

RUN09 RHIC BBQ Tune and Coupling Feedback

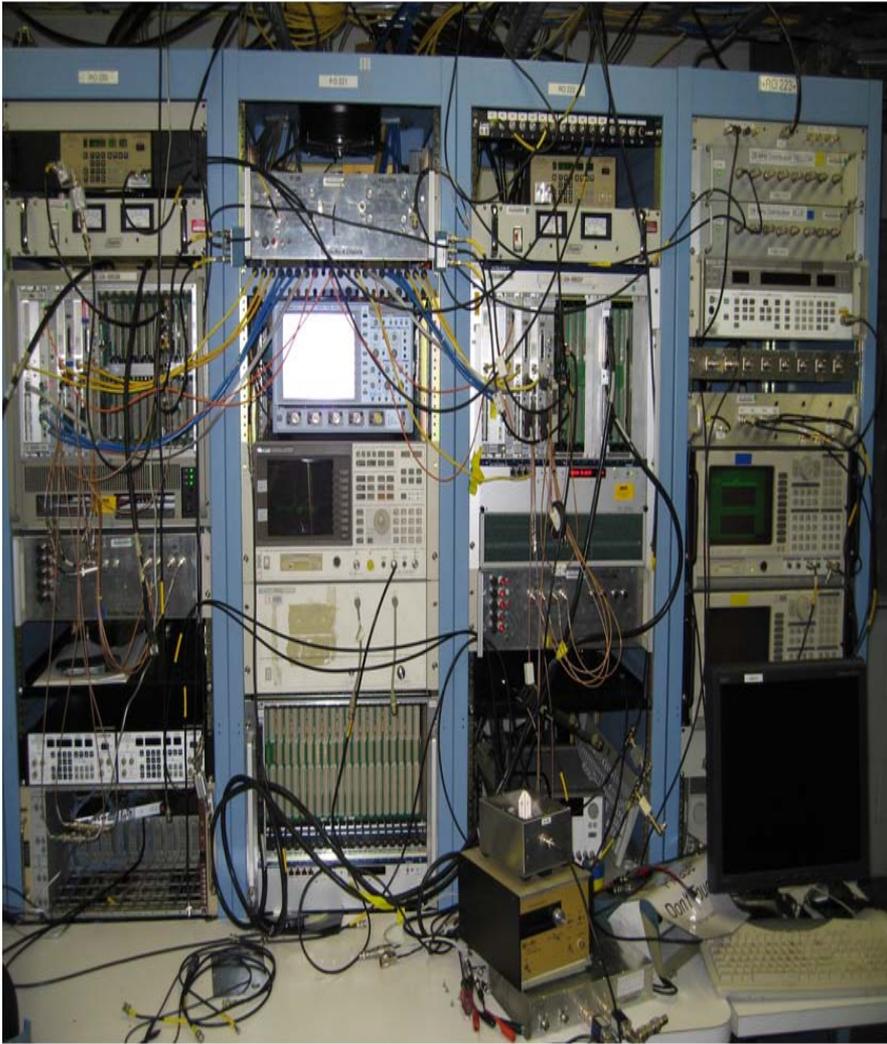
T. Curcio, C. Dawson, C. Degen, Y. Luo, K. Mernick,
A. Marusic, M. Minty, T. Russo, R. Schroeder, M. Wilinski
+ Shift Leaders and Operations Support (notably G. Marr, B. Martin, and V. Schoefer)

- I Hardware/Software Development
 - A) RUN09
 - B) APEX (250 GeV, near-integer tune)
- II Tune/Coupling Ramp Development Summary
- III Selected Data Highlights
- IV Summary and Outlook

APPENDED:

System Overview
(Selected) Tabulated Ramp Histories

BBQ Rack Layout (before)



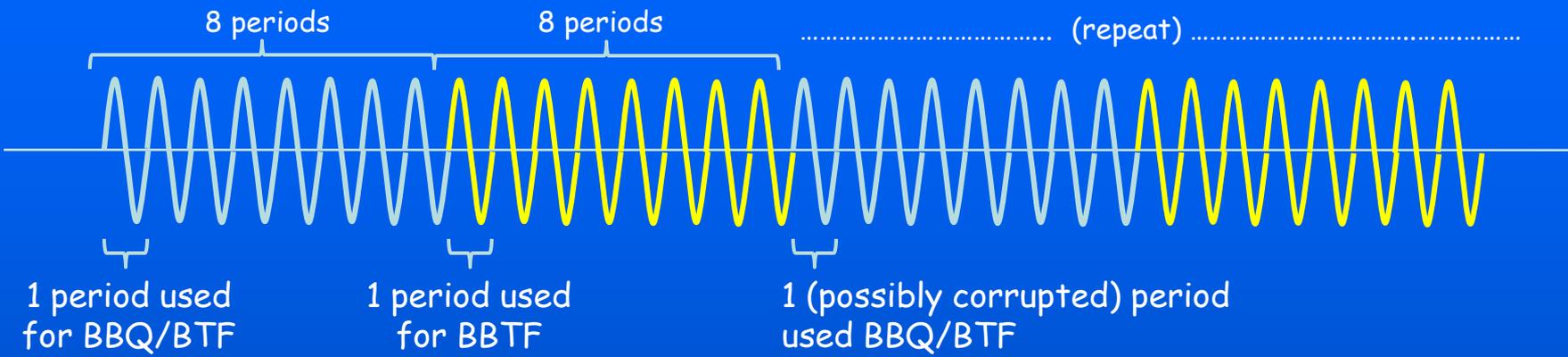
BBQ Rack Layout (after)



➔ details and more: presentation "Instrumentation" by T. Russo tomorrow

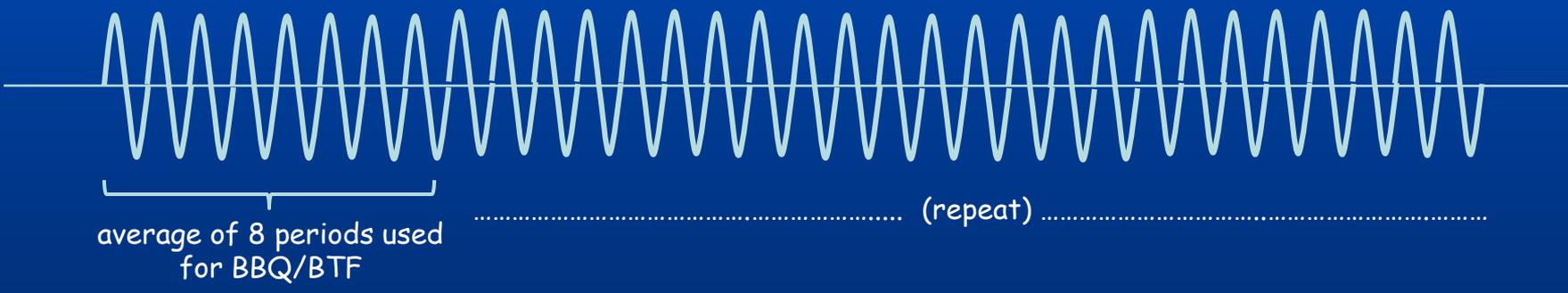
IA Software Development (RUN09), AI's Algorithm

before:



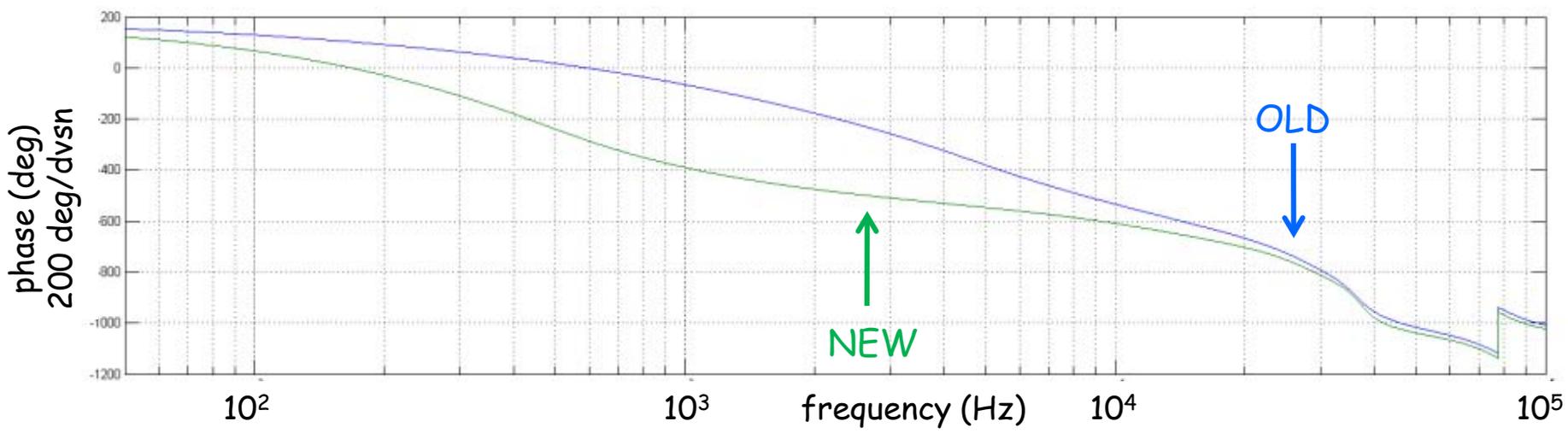
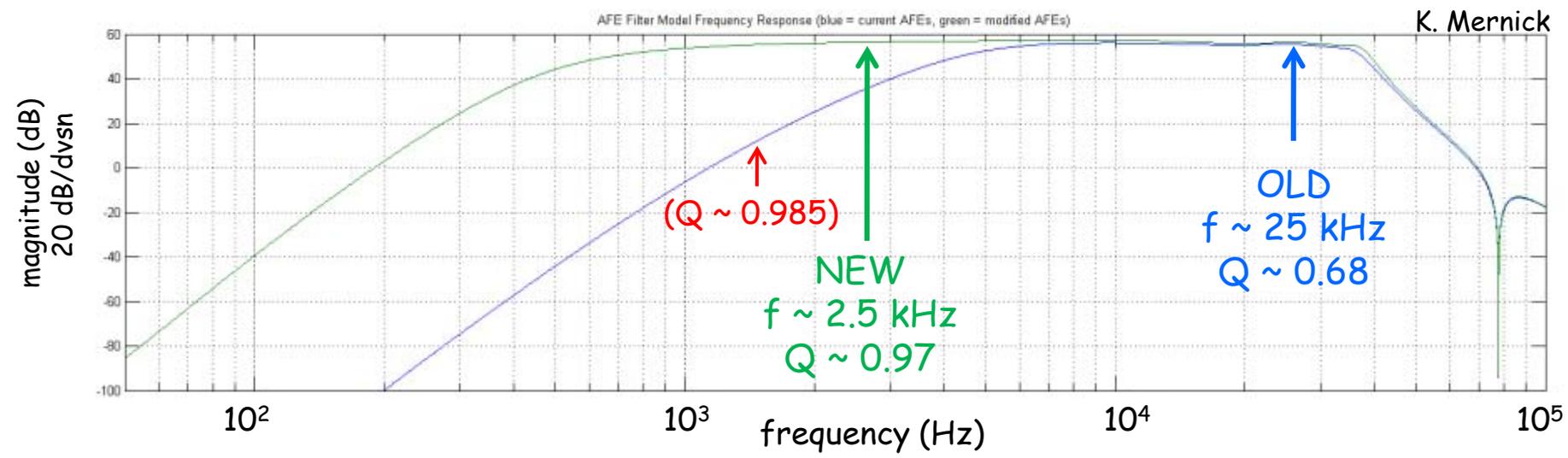
➔ 1 in 16 periods of data (AFE output, I/Q demodulator input) used for BBQ/BTF
intermittent corruption of this data due to CPU-limits and
data overwrites with BBTF (ADOs removed)

after:



IB Hardware Development (APEX: 250 GeV near integer tune)

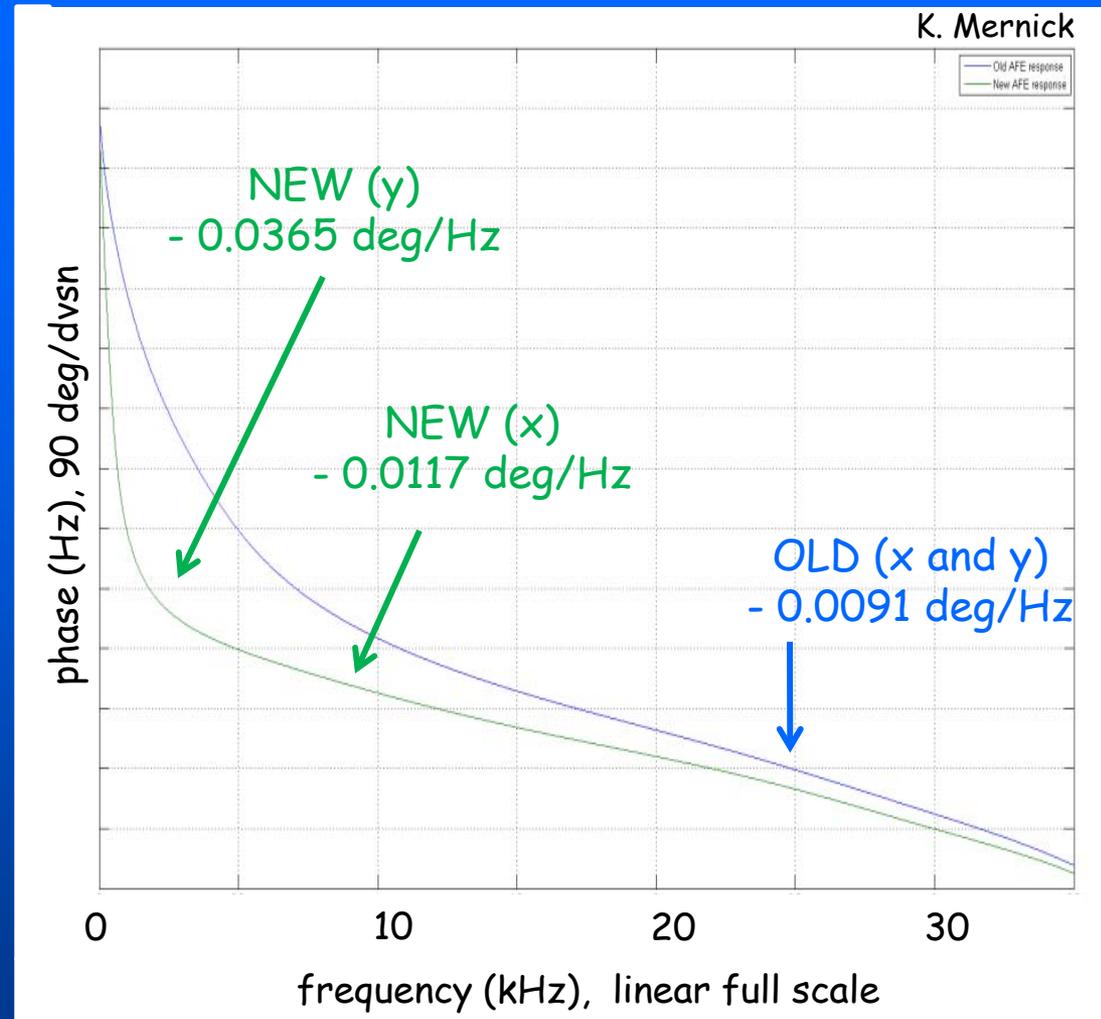
K. Mernick



➔ all (new) spare BBQ AFEs modified for increased bandwidth (installed 06/03/09); existing functionality preserved

IB Software Development (APEX: 250 GeV near integer tune)

→ software upgraded (06/04/09) for user-specified dual plane (horizontal vs vertical) phase correction

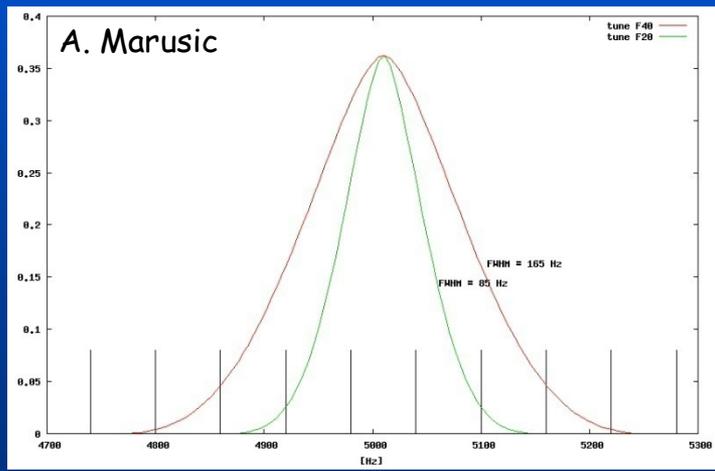
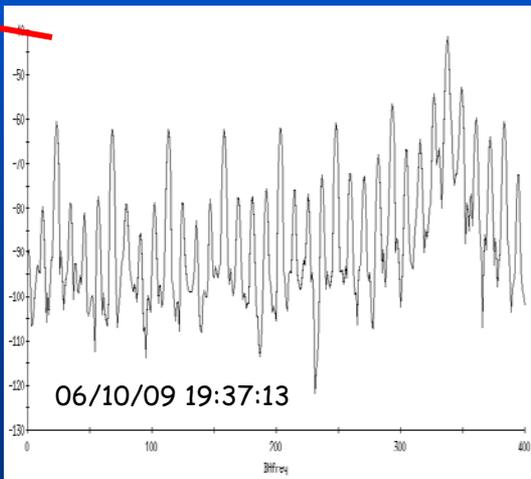
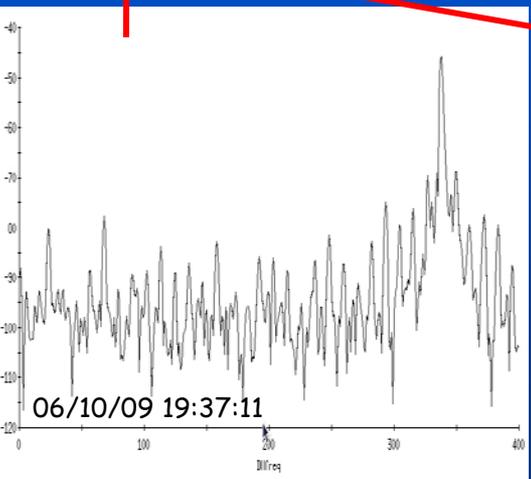
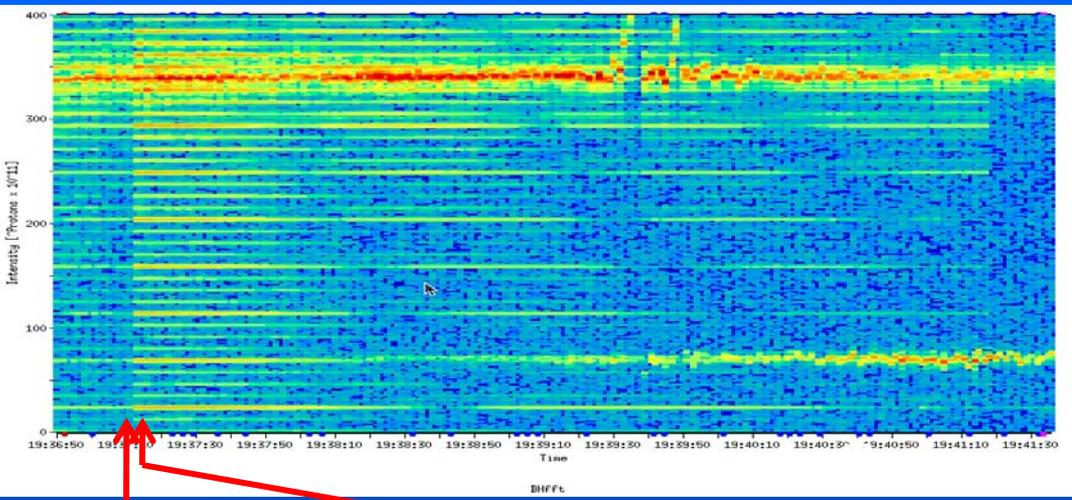


→ software upgraded (06/10/09) for rate-independence of PID loop parameters (data delivery rate down by factor ~ 10 = ratio of old to new betatron frequencies)

IB Software Development (APEX: 250 GeV near integer tune), cont'd:

change in frequency bandwidth of digital filter applied during RUN09 (with high data rate), maximum benefit observed during APEX

Blue Ring, DSA, first ramp to 250 GeV (06/10/09)

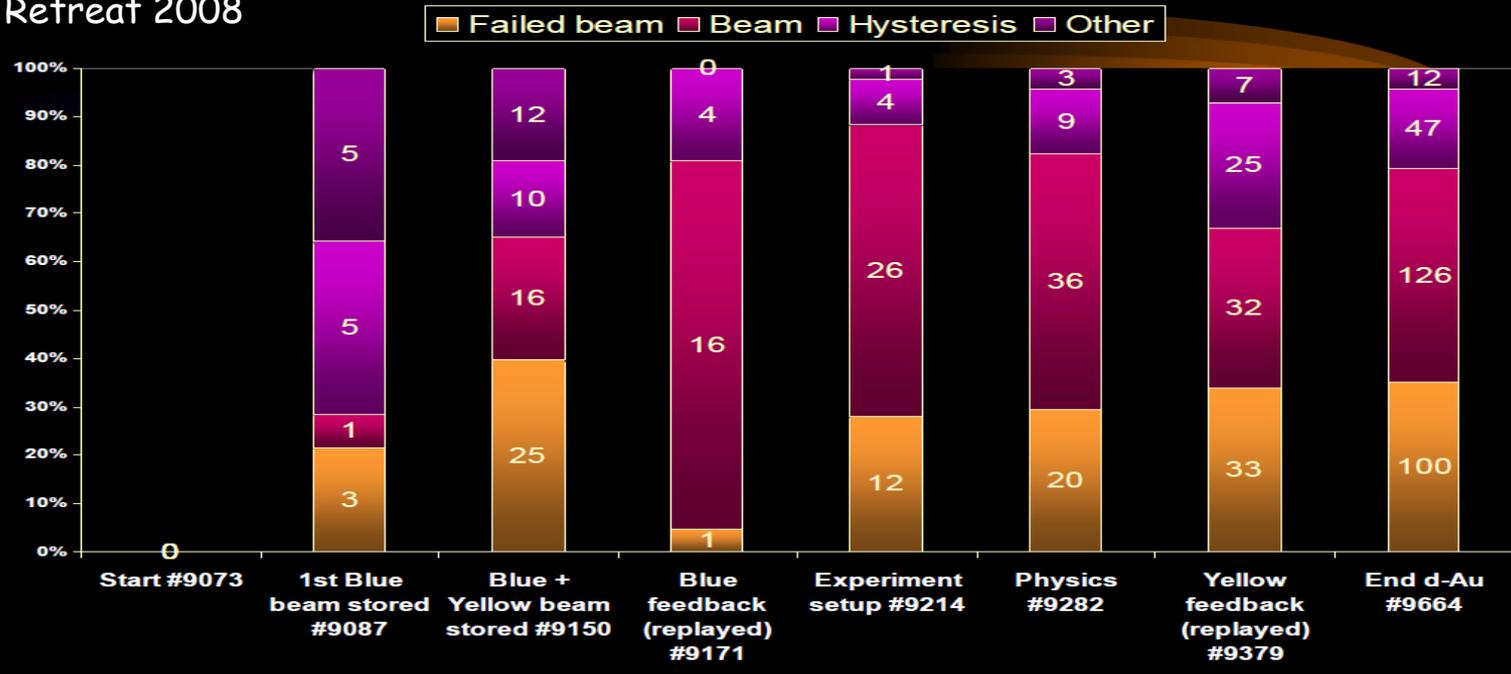


➔ simulation indicate factor ~25% less interference from nearest 60 Hz lines
immunity to the many 60 Hz multiples outside filter bandwidth

II Tune/Coupling Ramp Development Summary

ramp	date	commissioning hours to first replay ramp	# ramps to first replay ramp	comment
250 GeV 0.7 m beta*	02/14-16/09	6 (blue) + 5 (blue + yellow)	12	(ramps for LLRF commissioning not counted)
100 GeV 0.7 m beta*	04/16/09	3 (blue + yellow)	4	followed by 6 more hours tuning orbits by OPS using tune/coupling feedback
100 GeV 20 m beta*	06/29/09	3 (blue + yellow)	5	
250 GeV near-integer tune	06/11/09	3 hours setup 2 hours to full energy (blue + yellow) 4 additional hours (tune mode)	(7 ramps, no replay)	8 ramps total to first replay
(same)	06/24/09	0 hours	1	
(same)	07/04/09	0 hours	1	

d-Au Fill Usage, by milestone



RUN08: 84 (9171-9087)
 RUN09: 49 (10084-10035)

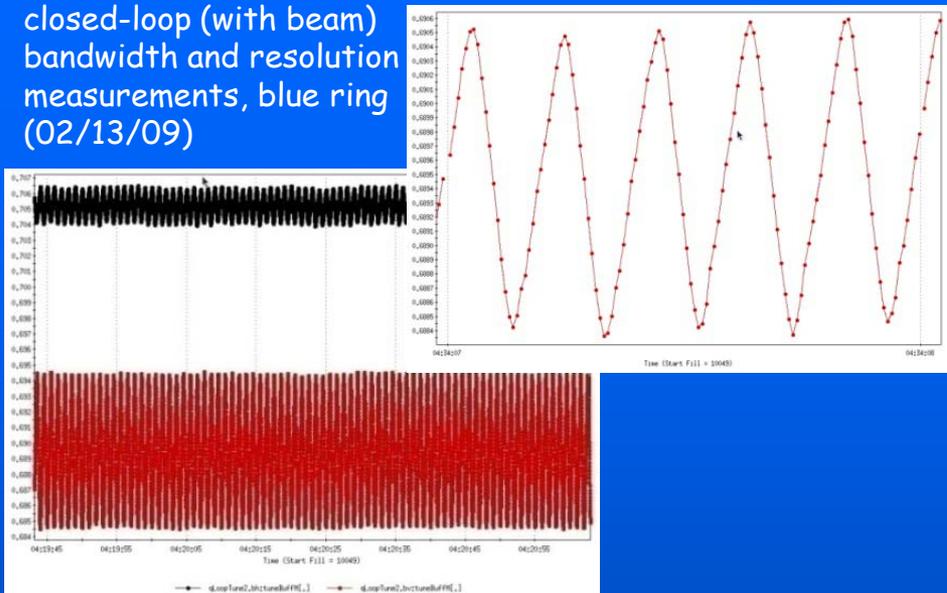
RUN08: 229 (9379-9150)
 RUN09: 34 (10084-10050)

RUN08: 292 (9379-9087) ~ 1 month
 RUN09: 49 (10084-10035) ~ 1 week

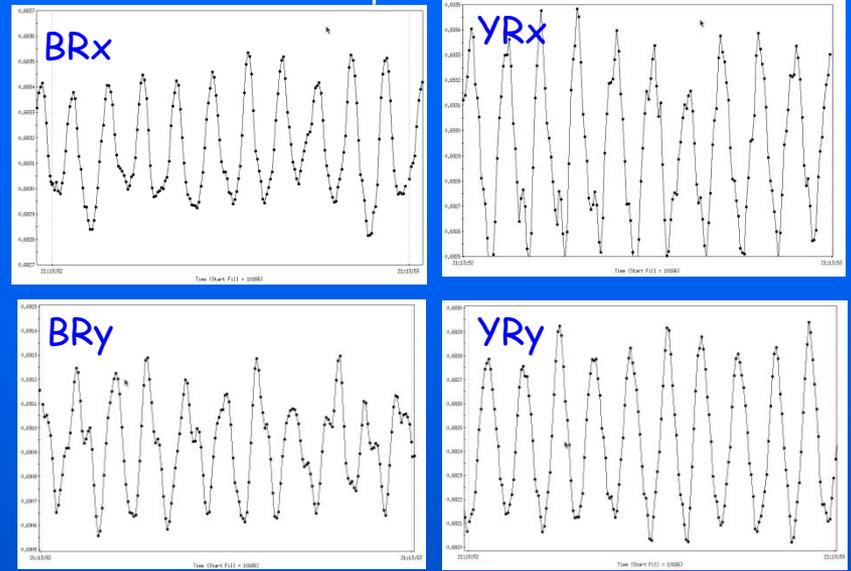
➔ factor 6 fewer ramps for tune and coupling control (replay) of both beams in RUN09

III Selected Data Highlights

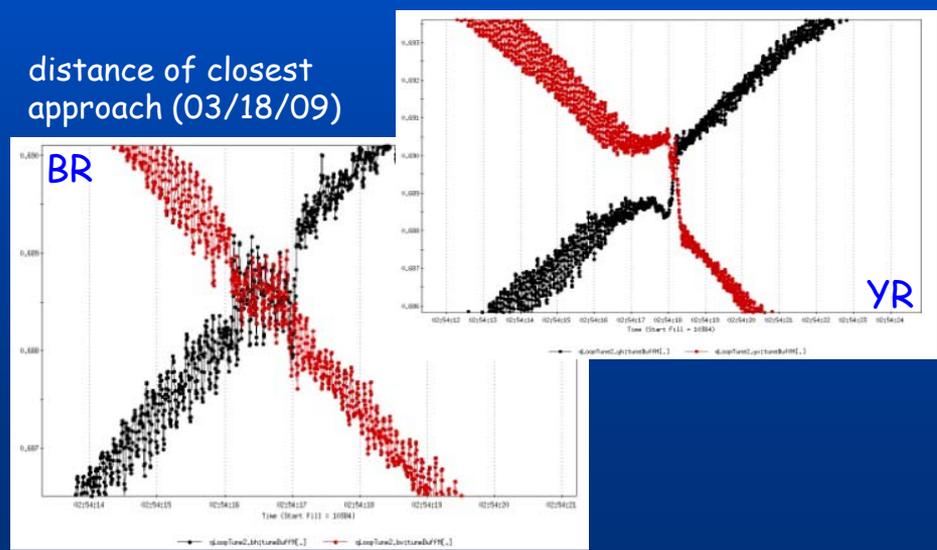
closed-loop (with beam) bandwidth and resolution measurements, blue ring (02/13/09)



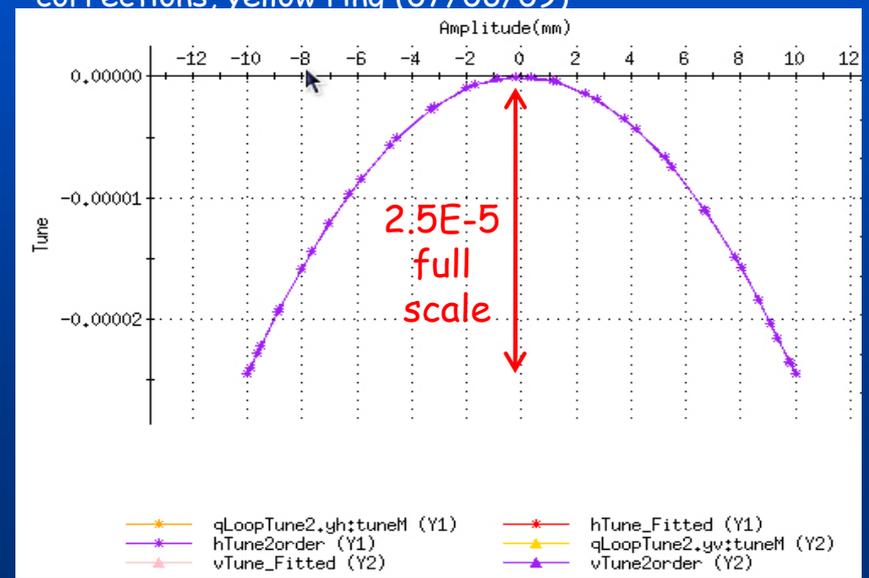
significant tune modulation at 10 Hz (02/20/09)
renewed interest in triplet vibration remediation



distance of closest approach (03/18/09)



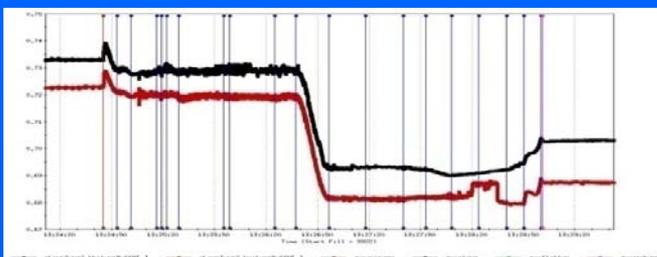
precision tune measurements during nonlinear field corrections, yellow ring (07/06/09)



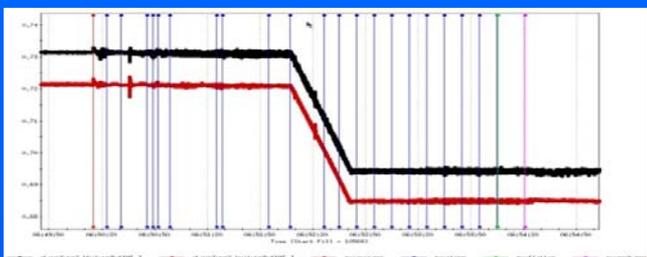
EXAMPLE TUNE AND COUPLING CONTROL WITH REPLAY (100 GeV P+P)

BLUE
TUNES

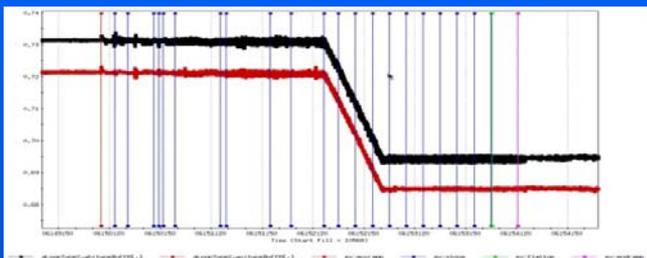
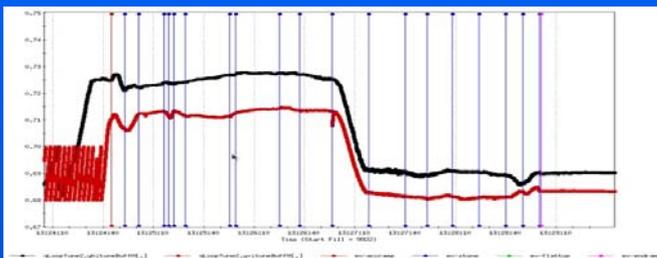
RUN08 (fill 9922, 02/21/08)



RUN09 (fill 10569, 04/16/09)



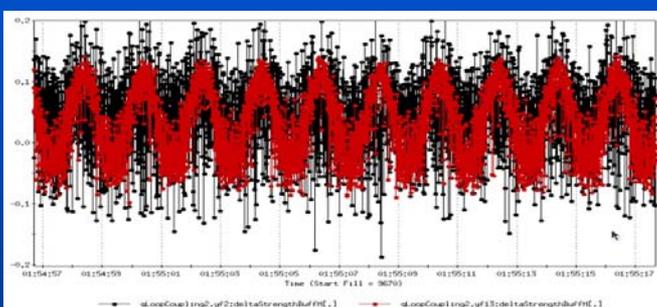
YELLOW
TUNES



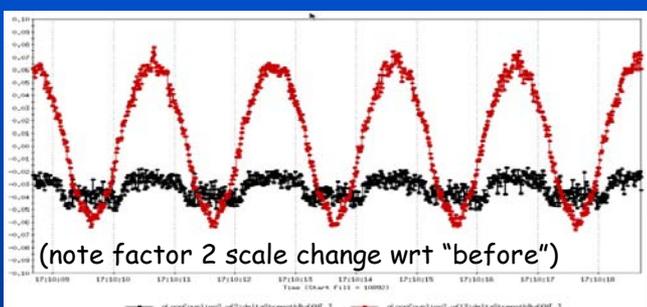
precision
measurement
and control
of tunes (with
tune "jump")

YELLOW
COUPLING

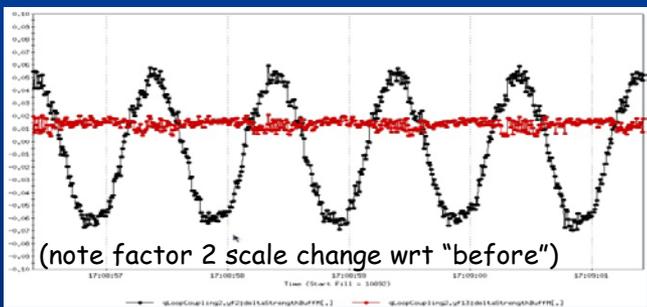
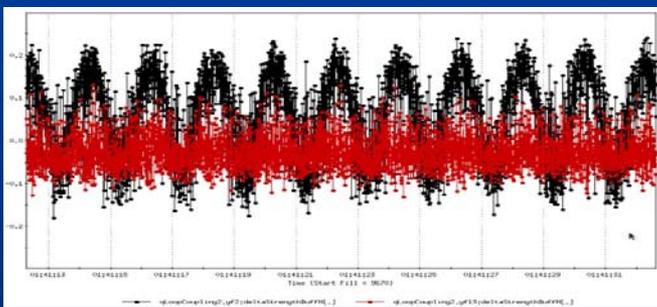
RUN08 (fill 9670, 01/31/08)



RUN09 (fill 10892, 06/10/09)

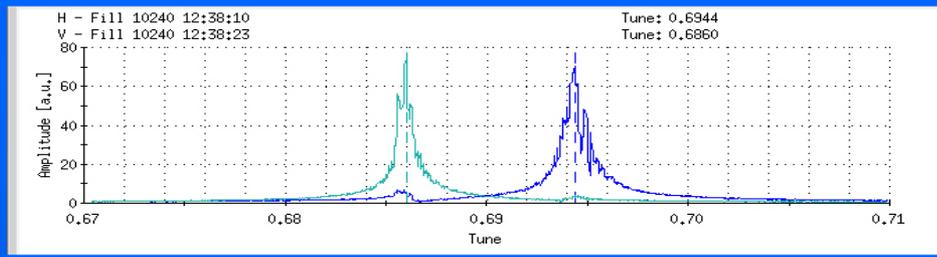


precision
measurement
and control
of coupling



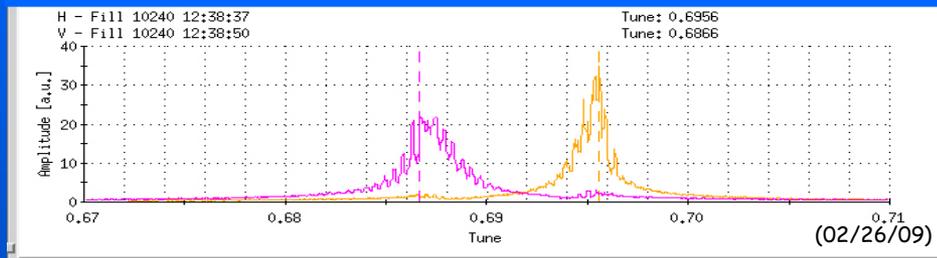
Beam Transfer Function (BTF) application: precision measurements of coherent modes with beams in collision

BLUE
TUNES

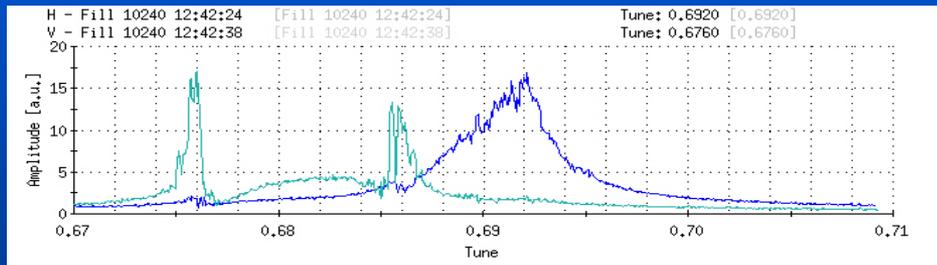


NO
COLLISIONS

YELLOW
TUNES

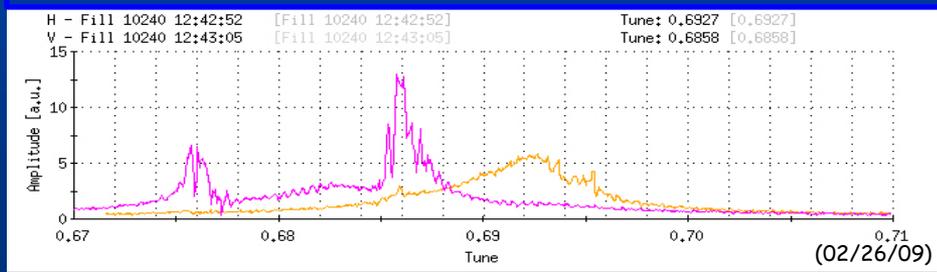


BLUE
TUNES



WITH
COLLISIONS

YELLOW
TUNES



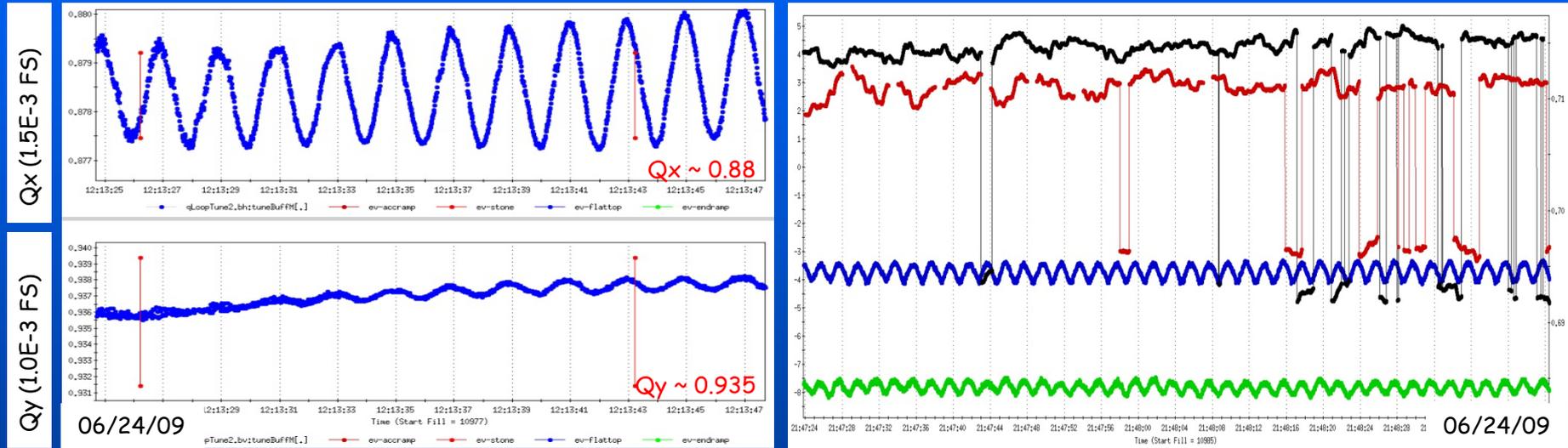
IV Summary and Outlook

solved problems:

issues with sign of coupling angle correction
ability to work in presence of strong 60 Hz harmonics
ability to measure and control tune and coupling with "tune swing"
operator ease ("hands-off" ramps)
demonstrated ability to establish (any) ramp on time scale < 1 shift

work in progress:

chromaticity measurements / feedback during energy ramp



system calibration (cross-calibration with AC dipole data)
performance post mortem

to be commissioned:

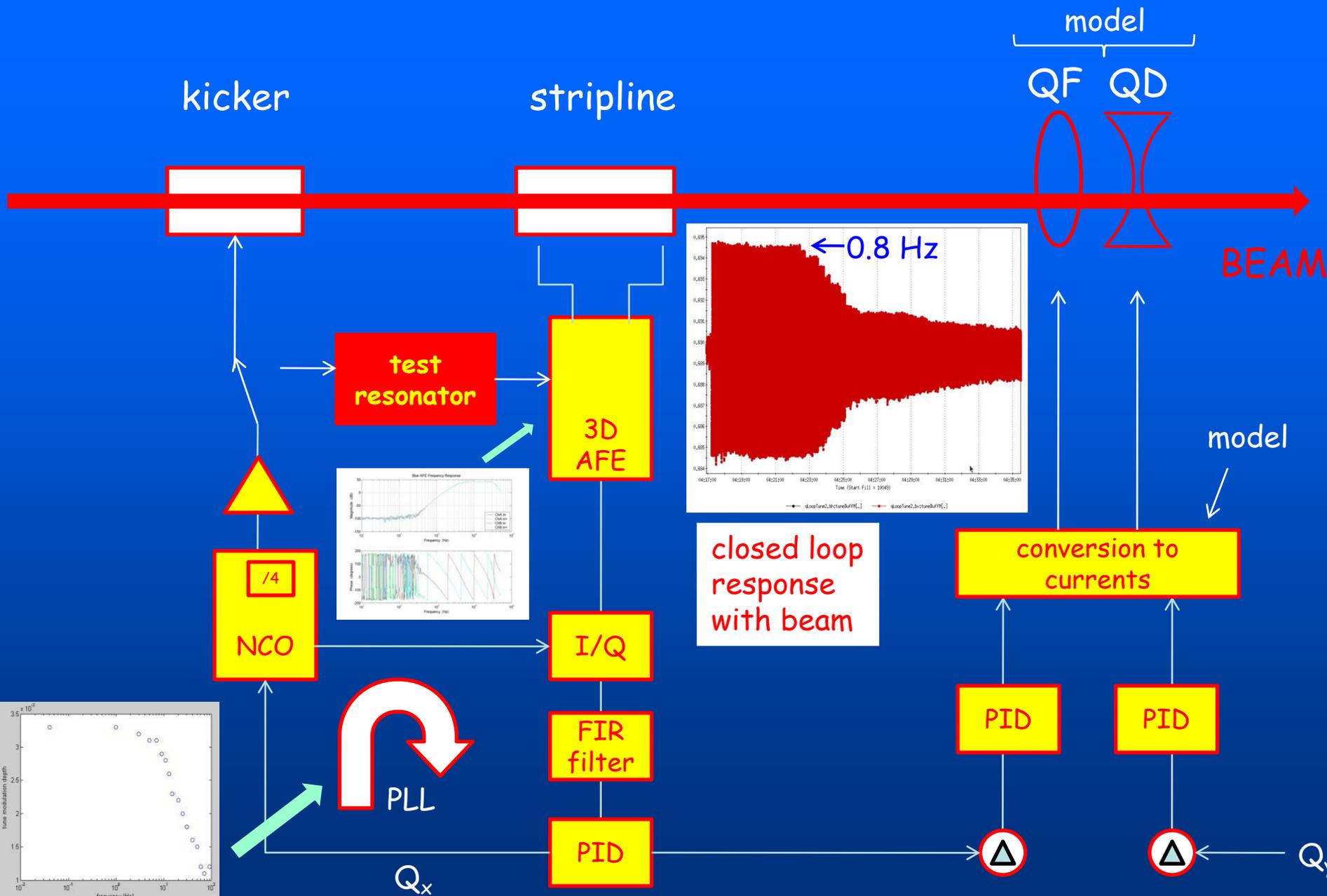
(existing) chromaticity feedback during ramp

to be developed:

orbit feedback during ramp
understanding of previously reported "anomalous BTF" with ions

C/AD note to follow

V System Overview



Tune/Coupling Feedback ramp history to 250 GeV, RUN09 in Blue Ring 02/14/09-02/15/09

FB Ramp	Fill	Date	Time	Energy Attained (GeV)	Cause for Beam Loss
1	10050	02/14/09	23:13	24	gamma T event
2	10051	02/15/09	00:24	< 154	orbit
3	10052	02/15/09	01:45	< 174	model
4	10053	02/15/09	04:02	< 195	orbit
5	10054	02/15/09	04:40	< 195	orbit
	10055	02/15/09	05:02		(newfill during ramp?!?)
6	10056	02/15/09	05:38	< 241	model
7	10057	02/15/09	06:16	250 BLUE	(success)
1	10057	02/15/09	06:16	< 37 YELLOW	orbit (start in Yellow Ring)

Tune/Coupling Feedback ramp history to 250 GeV, RUN09 in Yellow Ring 02/15/09-02/16/09

FB Ramp	Fill	Date	Time	Energy Attained (GeV)	Mode	Cause for Beam Loss (if any)
1	10057	02/15/09	06:16	250 BLUE	tune	(success)
				< 37 YELLOW	tune	orbit
2	10058	02/15/09	06:56	171 BLUE	tune	QLI, instrumental
				171 YELLOW	tune	QLI, instrumental
	10073	02/15/09	16:24	} 190 BLUE 190 BLUE	off	QLI, real
	to 10080	02/16/09	00:04		off	QLI, real
3	10081	02/16/09	01:13	247 BLUE	tune	orbit (blue)
				247 YELLOW	tune	
4	10082	02/16/09	01:51	250 BLUE	tune	72.6% efficiency
				250 YELLOW	tune	81.8% efficiency
5	10083	02/16/09	02:57	250 BLUE	tune	99.6% efficiency
				250 YELLOW	tune	97.9% efficiency
	10084	02/16/09	04:04	250 BLUE	replay	99.9% efficiency
				250 YELLOW	replay	94.7% efficiency (4E11 per ring)

Tune/Coupling Feedback ramp history, continued (250 GeV, RUN09): 03/30/09

purpose: tune optimization for higher polarization

Ramp	Fill	Date	Time	Energy (GeV)	Mode	Ramp Eff.	
1	10458	03/30/09	13:59	250 BR	tune	96.9%	} optimizing desired tunes for optimum polarization
				250 YR	tune	92.2%	
2	10459	03/30/09	15:05	250 BR	tune	96.8%	
				250 YR	tune	92.1%	
3	10460	03/30/09	16:19	250 BR	replay	0%	} loss due to handshake error between energy and rotator ramps (270 vs 275 seconds)
				250 YR	replay	0%	

Tune/Coupling Feedback ramp history to 100 GeV, RUN09

04/16/09-04/16/09

Ramp	Fill	Date	Time	Energy (GeV)	Mode	Ramp Eff.
1	10566	04/16/09	04:48	~24 BR / 24 YR	tune / tune	0% / 0% (hysteresis)
2	10567	04/16/09	05:42	100 BR / 100 YR	tune / tune	23.3% / 36.2
3	10568	04/16/09	06:54	100 BR / 100 YR	tune / tune	23.6% / 19.6%
4	10569	04/16/09	07:47	100 BR / 100 YR	replay/replay	86.3% / 2.9%
5	10573	04/16/09	12:57	100 BR / 100 YR	tune / tune	85.7% 12.3%
6	10574	04/16/09	13:54	100 BR / 100 YR	tune / tune	87.7% / 12.0%
7	10575	04/16/09	15:04	100 BR / 100 YR	tune / tune	89.5% / 76.3%
8	10576	04/16/09	16:15	100 BR / 100 YR	tune / tune	89.1% / 75.6%
9	10577	04/16/09	16:59	100 BR / 100 YR	replay/replay	89.4% / 81.7%

(by operations)

Tune/Coupling Feedback ramp history to 250 GeV, near integer tune 06/11/09 [APEX 1]

[Jun-11-2009 00:38:](#)

Tune/Coupling Feedback ramp summary (06/10/09), RUN09 pp94nearInt

The (new) spare BBQ AFEs were modified for increased bandwidth as needed for near-integer tune measurements and installed on 06/03/09. Specifications, modeling, and comparison with measurement by Kevin Mernick. Many thanks to Tom Russo, Tony Curcio and crew for the fast and perfect realization.

The BBQ/PLL code was modified by Al Marusic on 06/04/09 to accommodate user-specified, frequency-dependent phase corrections (as required in particular during energy/frequency ramp and in BTF measurements). The previously used value (pre 06/04/09 of $1E-3$ tune units per 100 kHz, or -0.0128 degrees/Hz, was corrected based on measurement to -0.0116 deg/Hz for nominal 100 GeV operations on 06/04/09. This change was required since the phase response of the modified AFEs is necessarily significantly different at near-integer betatron tunes and will be different between the horizontal and vertical planes in the 250 GeV near-integer tune optics.

These modifications were checked (found to be fully functional on first try) during APEX on 06/04/09 and during machine development with tune/coupling feedback ramps on 06/05/09.

The BBQ/PLL code was further modified by Al to dynamically maintain constant PLL-PID loop parameters which until now would change in an unwanted fashion (scale with ratio of old-to-new betatron frequencies). We are presently operating with new values for these parameters (as noted in the "config" entry of 19:03). This change was essential for accommodating tune/coupling feedback ramps with a betatron frequency a factor 10 different from that used for the 100 GeV operations.

Tune/Coupling Feedback ramp history log (06/10/09), RUN09 pp94nearInt

Blue Ring: Qx/Qy=0.880/0.935

Yellow Ring: Qx/Qy=0.820, 0.810

Tune Feedback in Blue Ring (no need for coupling feedback with widely separated tunes)

Tune and Coupling Feedback in Yellow Ring

Ramp 1, 06/10/09, 17:48 (10892, feedback ramp)- lost just after ACCRAMP due to orbit (2.5 mm rms vertical in BR, ~2 mm rms horizontal in BR/YR) at I_dipole=465 A

Ramp 2, 06/10/09, 18:51 (10893, feedback ramp) - lost just after ACCRAMP due to orbit (~5 mm rms vertical in BR, ~4 mm rms horizontal in YR) at I_dipole=486 A

Ramp 3, 06/10/09, 19:41 (10894, feedback ramp) - successful (despite 8 mm rms vertical orbit deviation in BR); efficiencies 67.4% (blue), 19.4% (yellow)

Ramp 4, 06/10/09, 21:08 (10895, feedback with feedforward of 10894) - yellow beam lost just before ENDRAMP at I_dipole=5041 A due likely to chromaticity; efficiencies (dumped to log!?) 96.6% (blue), 27.5% (yellow)

Ramp 5, 06/10/09, 22:25 (10896, feedback with feedforward of 10895) - blue beam lost just before ENDRAMP at full dipole field (I_dipole=5057 A) due PS bi8-tv2 trip; efficiencies 86.3%, 26.6%

Ramp 6, 06/10/09, 23:14 (10897, feedback with feedforward of 10897) - blue beam lost at ENDRAMP due to horizontal chromaticity; efficiencies 88.5%, 54.0%

Ramp 7, 06/10/09, 23:48 (10898, feedback, blue beam only) - blue beam lost at I_dipole=4500 A due to vertical chromaticity -Marusic, Minty and the many people involved in r

Tune/Coupling Feedback ramp history to 250 GeV, near integer tune 06/24/09 [APEX 2]

[21] Jun-24-2009 17:20 Summary of 6 ramps of near integer development:

-ramps 10976, 10977 (12 bunches): orbit corrections and chromaticity measurements
 $Q_x=0.88$, $Q_y=0.935$ on the whole ramp
~0% polarization at the store
orbit rms below 0.3mm, except snapback area.

-ramp 10978 (12 bunches): applied chromaticity corrections and vertical tune shift
 $Q_x=0.88$, $Q_y=0.94$ on the whole ramp
~7% polarization at the store

-ramp 10979 (20 bunches): polarization ramp measurement and small Q_y adjustments
 $Q_x=0.88$, $Q_y=0.94$ on the whole ramp
~25% polarization at the store
no polarization loss was seen on 100 GeV part of the ramp
transmission efficiency 99%

-ramp 10980 (28 bunches): tune feedback on and polarization ramp measurements
 $Q_x=0.88$, $Q_y=0.93$ (stones 1-12), $Q_y=0.95$ (stones 13-29).
~7% polarization at the store, considerable polarization losses before 100 GeV
only 65% ramp transmission

-ramp 10981 (28 bunches): reply on the basis of ramp 10980
 $Q_x=0.88$, $Q_y=0.91$ (stones 2-12), $Q_y=0.95$ (stones 13-29)
lower tune (0.91) on first part of the ramp due to human error
large horizontal instability
~50% depolarization before 100 GeV
~8% polarization at the store
98% transmission

General notes:

-large vertical emittance (30-40 Pi) is measured by IPM already at the injection
-considerable coupling was measured by BBQ on second part of the ramp

VP, Michiko, AI, TJS, GJM, ST, Haixin, Thomas, Mei(phone)

Tune/Coupling Feedback ramp history 100 GeV, 20m beta* for PP2PP 06/29/09

[æ 20:23:cp](#) **Summary:** Tune/coupling feedback ramp history

Ramp 1, 06/29/09, 12:47, fill 11008, tune/coupling feedback, energy ramp complete, yellow beam lost at 100 GeV (4 stones before end-ramp) due to orbit excursion during unsqueeze

Ramp 2, 06/29/09, 13:33, fill 11009, tune/coupling feedback, blue beam lost just after end-ramp due to chromaticity, ramp efficiencies 98.6% (blue), 0.0% (yellow, ?)

Ramp 3, 06/29/09, 14:20, fill 11010, tune/coupling feedback, ramp efficiencies 99.9% (blue), 91.8% (yellow) - another feedback ramp needed as this ramp had orbit corrections interpolated to end-ramp which did not include zeroing separation bumps)

Ramp 4, 06/29/09, 15:24, fill 11011, tune/coupling feedback, ramp efficiencies 99.5% (blue), 97.0% (yellow)

Ramp 5, 06/29/09, 16:31, fill 11012, replay, frequency modulation (wiggles), ramp efficiencies 99.9% (blue), 98.8% (yellow)

Ramp 6, 06/29/09, 18:23, fill 11013, replay, frequency modulation (wiggles), ramp efficiencies 99.9% (blue), 98.7% (yellow)

New code for chromaticity measurement along the ramp tested however found to be CPU-limited (resulting in gaps in acquired data).

-Marusic,Mernick,Marr,Tepikian,VHS,Bai,Minty

[Jul-07-2009 12:36](#): Correction: code was not necessarily CPU limited. Al Marusic has tracked down a sequence of events starting with a network switch just before this APEX followed by problems with the logging systems (which incidentally persisted for DAYS with mysterious symptoms like missing data with same one-second signature as observed during this APEX session). Am in process of tracking down details to then develop means to protect against such problems in the future... -Minty

Tune/Coupling Feedback ramp history to 250 GeV, near integer tune

07/04/09 [APEX 3]