
New Diagnostics for Run 5 and Beyond

Peter Cameron

Outline

PLL:

245MHz system

baseband plans

Head-tail/Instabilities

Cavity Polarimeter

E-Cooling:

ERL BPM electronics

Electron- Ion beam alignment

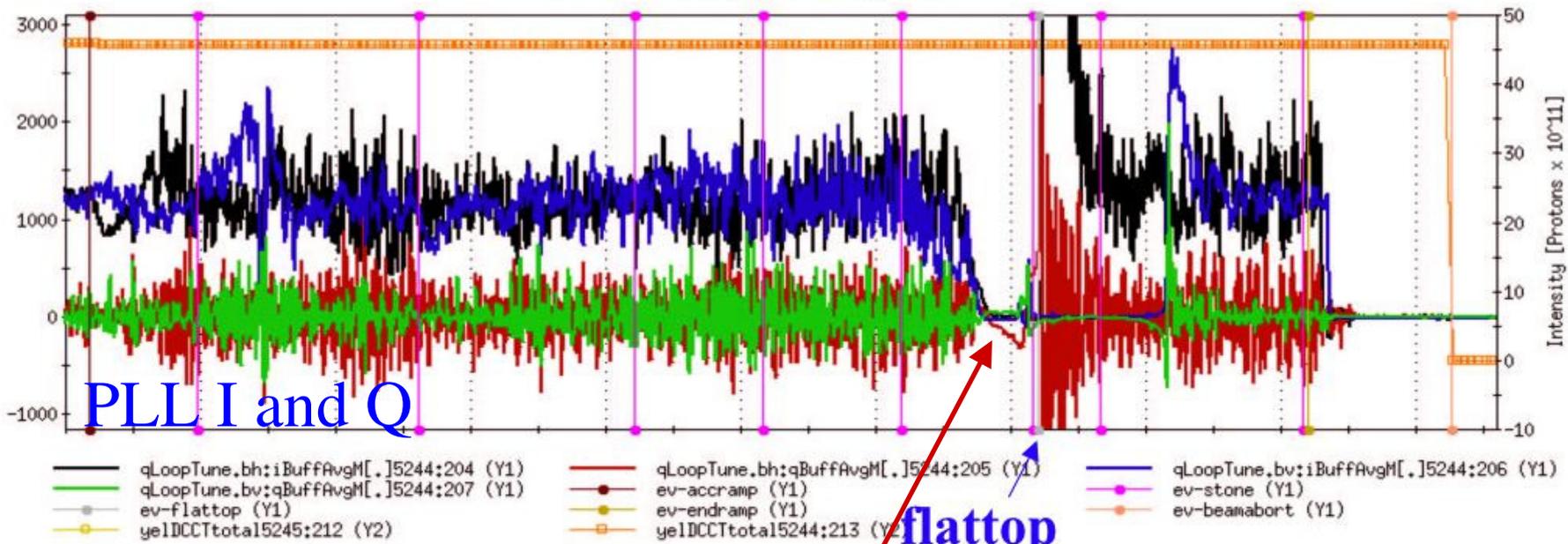
Solenoid center location?

245MHz system

- Essentially identical to last year, except
 - new operator interface (ϕ ambiguity resolved)
 - pet-controlled coupling measurement
- Will be available for operations and BMX
 - tune feedforward/feedback, IR corrections, beam-beam, e-cloud/pressure rise studies, resonance compensation, central frequency, nonlin chrom,...
 - coupling correction
 - chromaticity feedback at injection - LARP

Window Event

Blue ring, May 03



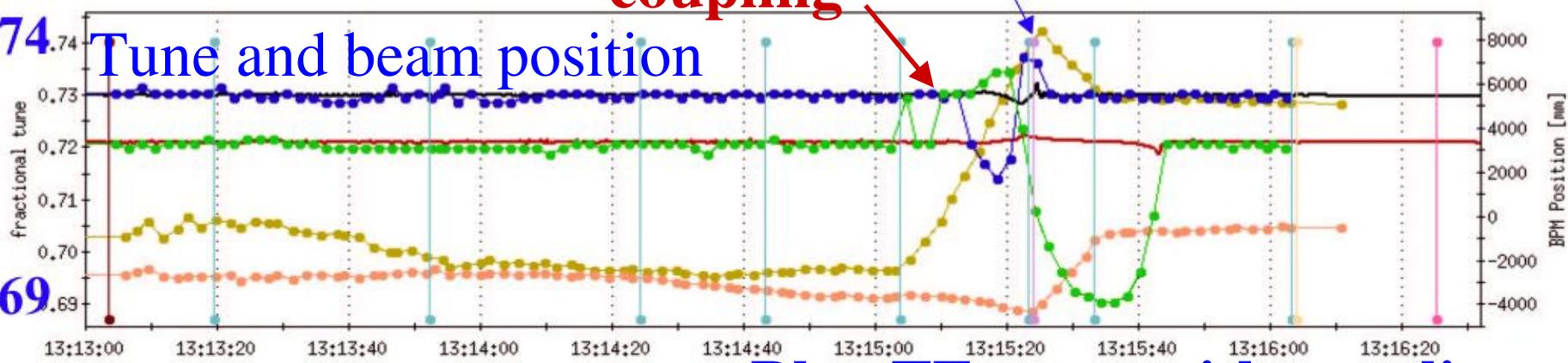
PLL I and Q

flattop

coupling

.74 Tune and beam position

.69



Blue TF ramp with coupling

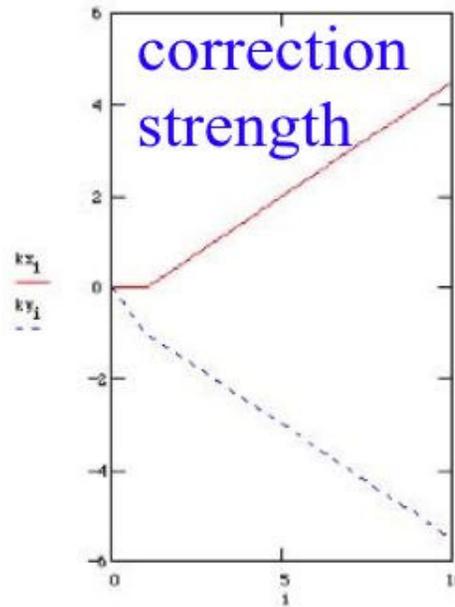
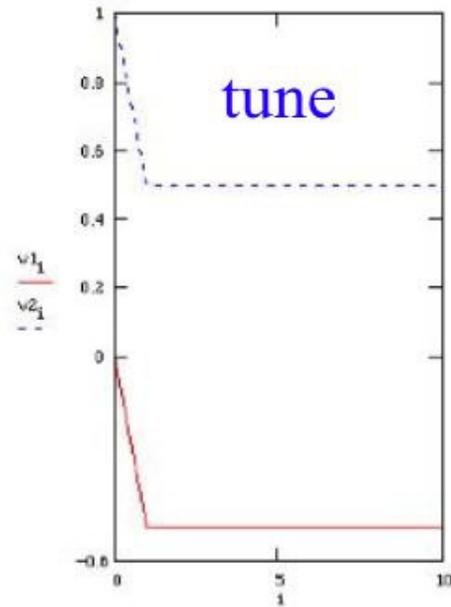
n := 10

i := 0 .. n

$$\begin{bmatrix} v1_0 \\ v2_0 \\ kx_0 \\ ky_0 \end{bmatrix} := \begin{bmatrix} 0 \\ 1 \\ 0 \\ 0 \end{bmatrix}$$

+ coupling terms

$$\begin{bmatrix} v1_{i+1} \\ v2_{i+1} \\ kx_{i+1} \\ ky_{i+1} \end{bmatrix} := \begin{bmatrix} v1_i + -0.5 \cdot (v1_i + v2_i) \\ v2_i + -0.5 \cdot (v1_i + v2_i) \\ kx_i - v1_i \\ ky_i - v2_i \end{bmatrix}$$



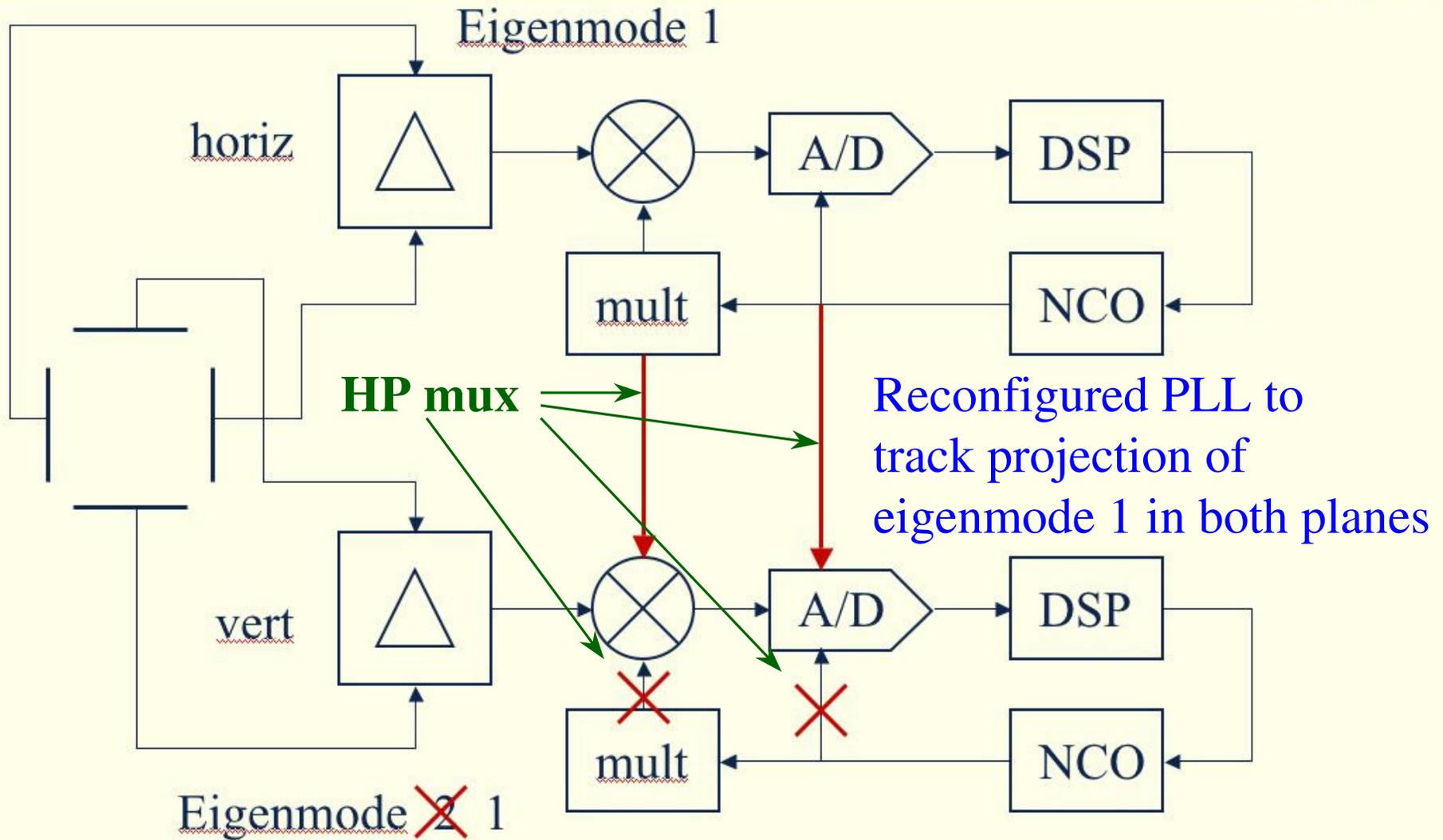
Tune Feedback and Coupling

- PLL measures normal modes
- works fine in the presence of strong coupling
- tune crossings problematic
- Tune Feedback corrects X and Y
 - not stable in the presence of strong coupling

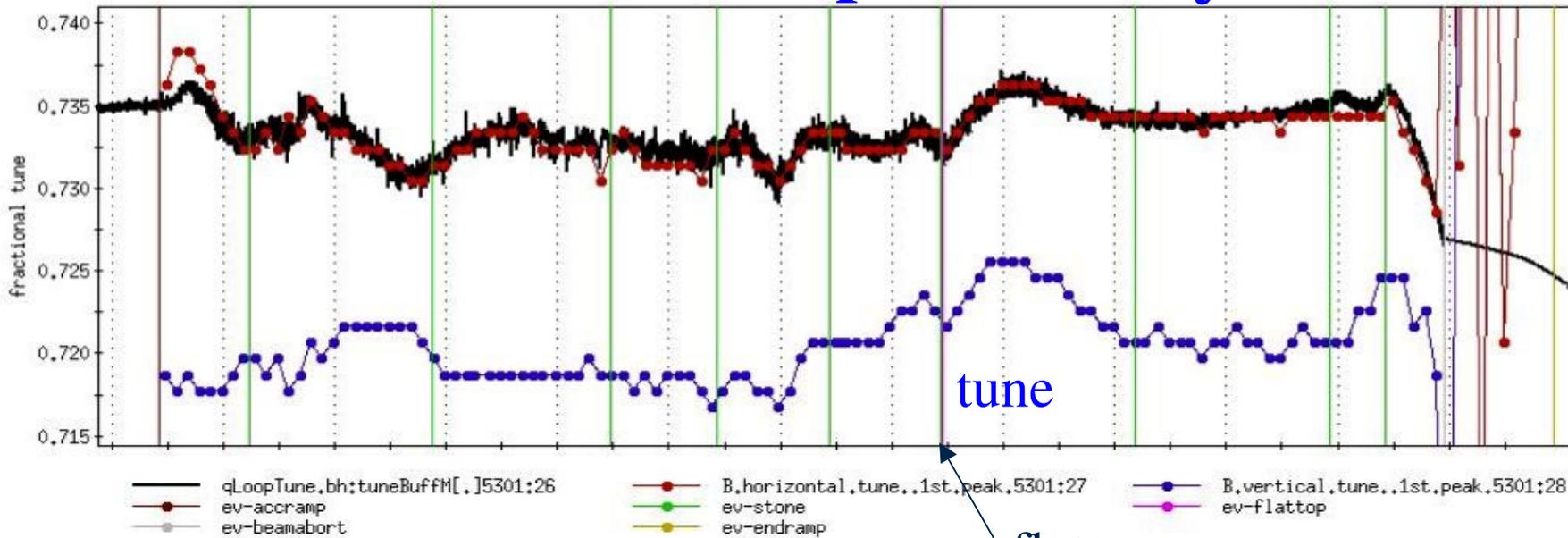
What We Learned and Did

- What we Learned
 - Large coupling exists due to change of $B\dot{\theta}$ as ramp approaches flattop
 - PLL is stable in the presence of coupling (without tune crossings)
 - The system of
Tune Feedback = PLL + magnet control
is not stable in the presence of large coupling
- What we Did
 - Improved coupling measurement

Coupling Measurement



Blue Ramp 5301 May 9th



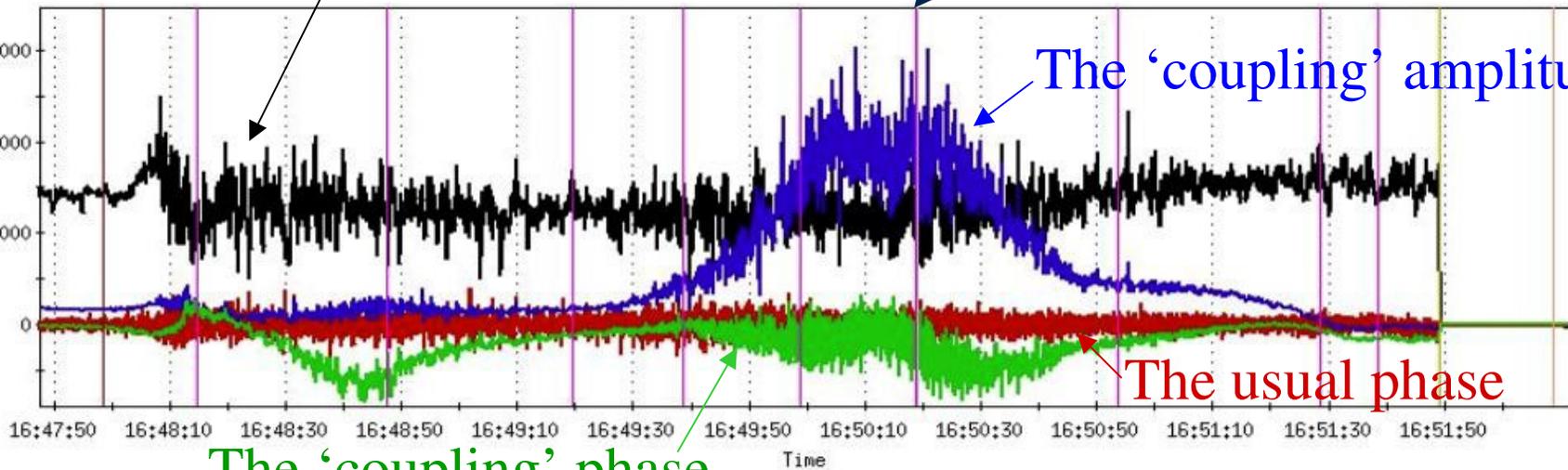
The usual amplitude

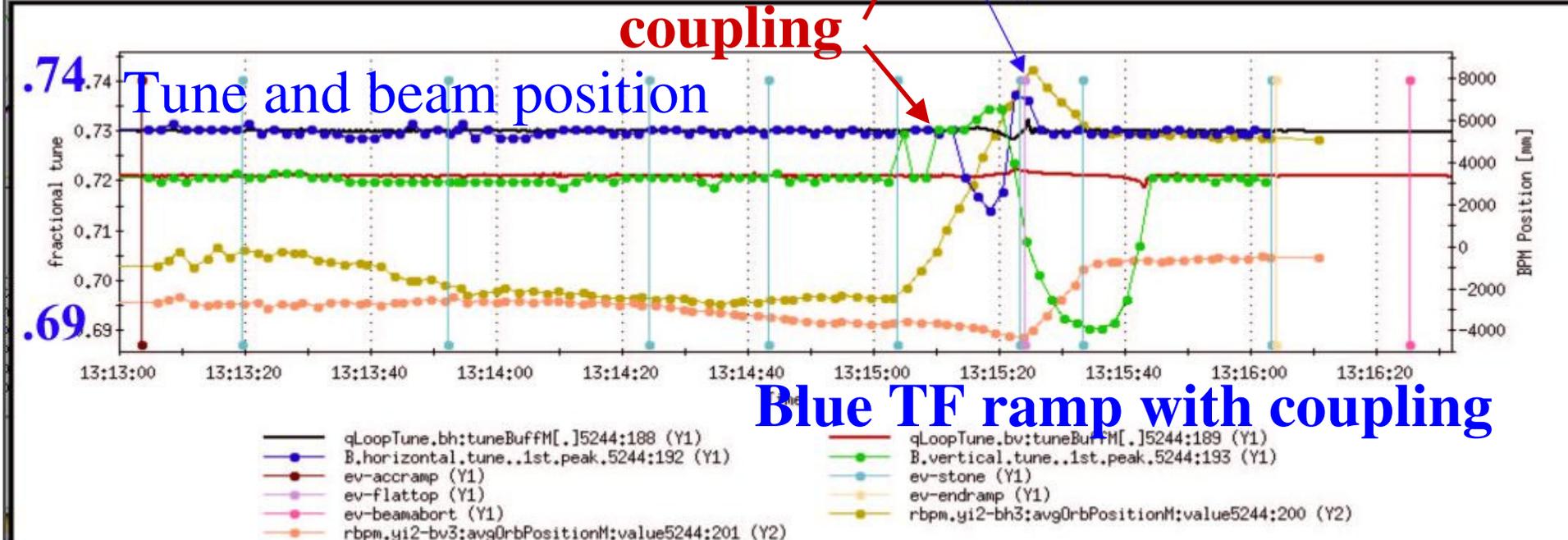
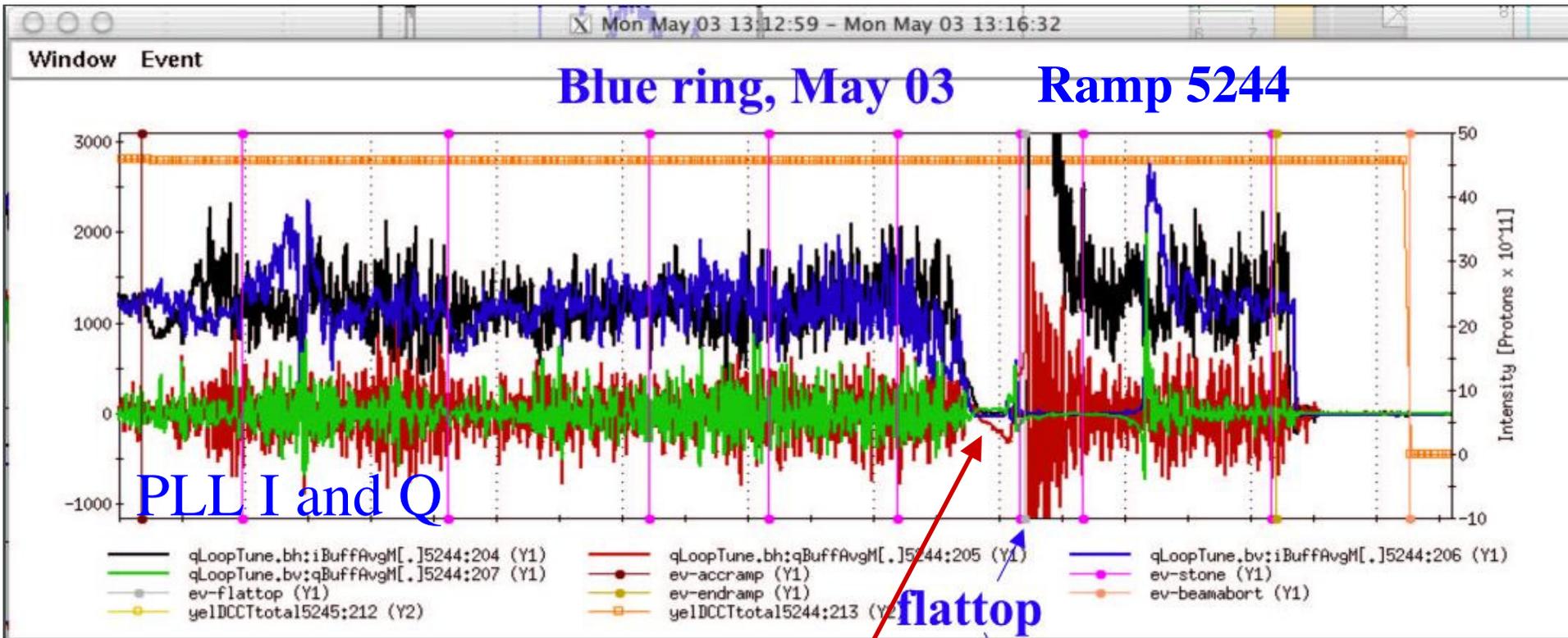
flattop

The 'coupling' amplitude

The usual phase

The 'coupling' phase





What we learned from what we did

- This method (phase lock to same eigenmode in both planes) gives very clean coupling measurement (amplitude **and** phase)
- Large coupling measured at the time the system of tune feedback (= PLL + magnet control) became unstable
- Issue – scaling/normalization/calibration
 - AGC in driven plane (max gain and min kick)
 - No AGC in orthogonal plane – gain setting?

Coupling summary

- New understanding
 - Coupling not a serious issue for PLL
 - **Coupling a very serious issue for tune feedback**
- New measurement technique
 - Non-perturbative, excellent S/N
 - Unlike skew modulation, does not stress PLL
 - Delivers both amplitude and phase of coupling
 - Beam Experiments – local vs global, LARP/LHC, ...
 - Calibration
 - Map effect of skew families at PLL pickup
 - Coupling correction, coupling **feedback**? Don't need cal?
 - **Tune feedback with eigenstates rotated to X and Y – need cal**

Chromaticity Feedback

Needed for LHC due to snapback effects

Category 1? 2?

At Injection

Close tune feedback loop??? Compare with and w/o TF?

Turn on radial modulation

Ramp ξ , determine max slew rate that can be tracked

Turn on ξ feedback

Ramp ξ , observe effect of feedback

.....?

Other 245MHz PLL studies

- Injection studies with all three feedbacks - tune, chrom, and coupling feedback
- Ramp with tune, chrom, and coupling feedback
 - if Cu run, only to transition
 - if protons, to full energy
- One can argue that ultimately all hadron machines will run in this mode
- Baseband PLL may open this possibility for RHIC
- We learn by trying

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Baseband PLL

- **Dynamic Range** - γ_t 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!)
dynamic range
- 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)
- Simplicity – get rid of mixers
- Possibility of many receivers scattered throughout ring

Approaches to Baseband PLL

- Resonant pickup (primarily BNL)
 - Filters revolution line, Improves S/N by $Q \sim 100$ (20dB)
 - Not yet approved by LHC impedance police
 - Tuning is a problem as operating point changes, hi-Z preamp noise,...
 - De-Qing - sensitive to power levels (waiting for power amplifier)
- Diode detection (primarily CERN)
 - Not envelope detection - use betatron oscillation to gate diode
 - Improves S/N by root h , h =number of lines mixed down $h \sim 1000$ (16dB)
 - With many bunches, spectrum becomes sparse - “AGC” - good and bad
- Homodyne detection (primarily BNL)
 - Use revolution comb to mix down betatron comb
 - Same principle as diode detection (S/N, “AGC”,...)
 - Uses COTS components

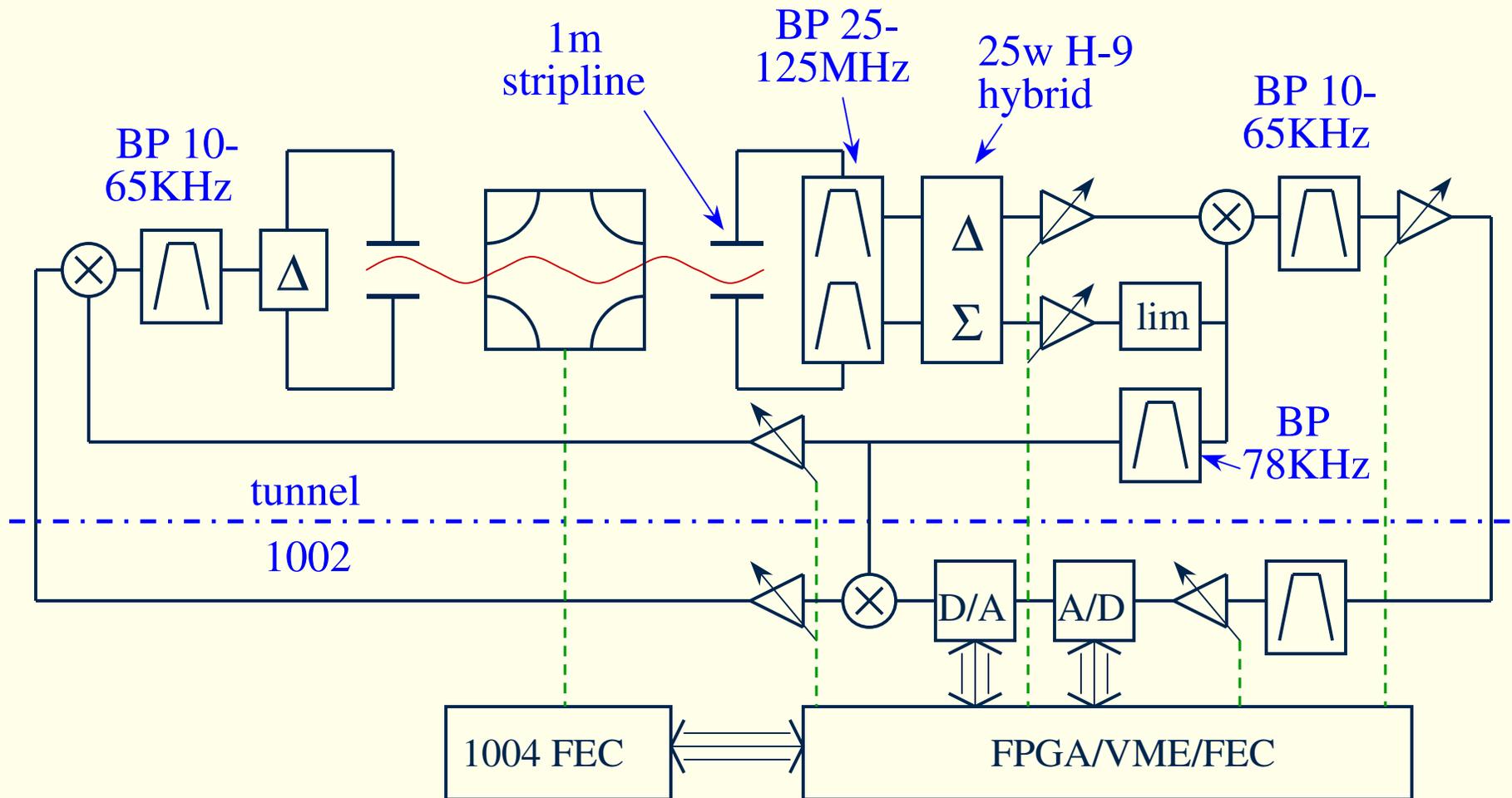
Comparison - Homodyne and Resonant

Assume 100MHz BW for homodyne, $Q=100$ for resonant
S/N is relative to single bunch, single line = $N * \sqrt{n}$

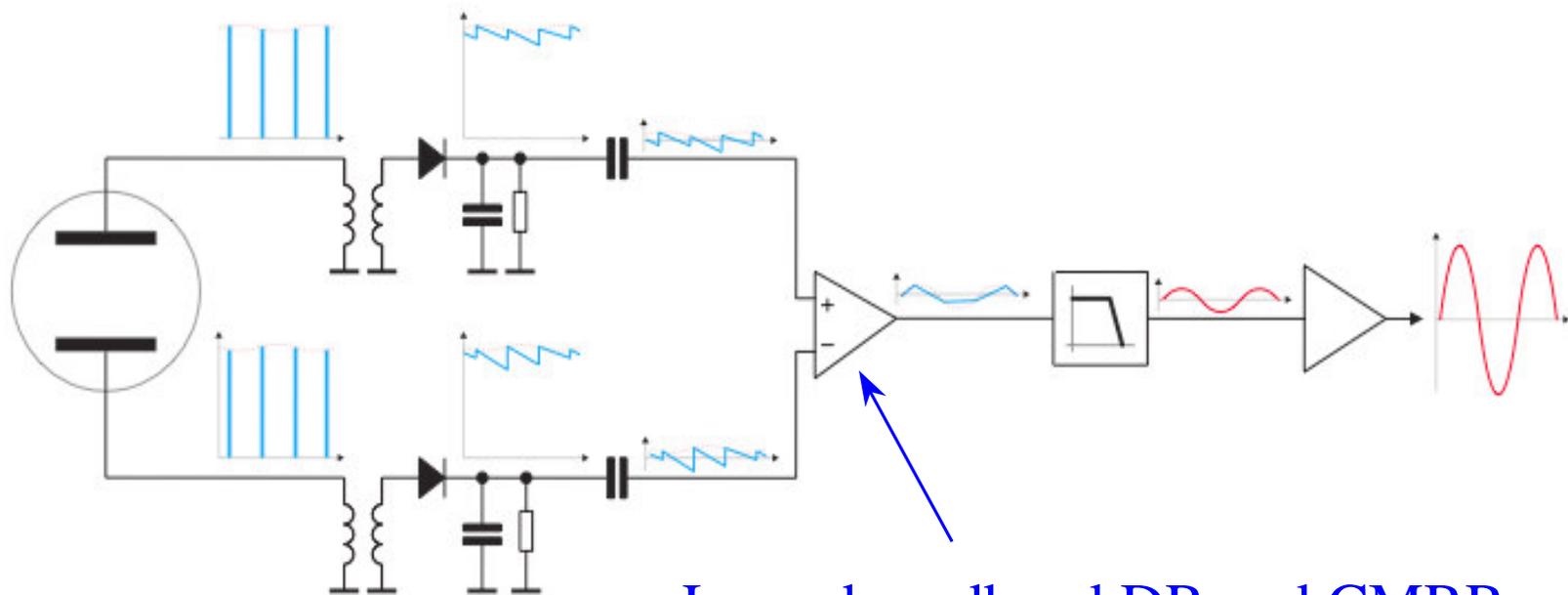
N = # of bunches	RHIC 1	RHIC 6	RHIC 60	LHC 1	LHC 2808
n = # of lines	1280	213	22	9090	5
sqrt n	36	15	4.7	95	2.2
H'dyne S/N, [dB]	16	20	24	20	38
BB Res S/N, [dB]	20	28	38	20	54
245 Res S/N [dB]	0 to 6	8 to 14	38	N/A	N/A

Conclusion - for now we focus on homodyne detectors

Baseband PLL Homodyne Architecture



Direct Diode Detection (3D) Method



Large broadband DR and CMRR needed?

AM due to betatron $\sim 10^{-5}$

AM due to bunches $\sim 10^{-1}$

BBPLL Plans for Run-5 and beyond

- Motion Control Pickups installed both rings (LARP \$)
 - 1m for BBPLL
 - 25cm for motion control
 - 1m for head-tail/instabilities
- One each direct diode and homodyne AFEs day one
 - Evaluate and make a decision - January
- Gate array support - Controls - BNL/TRIUMPF/CERN, both vXworks and LynxOS
- Goal - single plane complete system by end of run 5
- This work will be accomplished in the background, with **probable request for bmx time late in the run**
- Full 4 planes (plus coupling?) by day one run 6
- Coupling - multiple receiver locations?

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Head-tail/Instabilities

- Circumstances:
 - Rhodri Jones will visit for ~2 months, arriving early February
 - Adding 1m pickup to BBPLL motion control platform reduced demands on closed orbit offset module
 - Previous attempt foundered due to manpower limits at BNL, remote location of CERN collaborator, pickup Z match(?)
- Try again - the plan:
 - Get system running in LabVIEW, trigger from ARTUS
 - When data is good, port to a GPM via snap
 - Investigate compatibility with fast instability monitor
- **BMX time will be requested for calibration**

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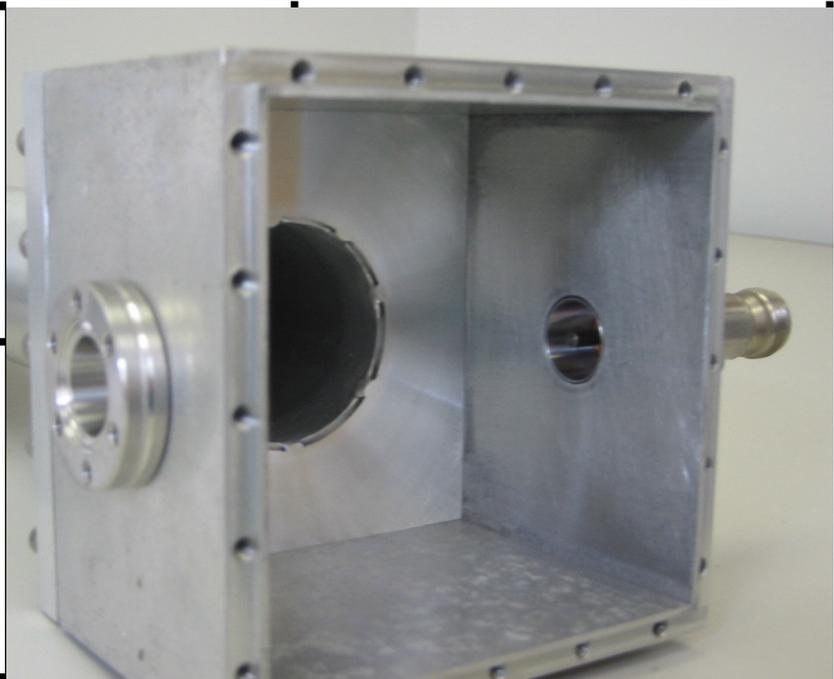
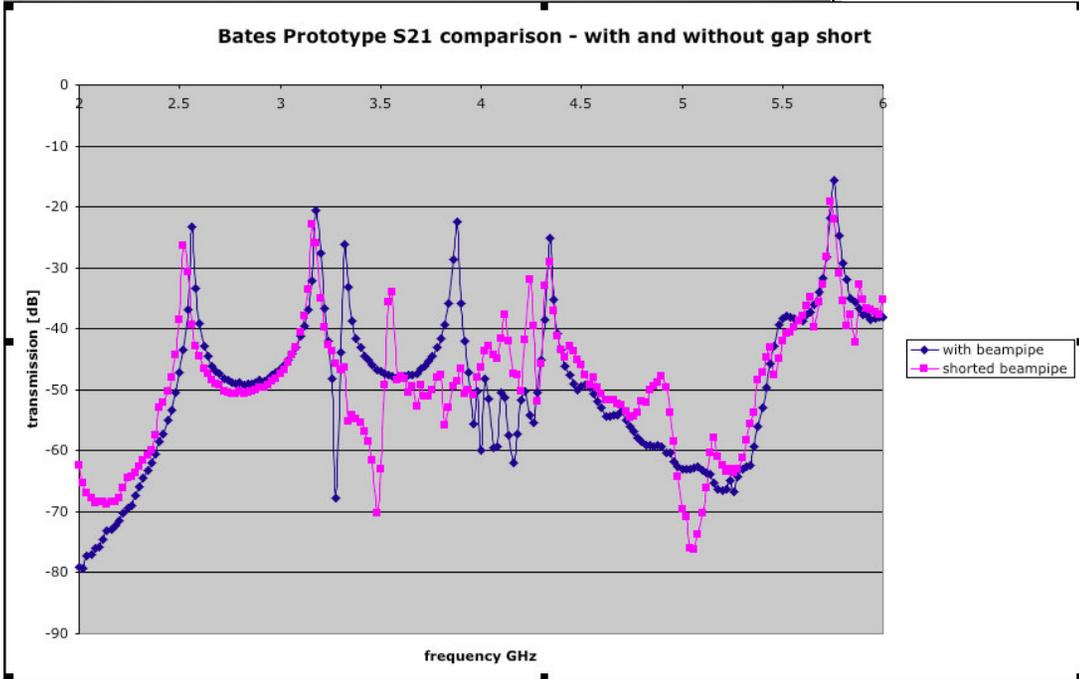
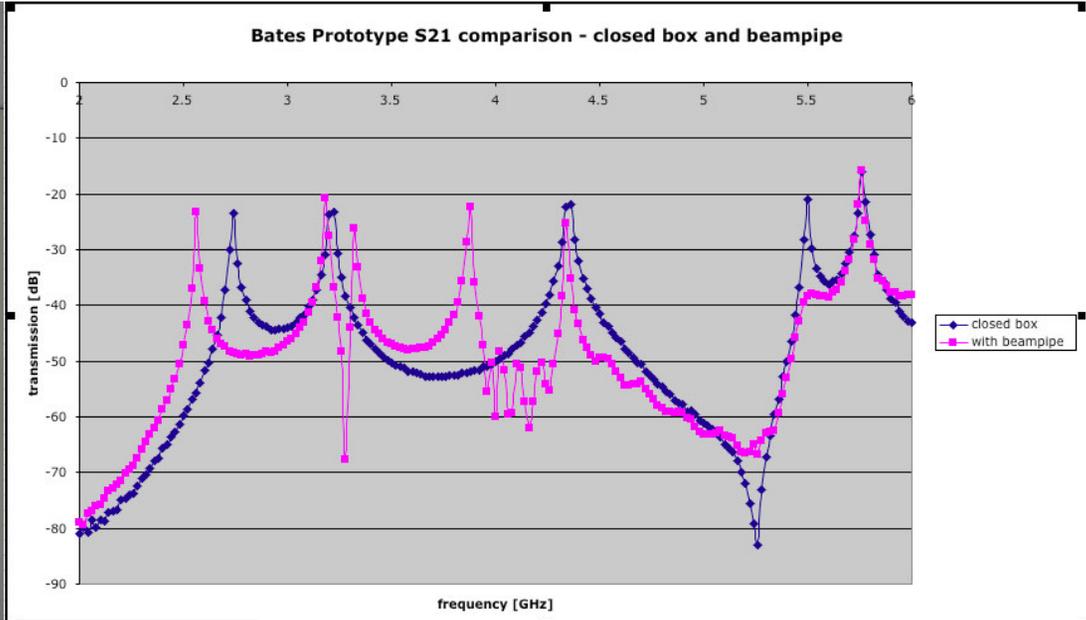
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Solenoid center location?

Cavity Polarimeter

- This BMX is at Bates, but possible long-term implications for RHIC
- Bates goals
 - See polarization signal in presence of charge background
 - Confirm γ^2
 - Calibrate to existing polarimeter
 - Learn - possible method to overcome more severe RHIC charge background problem
- Possibility of very high resolution measurement
- Absolute calibration is from first principles, falls out directly from signal/background ratio



Cavity Polarimeter

$$\text{sigpower}_i := 4 \cdot f_{\text{If}} \cdot Q \cdot \frac{\left(\left(\mu_e \cdot \tau \cdot n_e \cdot \gamma^2 \cdot P \right) \right)^2}{\left(\pi \cdot \epsilon_0 \cdot \text{Vol} \cdot c^2 \right)}$$

$$\text{bkgsigpower}_i := 2 \cdot f_{\text{If}} \cdot Q \cdot \frac{\left[q \cdot \tau \cdot n_e \cdot d \cdot \left(\sin(\theta_i) \right) \right]^2}{\left(\pi \cdot \epsilon_0 \cdot \text{Vol} \right)}$$

$$\gamma = 250$$

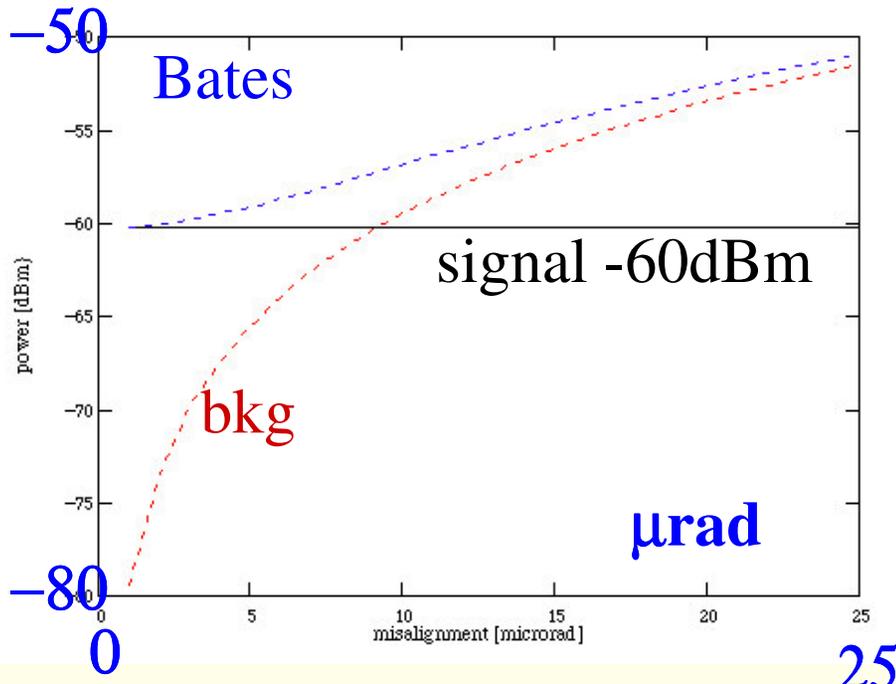
$$Q = 5 \cdot 10^8$$

$$\text{fillfactor} = 9.804 \cdot 10^{-3}$$

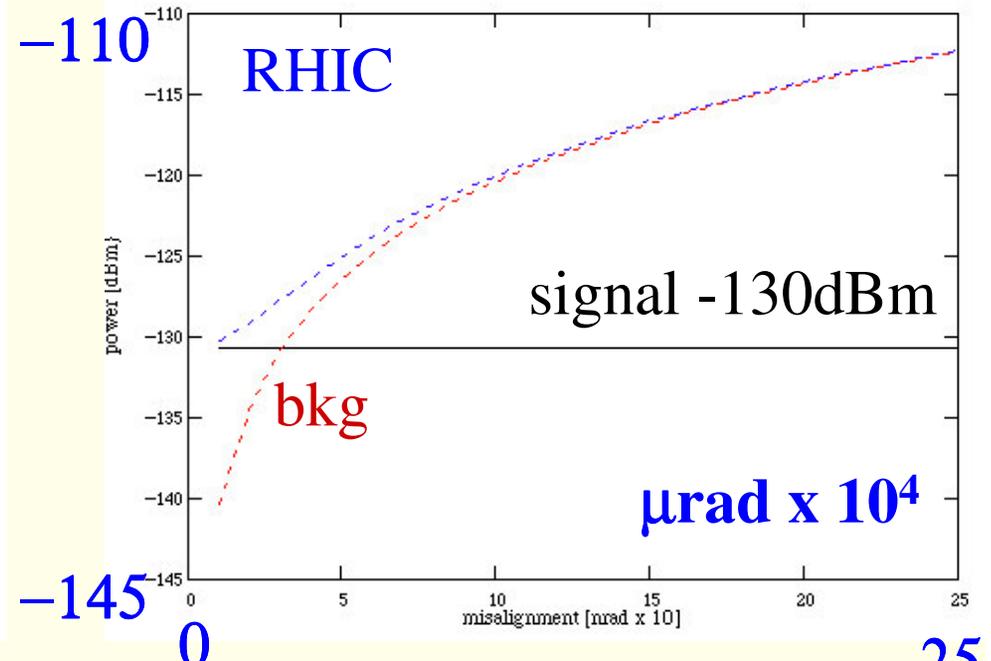
$$\text{bunchfactor} = 0.01$$

$$\text{sigpower}_i := 4 \cdot \text{fillfactor} \cdot \text{bunchfactor}^2 \cdot f_{\text{If}} \cdot Q \cdot \frac{\left(\left(\mu_p \cdot \tau \cdot n_p \cdot \gamma^2 \cdot P \right) \right)^2}{\left(\pi \cdot \epsilon_0 \cdot \text{Vol} \cdot c^2 \right)}$$

$$\text{bkgsigpower}_i := 2 \cdot \text{fillfactor} \cdot \text{bunchfactor}^2 \cdot f_{\text{If}} \cdot Q \cdot \frac{\left[q \cdot \tau \cdot n_p \cdot d \cdot \left(\sin(\theta_i) \right) \right]^2}{\left(\pi \cdot \epsilon_0 \cdot \text{Vol} \right)}$$



Run 5 Beam Experiments



17 Sep 04

27

25

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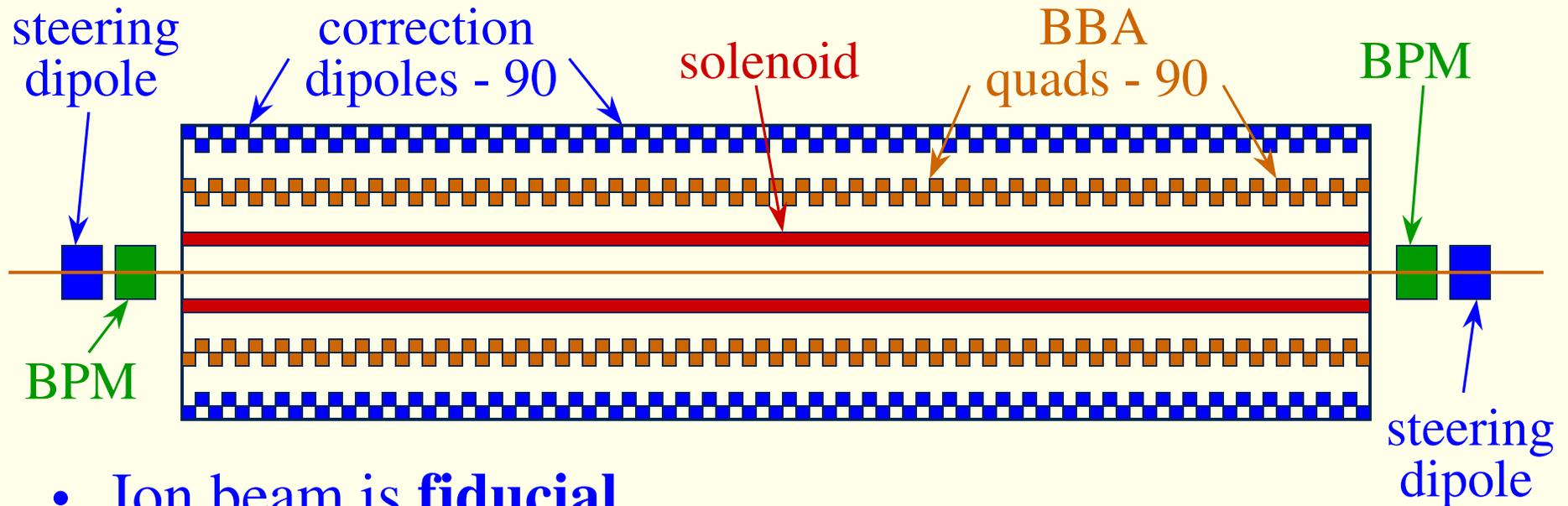
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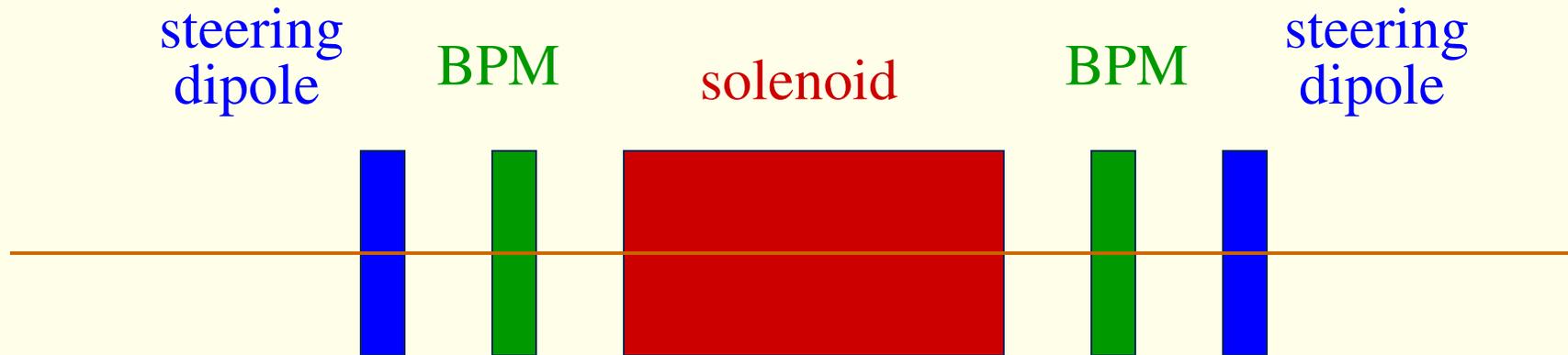
- Plan is to use SNS BPM electronics for ERL, with modifications
 - Timing decoder
 - Mixers and filters
- If possible, it would be good to get at least one set of electronics on RHIC beam during run-5, while they are still in production and all are up to speed on this hardware/software
- No requirement for BMX time?

electron-Ion Beam Alignment



- Ion beam is **fiducial**
 - modulate quad (few Hz), sweep Ion beam steering dipole
 - lockin RHIC BPM to modulation, **find quad position**
- Knowing quad position relative to Ion beam **fiducial**
 - modulate quad (few Hz), sweep e-beam steering dipole
 - lockin electron BPM to modulation, **find e-beam position**

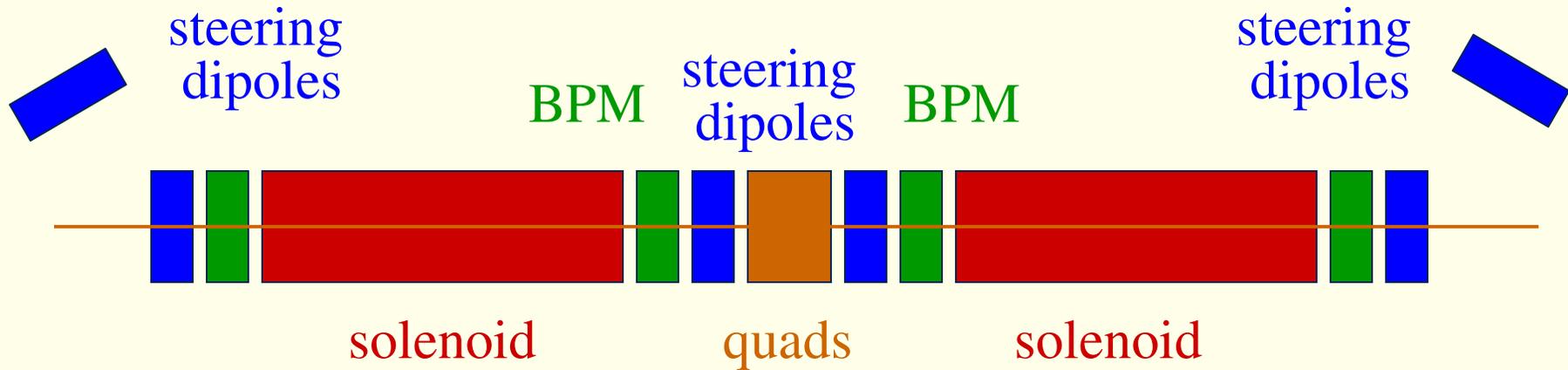
Solenoid Center Location



transverse component of fringe field imparts kick, increases transverse temperature of electron beam - most recent argument is that you correct this with quad modulation alignment and/or entrance steering (more tricky at second solenoid?)

- Modulate e-beam position with steering dipole (few Hz)
- Adjust solenoid field (1% $\sim 1\lambda$) to half-integer λ_{larmor}
- lockin downstream orthogonal electron BPM plane
- null gives entrance center

Solenoid Center Location 2



Two(?) e-Cooling Beam Experiments

1. Beam position relative to quad center

- Modulate RHIC quad at ~few Hz
- Sweep steering dipole
- Lock in on modulation with BPM
- Determine sensitivity, repeatability

2. Beam position relative to solenoid center?

- Use Physics experiment solenoid
- Modulate beam position/angle at ~few Hz
- Lock in on modulation with orthogonal BPM
- Determine sensitivity, repeatability
- Scale to e-Cooling

Summary/Conclusion - BMX's

- Coupling - configure PLL to give Yun's 6 parameters
 - Calibrate
 - Map families, attempt coupling correction (feedback?)
 - Tune feedback with eigenstates rotated to X and Y
- Chromaticity Feedback (category 2?) - w/ and w/o TF
- Tune, Chrom, and coupling feedback at inj/ramp
- Baseband PLL studies - emittance growth,...?
- e-cooling
 - Beam position relative to quad center
 - Beam position relative to solenoid center?