Nonlinear studies

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Following studies performed during Au run are covered in this talk:

1. Nonlinear chromaticity
2. Dynamic aperture

Nonlinear chromaticity

Steve T, Al Della Penna, Vadim

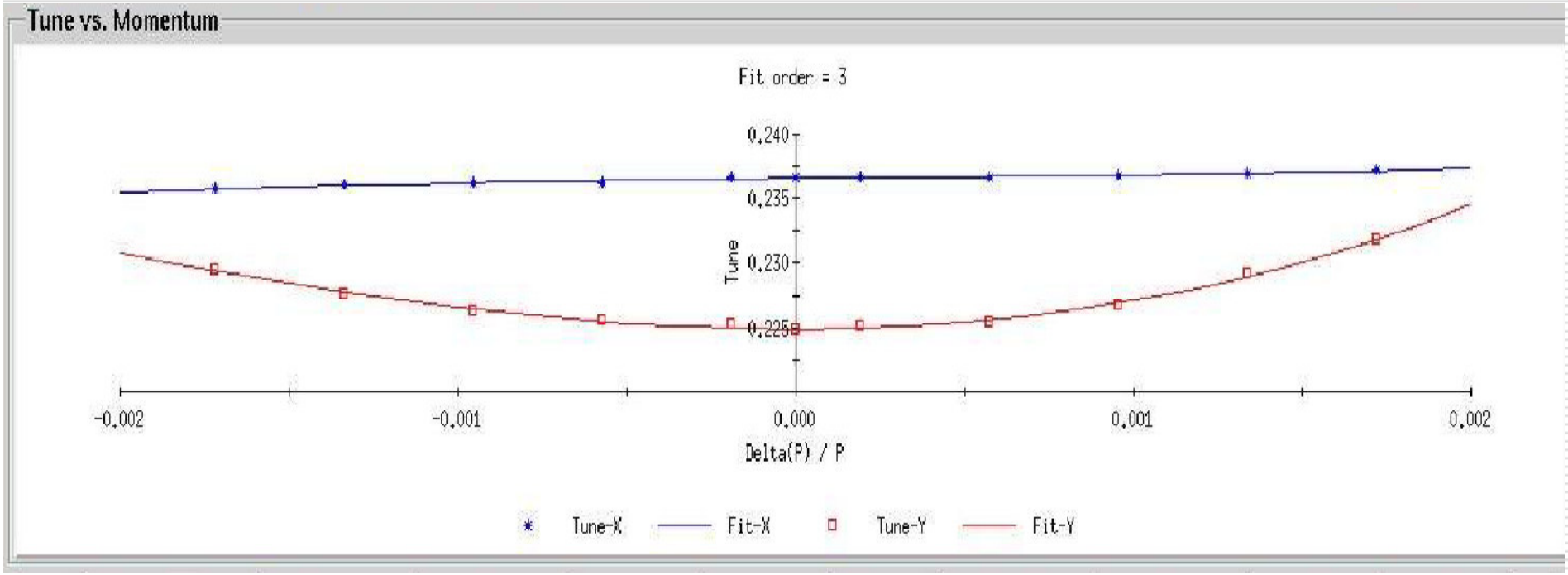
PLL tune measurements as orbit radius changes (by 1.5-2mm) following RF cavity frequency changes

Linear chromaticity (ξ_1) is put as close as possible to 0 in order to make higher order effects more pronounced

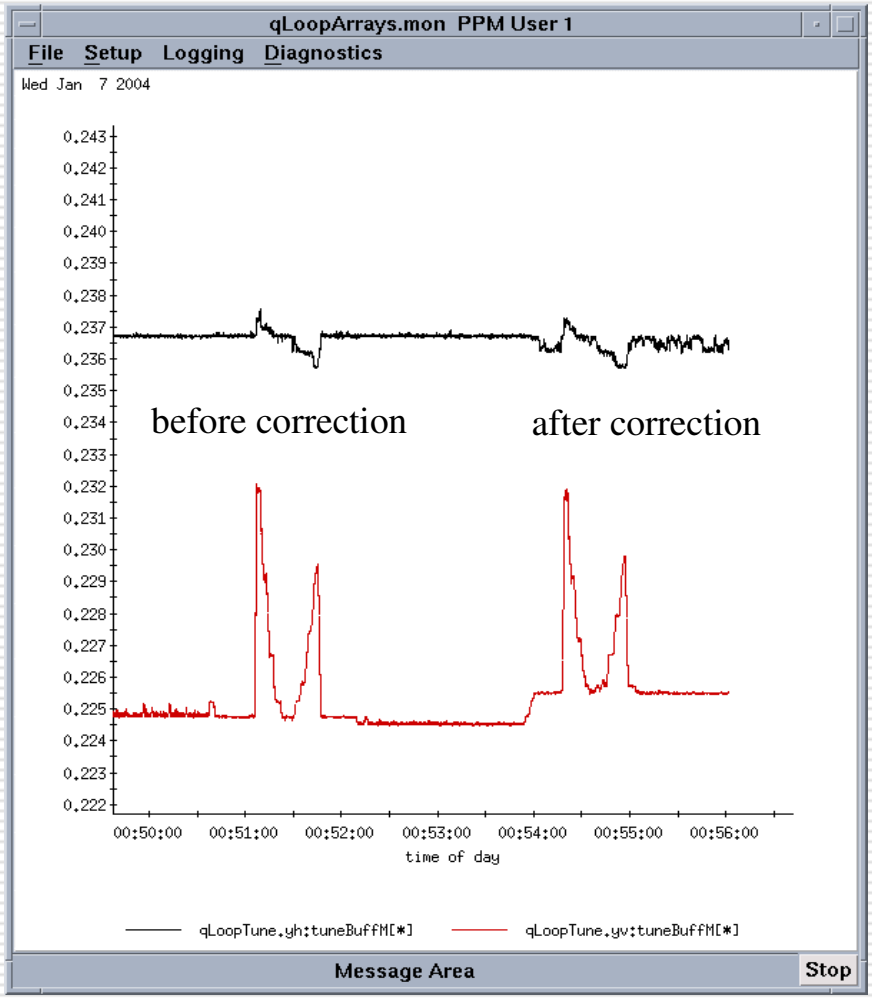
Coupling minimized, tunes separated by 0.012

$$\Delta Q = \xi_1 \frac{\Delta p}{p} + \xi_2 \left(\frac{\Delta p}{p}\right)^2$$

Measured (Yellow): $\xi_{2x} \approx -50$, $\xi_{2y} \approx 1900$

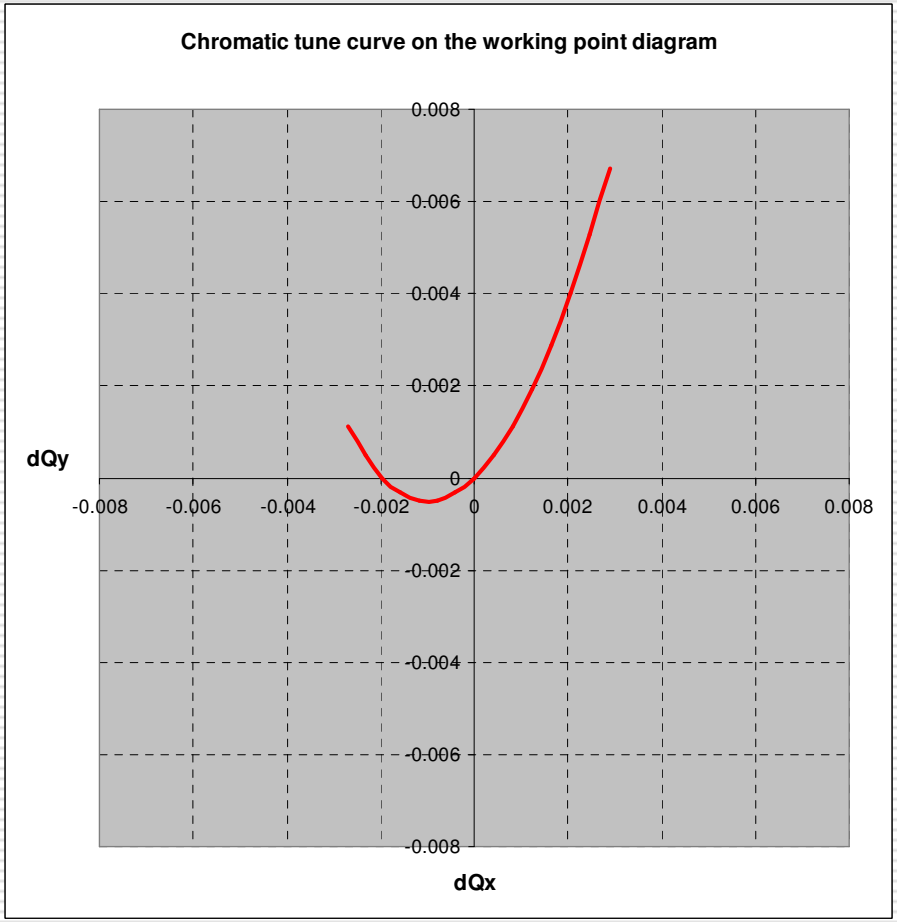


Nonlinear chromaticity



- Correction using 4 arc octupole families
- Octupole knobs (calculated by SteveT) to change ξ_2 without affecting nonlinear tune spread
- Knobs worked well but available octupole strength allows to reduce ξ_{2y} only by 20-25% (in agreement with model)

Nonlinear chromaticity



When does it matter? Only after rebucketing .

The second order chromatic tune spread ~ V_{rf}

For V_{rf} = 4 MV, ΔQ_y ~ 0.007, thus nonlinear chromaticity defines tune spread for Au beam after rebucketing

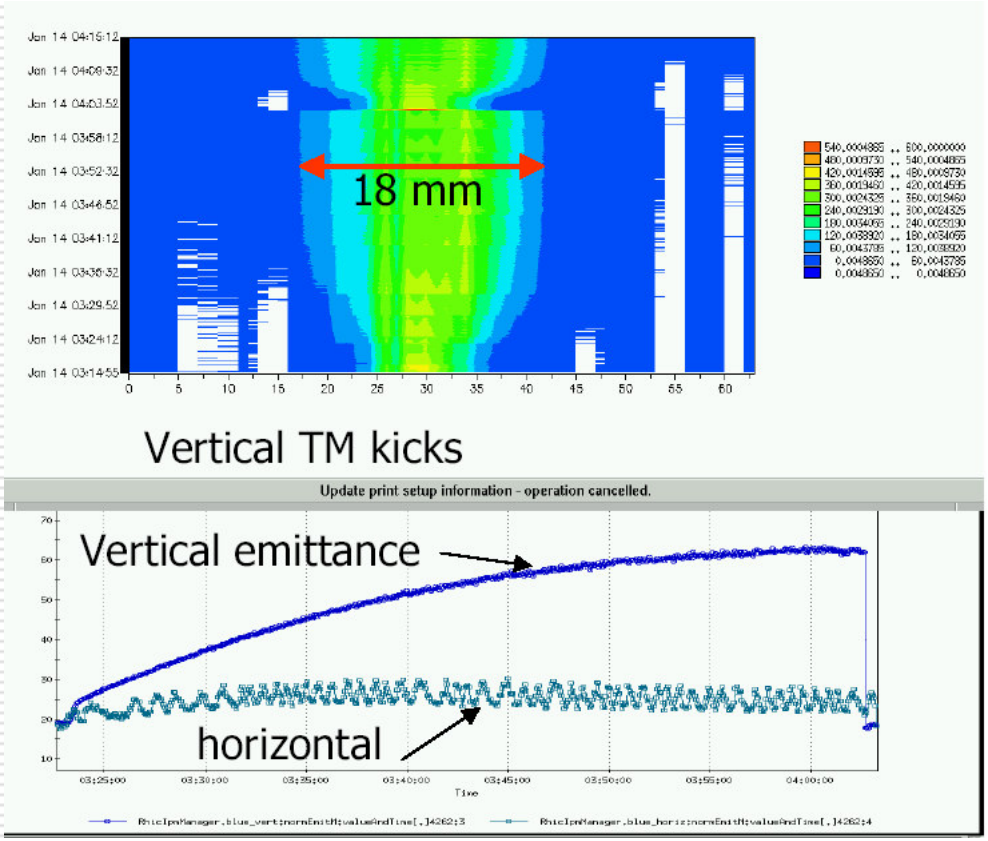
$\xi_1 = 2$

$\frac{\Delta p}{p} = \pm 0.0014$ V_{rf}=4 MV

Dynamic aperture

Fulvia, Nikolay, Steve T, Vadim

IPM measurements



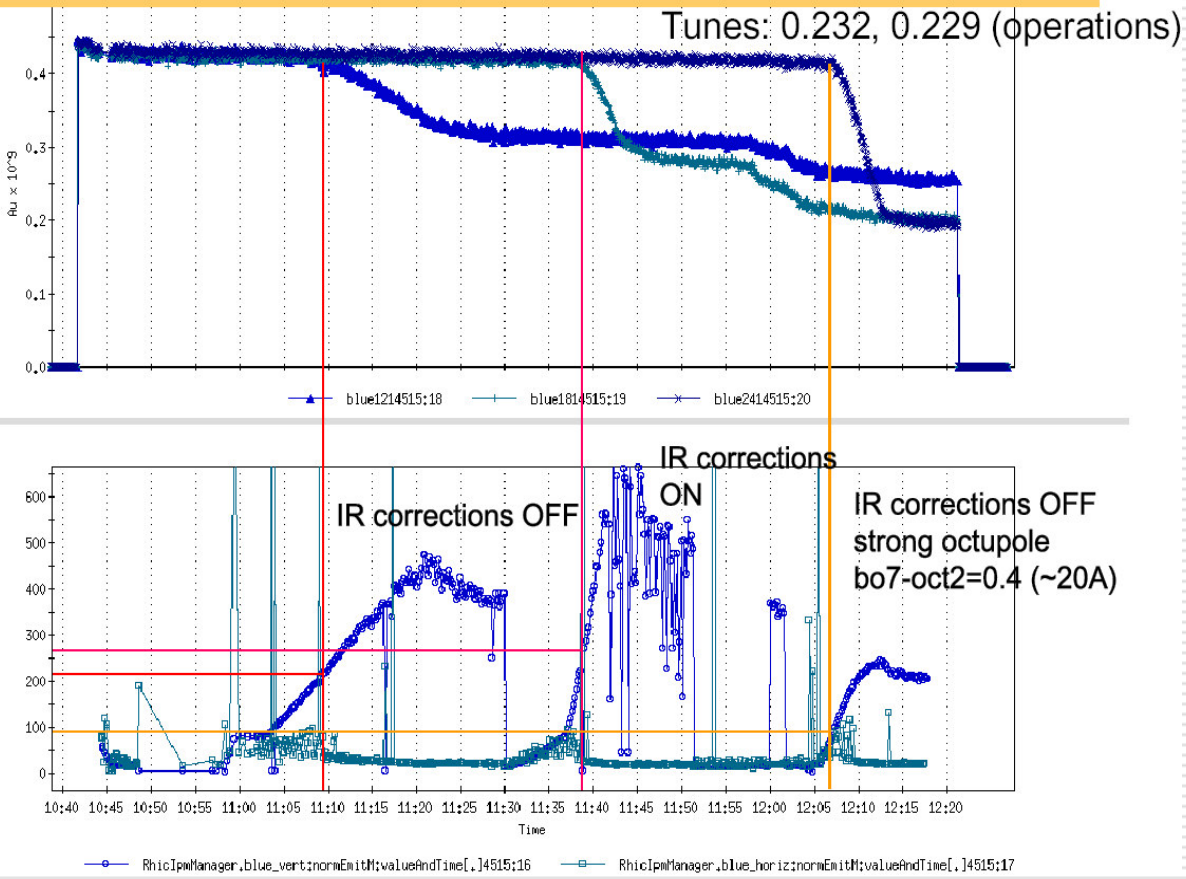
- Gradually increase beam size with tunemeter kicker to reach dynamic aperture limits
- Manifestation:
  - IPM emittance saturation
  - reaching limit of transverse distribution width
  - beam losses
- Beam loss location was at 6 and/or 8 o'clock triplets

DA measurement by beam losses

Noting emittance when losses starts

Measurement uses different bunches each time

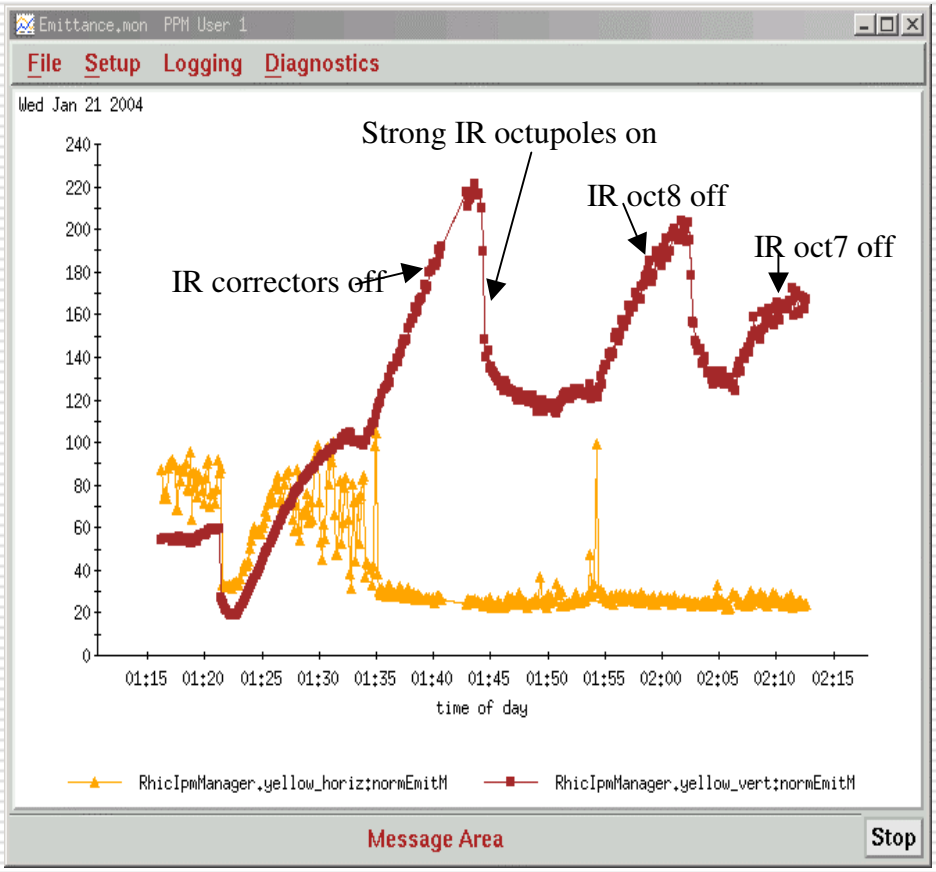
Dynamic aperture – blue (february 11)



- Measurement precision is limited to +-30
- Measurements have been done with different IR corrector settings, with and without beam-beam and for different working points
- Vertical aperture > horizontal
- Blue – Yellow consistent
- Dynamic aperture is tune dependent (no surprise)
- IR correction help (~30% hor - ~15% vert.)
- Best measured aperture (good working point, no beam-beam, IR correctors On) is about 11 σ (for 10π initial emittance)

DA measurement

Dynamic aperture shrinking from strong octupoles
Measurement with one bunch



- The DA measurement have been used to calibrate the model using predetermined nonlinear sextupoles/octupoles
- Comparison of the measured results with the model has been done (Nikolay)
- The DA measurement have been used to verify quality of IR nonlinear correction (and, thanks to this, the problem was identified and fixed on the initial stage of IR correction at IR8)

Conclusions

- Second order chromaticity provides important contribution to the betatron tune spread after rebucketing.
  It can not be corrected because of limited octupole corrector strength.
- Dynamic aperture measurement showed the DA dependence on working point and IR corrector settings. It was used to verify that IR correctors (sextupoles and octupoles), set for machine operation, really improve the dynamic aperture of the machine.