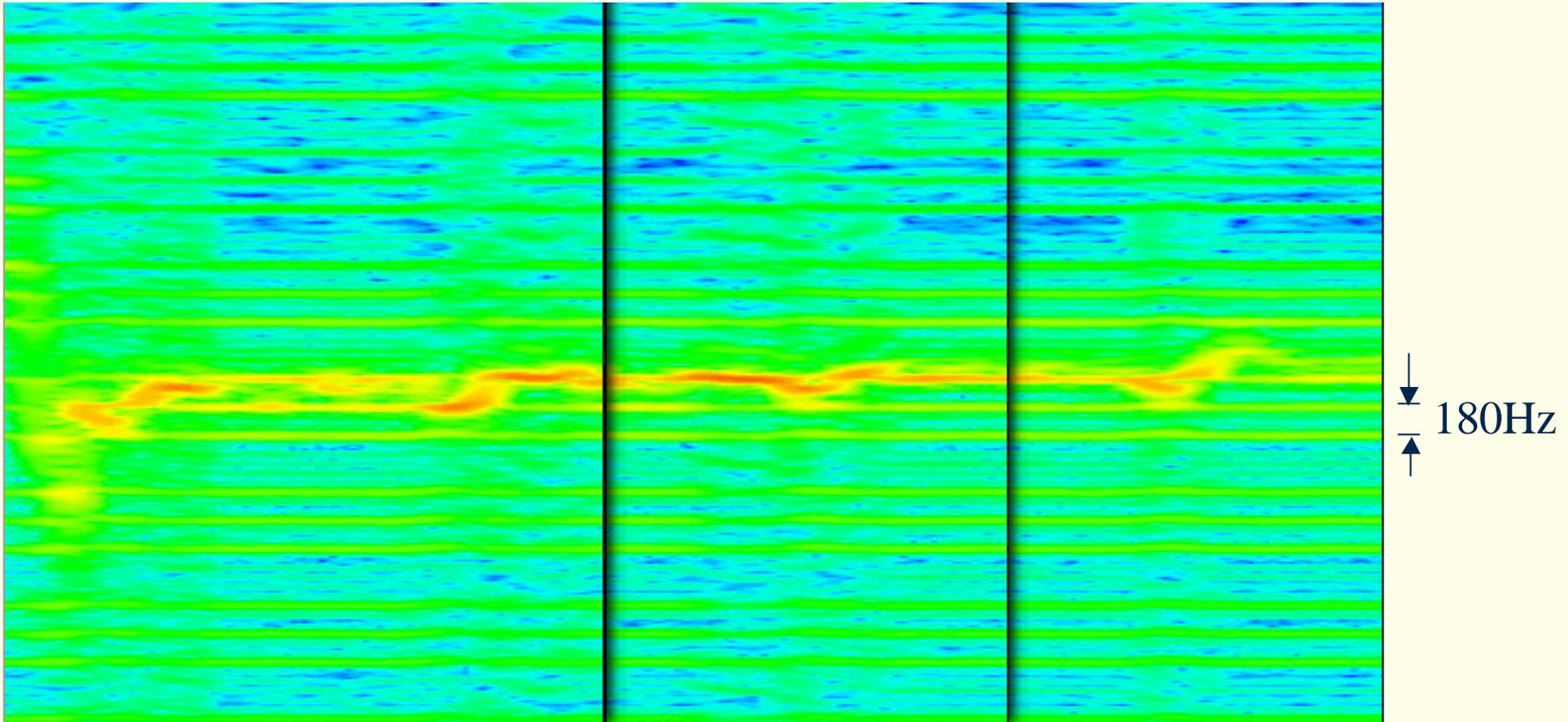
BBQ PLL on a Ramp



locked on 60Hz harmonic, then catches the passing tune

ramping supplies kick in

Transition Instability Studies



head-tail instability at transition, persists 3 synchrotron periods,
fast tune fluctuations in tail, correlations with 180Hz lines?

Summary



- Good progress at both FNAL and BNL
- Tracking performance appears equal or superior to 245MHz system, even in this early stage of development
 - In-depth study of tracking performance is lower operations priority than 245MHz ramp tune tracking - potential interference with both kickers running
 - Tracking is limited by poor Wavetek transfer function
 - Tracking study has taken back seat to 60Hz problem
- Emittance performance appears superior to 245MHz system - because 245MHz excites subset to higher amplitude?
- Bleedthru is not a problem
- Primary outcome has been focus on 60Hz problem, we have been taking for granted real progress is other areas of BBQ