

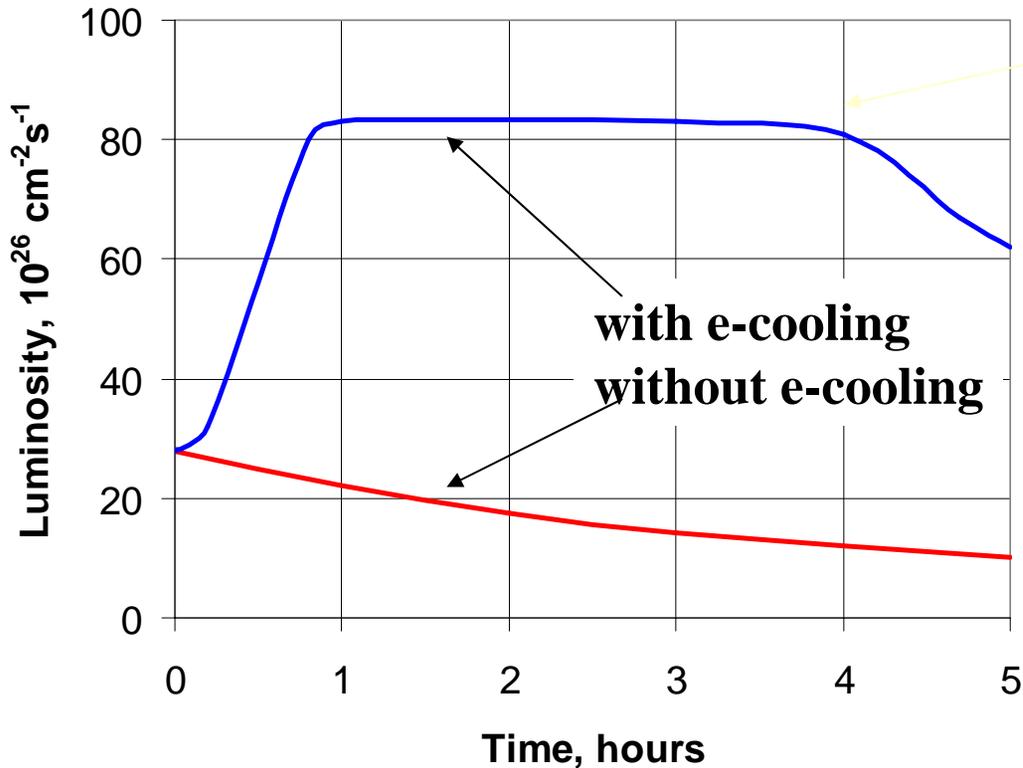
Beam studies for RHIC II

Wolfram Fischer, BNL



RHIC APEX Workshop, BNL
09 November 2005

RHIC II – luminosity evolution



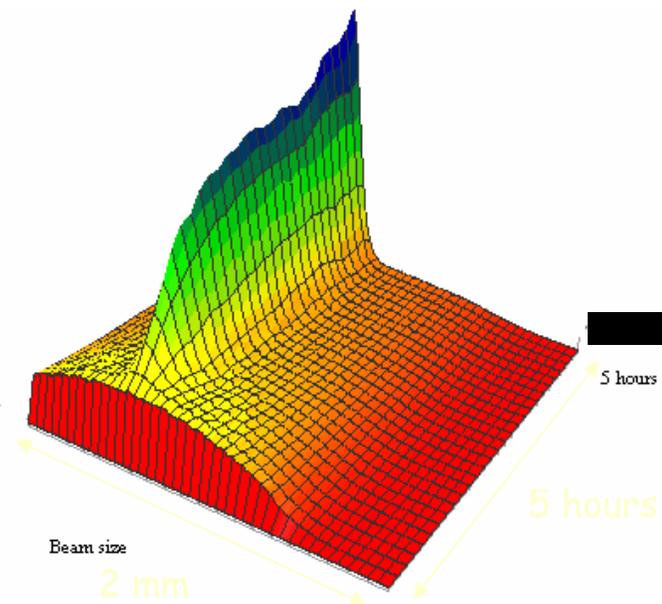
Luminosity leveling through continuously adjusted cooling

Store length limited to 4 hours by “burn-off”

Four IRs with two at high luminosity

Transverse beam profile during store

Also may be able to pre-cool polarized protons at injection energy



RHIC II Luminosities with Electron Cooling

Gold collisions (100 GeV/n × 100 GeV/n):	w/o e-cooling	with e-cooling
Emittance (95%) μm	15 → 40	15 → 10
Beta function at IR [m]	1.0	1.0
Number of bunches	112	112
Bunch population [10^9]	1	1 → 0.3
Beam-beam parameter per IR	0.0016	0.004
Peak luminosity [$10^{26} \text{ cm}^{-2}\text{s}^{-1}$]	32	90
Ave. store luminosity [$10^{26} \text{ cm}^{-2}\text{s}^{-1}$]	8	70
Polarized proton collision (250 GeV × 250 GeV):		
Emittance (95%) μm	20	12
Beta function at IR [m]	1.0	0.5
Number of bunches	112	112
Bunch population [10^{11}]	2	2
Beam-beam parameter per IR	0.007	0.012
Ave. store luminosity [$10^{30} \text{ cm}^{-2}\text{s}^{-1}$]	150	500

Maximum luminosity estimates: p-p, Au-Au, U-U

Maximum Luminosity Estimates for RHIC II					
Beams	unit	p	p	Au	U
Charge number Z	...	1	1	79	92
Mass number A	...	1	1	197	238
Relativistic γ	...	108	271	107	107
Revolution frequency	kHz	78.2	78.2	78.2	78.2
Normalised emittance, 95%, min	mm mrad	12	12	10	10
Ions/bunch, initial	10^9	200	200	1.0	0.9
Charges per bunch	$10^9 e$	200	200	80	80
No of bunches	...	110	110	110	110
Average beam current/ring	mA	275	275	110	110
Luminosity at one IP	unit	p-p	p-p	Au-Au	U-U
Beam-beam parameter per IP	...	0.0123	0.0123	0.0024	0.0023
β^*	m	1.0	0.5	0.5	0.5
Peak luminosity	$10^{30} \text{ cm}^{-2} \text{ s}^{-1}$	150	750	90	67
Peak / average luminosity	...	1.5	1.5	1.3	1.3
Average store luminosity	$10^{30} \text{ cm}^{-2} \text{ s}^{-1}$	100	500	70	52
Time in store	%	55	55	60	60
Luminosity/week	pb^{-1}	33	166	2.5	1.9
Luminosity/week, achieved	pb^{-1}	0.9		0.16	

Maximum luminosity estimates: Si-Si, Cu-Cu, d-Au, p-Au

Maximum Luminosity Estimates for RHIC II						
Beams	unit	Si	Cu	d	p	Au
Charge number Z	...	14	29	1	1	79
Mass number A	...	28	63	2	1	197
Relativistic γ	...	108	108	107	108	107
Revolution frequency	kHz	78.2	78.2	78.2	78	78.2
Normalised emittance, 95%, min	mm mrad	12	12	12	12	12
Ions/bunch, initial	10^9	10.7	5.2	150	200	1.0
Charges per bunch	$10^9 e$	150	150	150	200	80
No of bunches	...	110	110	110	110	110
Average beam current/ring	mA	206	206	206	275	110
Luminosity at one IP	unit	Si-Si	Cu-Cu	d-Au	p-Au	Au-Au
Beam-beam parameter per IP	...	0.0046	0.0043	0.0024	0.0048	
				0.0036	0.0048	
β^*	m	1.0	1.0	2.0	2.0	
Peak luminosity	$10^{28} \text{ cm}^{-2} \text{ s}^{-1}$	42	10	28	37	
Peak / average luminosity	...	1.3	1.3	1.5	1.5	
Average store luminosity	$10^{28} \text{ cm}^{-2} \text{ s}^{-1}$	32	8	19	25	
Time in store	%	55	55	55	55	
Luminosity/week	nb^{-1}	108	25	62	83	
Luminosity/week, achieved	nb^{-1}		2.4	4.5		

Challenges for RHIC II

2 main challenges (apart from actual cooling):

1. Beam-beam interaction

- Cooling may result in non-Gaussian profiles
- Lighter (than Au) ions can always run at the beam-beam limit

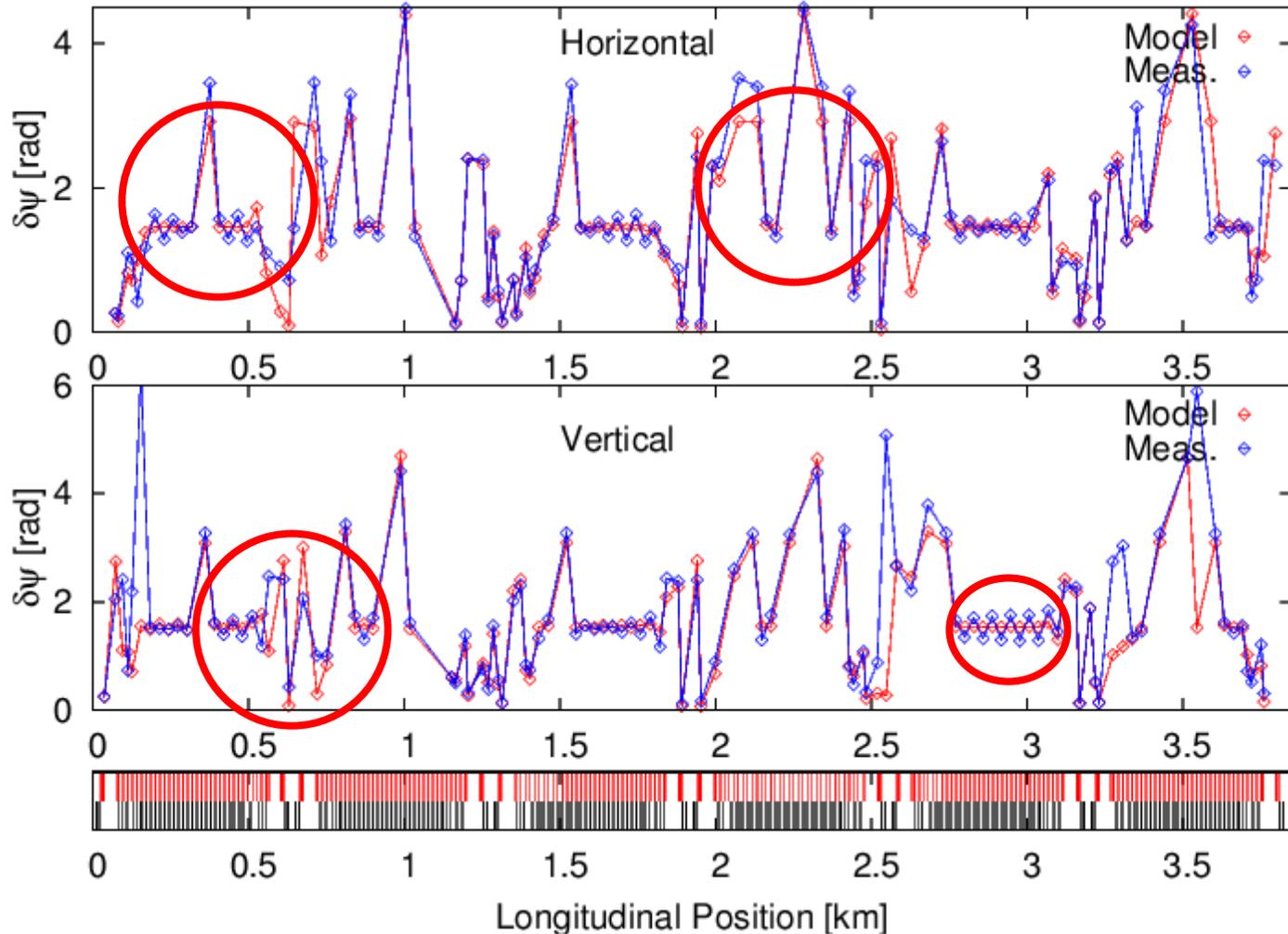
2. β^* -squeeze to 0.5m for polarized protons

- Requires better control of lattice

Towards RHIC II

1. Understand and correct linear lattice
2. Measure and reduce modulations
 - Orbit modulations
 - Tune modulations
3. Reduce or eliminate all nonlinearities other than beam-beam
 - Triplet errors (done)
 - Nonlinear chromaticity
 - Skew chromaticity
4. Reduce beam-beam effect
 - Shaping of ion beam
 - E-lenses

1. Understand and correct linear lattice

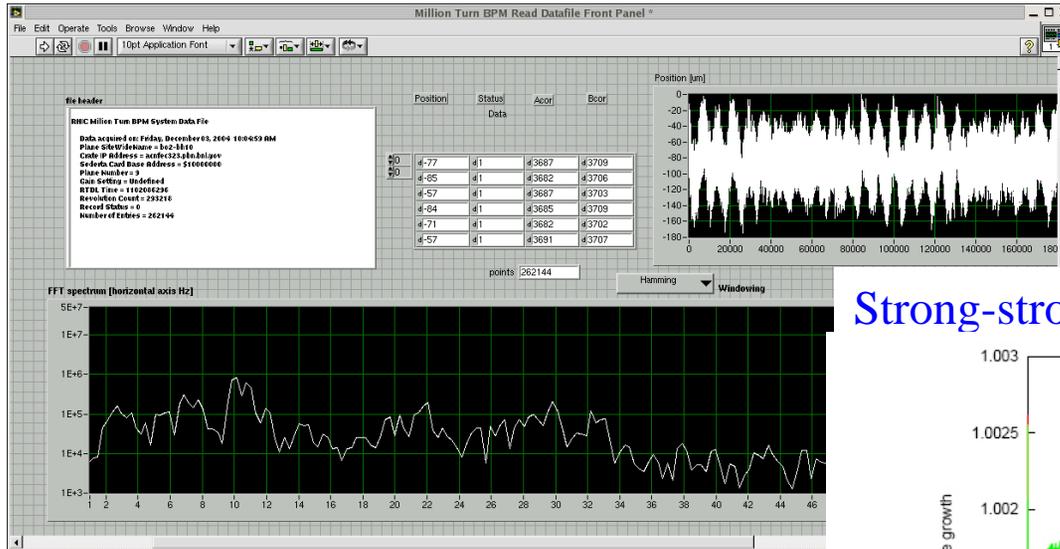


- Measurements so far limited by BPM (→ Rob et al.)
- Correction based on measurement of response matrix (→ Todd et al.)

May-31-2005 15:11 Comment: Optics Measurements from yesterday's ac dipole beam exps. for normal operational settings for YELLOW injection. Quite a lot beating in the arcs!! -ram

2. Understand and reduce modulations (I)

10 Hz orbit oscillation leads to modulated beam-beam offset, needs orbit feedback (→ Christoph et al.)



Dec-03-2004 10:08 Million-turn data at flattop, from bo2-bh10. bo2-bh8 has signal problems that I'll investigate later during the day. It seems that 10Hz signal is present. TJS

Strong-strong simulation of ϵ -growth (J. Qiang)

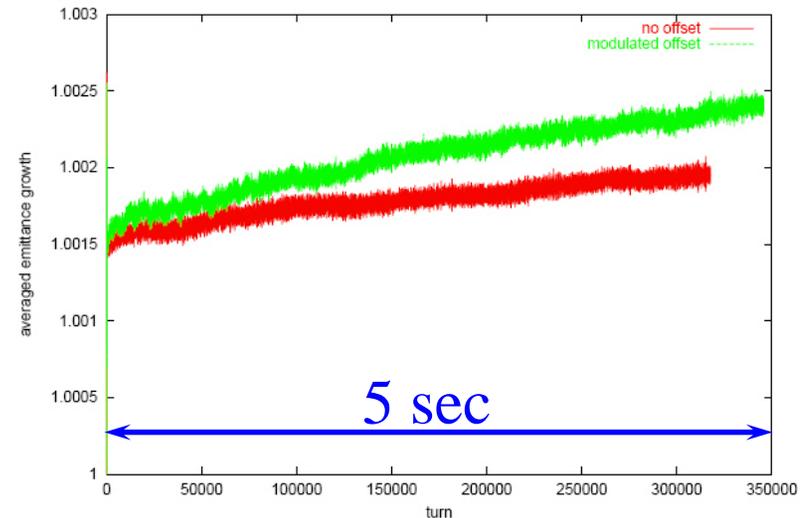


FIGURE 2. Emittance evolution (averaged over horizontal and vertical plane) with and without a time-modulated offset beam-beam collision in RHIC.

2. Understand and reduce modulations (II)

Measured tune modulation spectrum in SPS –
not known in RHIC (→ Kevin et al.)

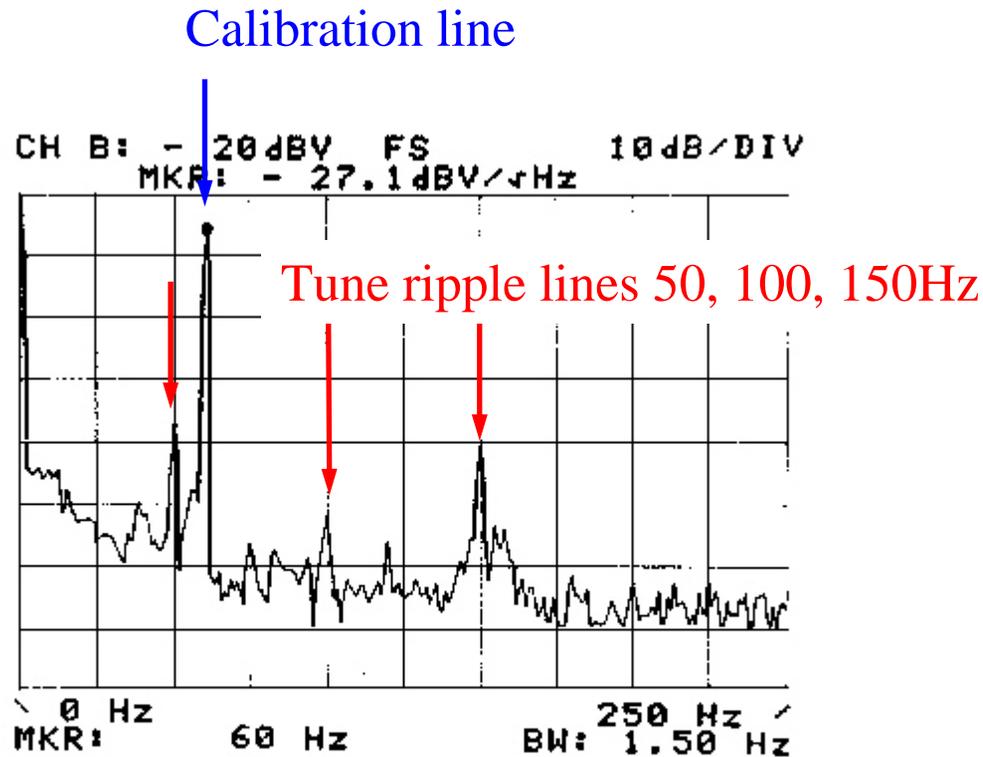
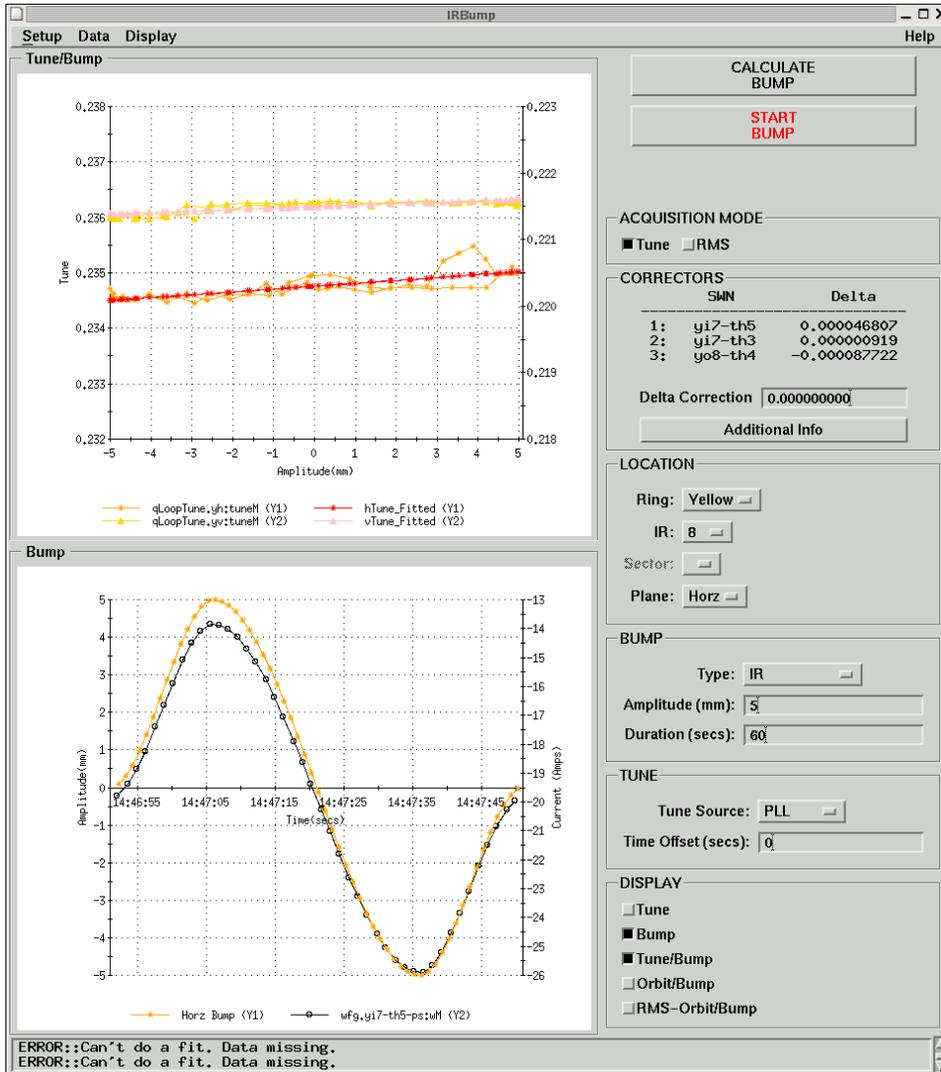


Figure 4.9: Natural tune ripple spectrum. Up to 250 Hz three natural tune ripple lines are above the noise level (50, 100 and 150 Hz) as expected from the voltage power supply ripple. The large 60 Hz line was introduced by the modulating quadrupole and is used for calibration purposes.

3. Reduce nonlinearities other than beam-beam (I)

Correction of triplet errors – done (Fulvia)

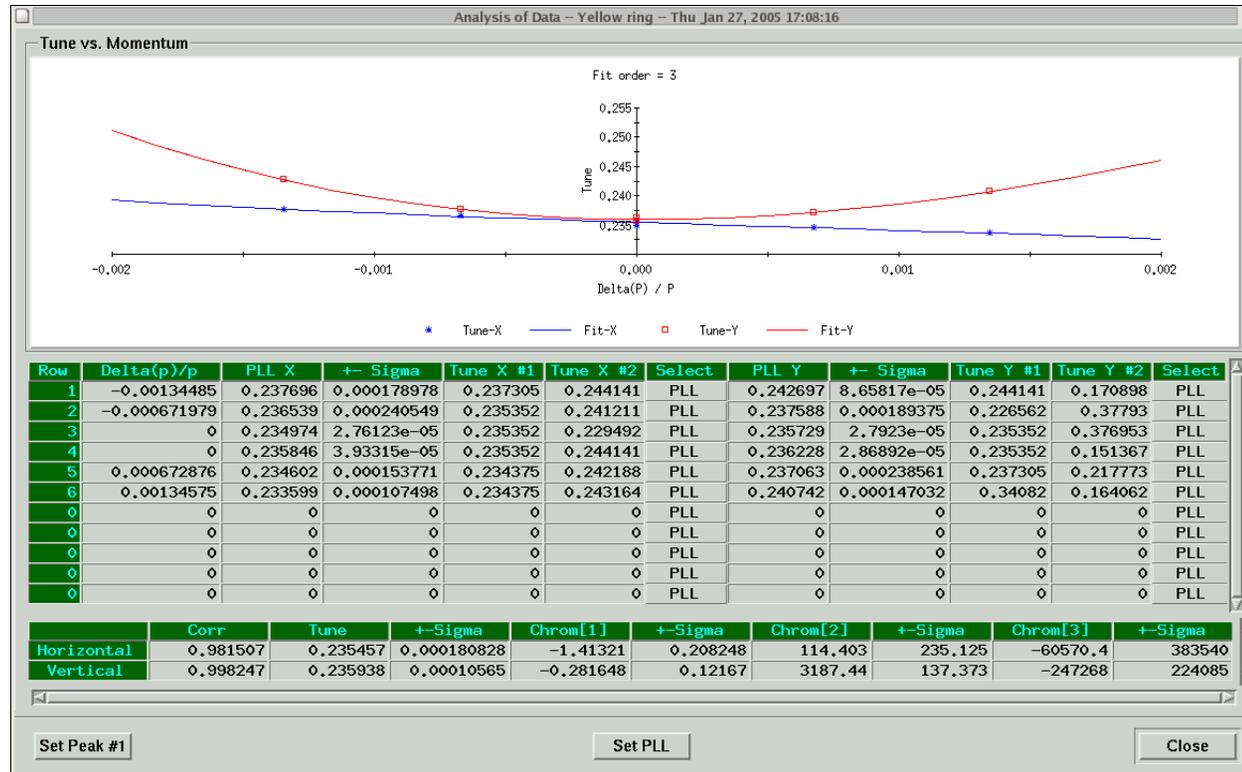


Feb-14-2005 14:57 Comment: ok - correction done in IR8 - IR6 will wait until we resolve the 12mm offset problem there -Fulvia

3. Reduce nonlinearities other than beam-beam (II)

Nonlinear chromaticity – SteveT, Vadim

- Need to check with new dispersion fitting
- Hardware in place for Run-6/7



Jan-27-2005 17:21 Comment: In this measurement we can clearly see the nonlinear chromaticity in the vertical tunes. Note, the tunes were very close together during this measurement. We tried to separate the tunes but lost the beam. We used 1.5mm radial steering. -Steve T, vp

4. Reduce beam-beam effects

consider e-lenses for head-on
consider wires for long-range (eRHIC)

See tomorrow

Summary

2 main challenges (apart from actual cooling):

- 1. Beam-beam interaction**
- 2. β^* -squeeze to 0.5m for polarized protons**

Need to:

1. Understand and correct linear lattice
2. Measure and reduce modulations
3. Reduce or eliminate all nonlinearities other than beam-beam
4. Reduce beam-beam effect