Flattop and Nonlinear studies

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Nonlinear dynamic effects and characteristics

- Nonlinear dynamics affects:
  - Beam lifetime
  - Beam size growth
  - Transition crossing efficiency (by limiting the tune space)

- Nonlinear characteristics:
  - Dynamic aperture
  - Amplitude dependent tune spread
  - Nonlinear chromatism
  - Resonance strength
  - Diffusion caused by nonlinearities or tune modulations.

Studies goals

- Main goal: To gain better knowledge of our machine and improve the machine performance
- Measure primary nonlinear characteristics (nonlinear chromatism, DA, tune versus amplitude) at flattop and compare with the machine model
- Define the optimal conditions for the machine operation, like the best working point
- Evaluate the nonlinear beam diagnostic and measurement methods, which is the best for the operation use
- Develop the nonlinear correction techniques

Operation tasks and last run data

- Immediate operation tasks:
  - IR corrections at IR8, IR2(?)
  - 0.2 and 0.25 resonance correction at transition

- Last run studies and data:
  - Lifetime versus beta*
  - IR closed bumps measurements at IR8 and IR2
  - Resonance measurements at injection.
  - Nonlinear chromaticity measurements (brief data)
  - Schottky spectra

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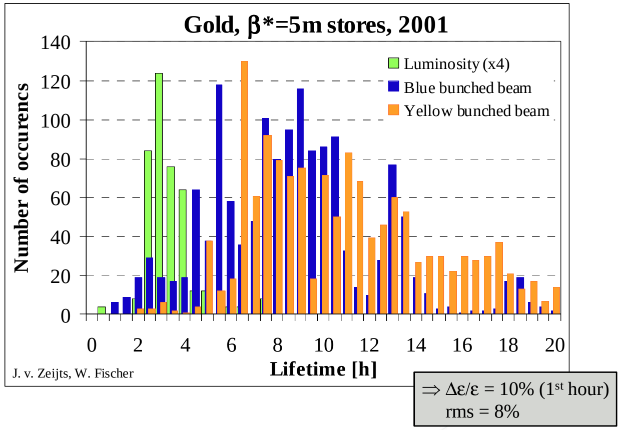
Lifetime versus β*

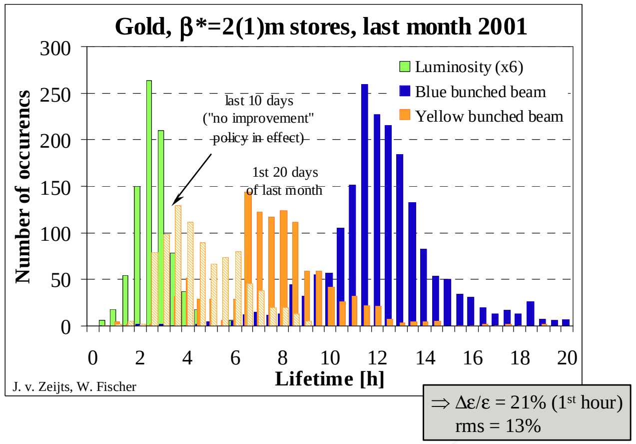
The analysis by J.van Zeijts and W.Fischer

Lifetimes (1)



Yellow lifetime at the storage decreases with β* squeeze

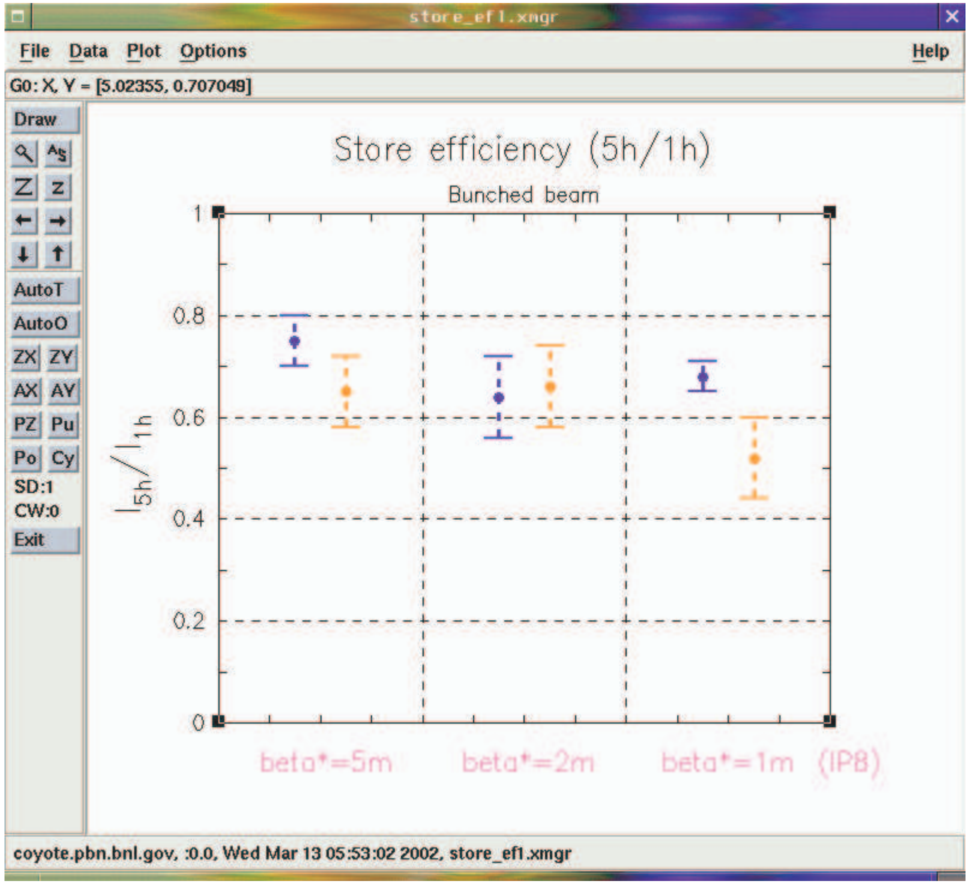
Lifetimes (2)



Lifetimes Summary

	Average luminosity lifetime	Average beam lifetime Blue / Yellow	Average emittance growth (first 1h)	Likely dominating effect
Au, β*=5m	**3.1h**	9h / 11h	**10%**	IBS
Au, β*=2(1)m	**2.4h**	13h / 7h	**21%**	IR Errors
p, β*=3m	**8.9h**	17h / 26h	**4%**	Beam-Beam

Store efficiency versus β^*



Ratio of beam intensities at 5h and 1h after the store starts. The data for selected 5 best (longest) storages for each β^* case.

Reduction of Yellow lifetime after the β^* squeeze from 2m to 1m

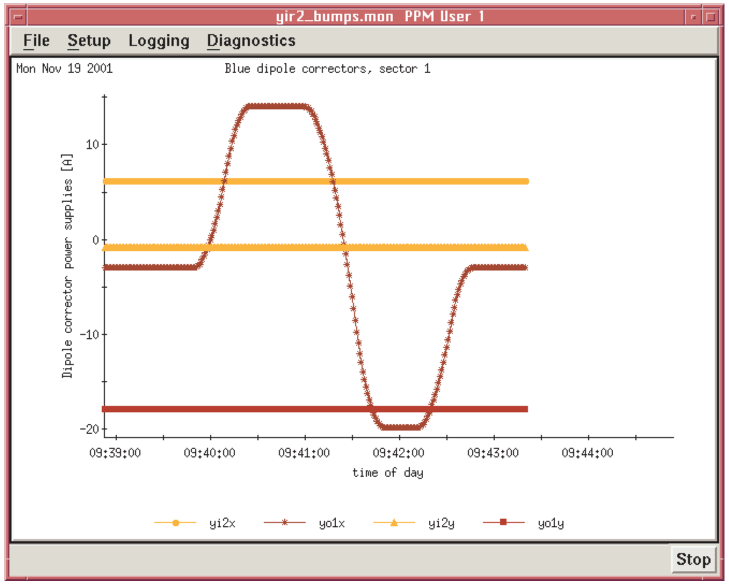
Conclusion:

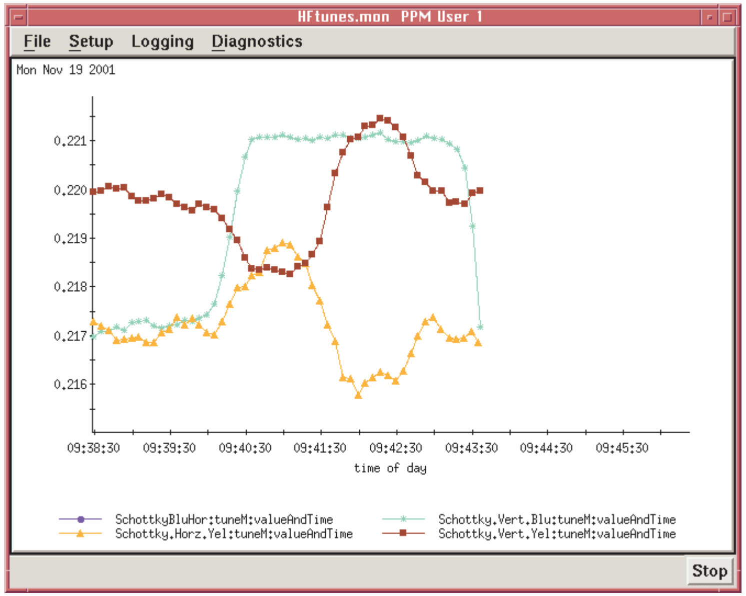
Local correction at IR8 is required inYellow ring

IR correction studies

- Betatron tuneshift versus orbit excursion in IR triplets (IR8,IR2)
- Nonlinear correctors settings for the next run

orbit bump in a triplet → betatron tune shift





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Nonlinear chromatism

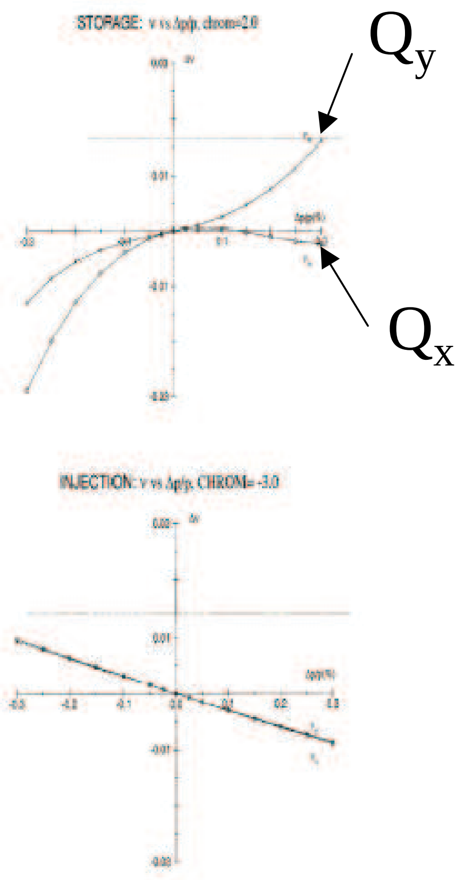


Fig. 11-12. Variation of betatron tunes with momentum at injection (6 × β*=10 m) and storage (2 × β*=1 m & 4 × β*=10 m). The chromaticity is corrected with 2 families of sextupoles.

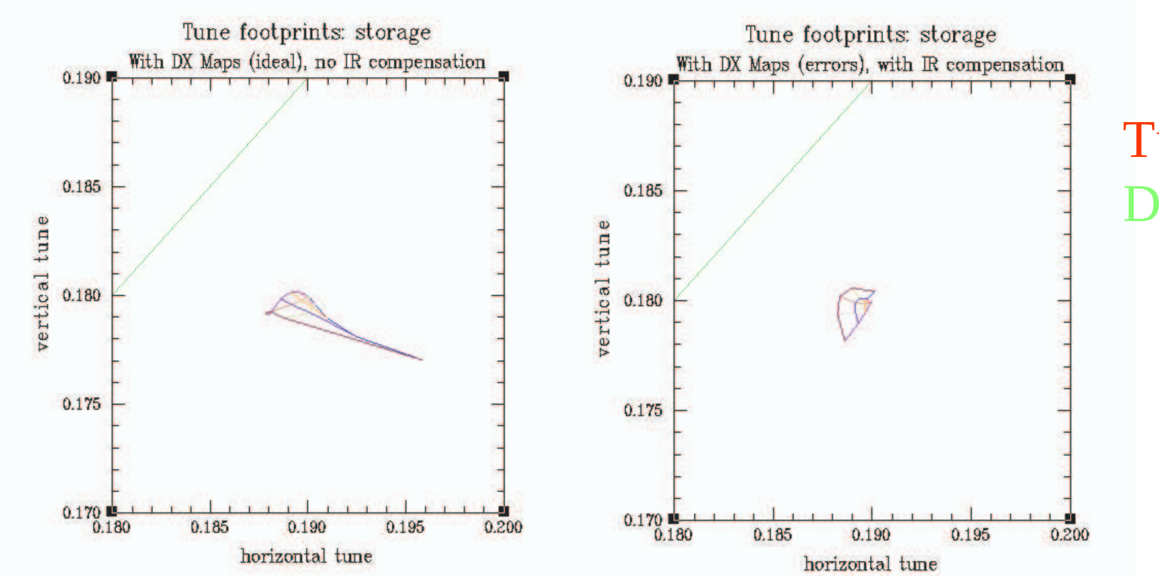
- Design Manual data shows considerable nonlinear chromaticity at the design collision lattice.
- It should be recalculated for current nominal lattice and compared with the beam measurements.
- Last run: some confusion with chromaticity correction at flattop at low beta* optics. Indications of considerable nonlinear chromaticity.
- Betatron tune scan versus RF frequency
- Chromatic effects on betatron functions

(After measurement technique using AC dipole has been developed)

Dynamic aperture

- The tracking studies for design RHIC lattice (4x10m+2x1m) indicated that DA is not large: 6-7 sigma for 20π mm*mrad (without beam-beam!)
- Mesurements should be done to determine the DA and compare with the predictions
- Technique:
  - Gradually increase the beam emittance with the small kicks
  - Observe the limiting emittance value
- Insrumentation required: tunemeter kickers, IPM
- Compare with and without beam-beam interactions

Nonlinear detuning/tune spread at flattop

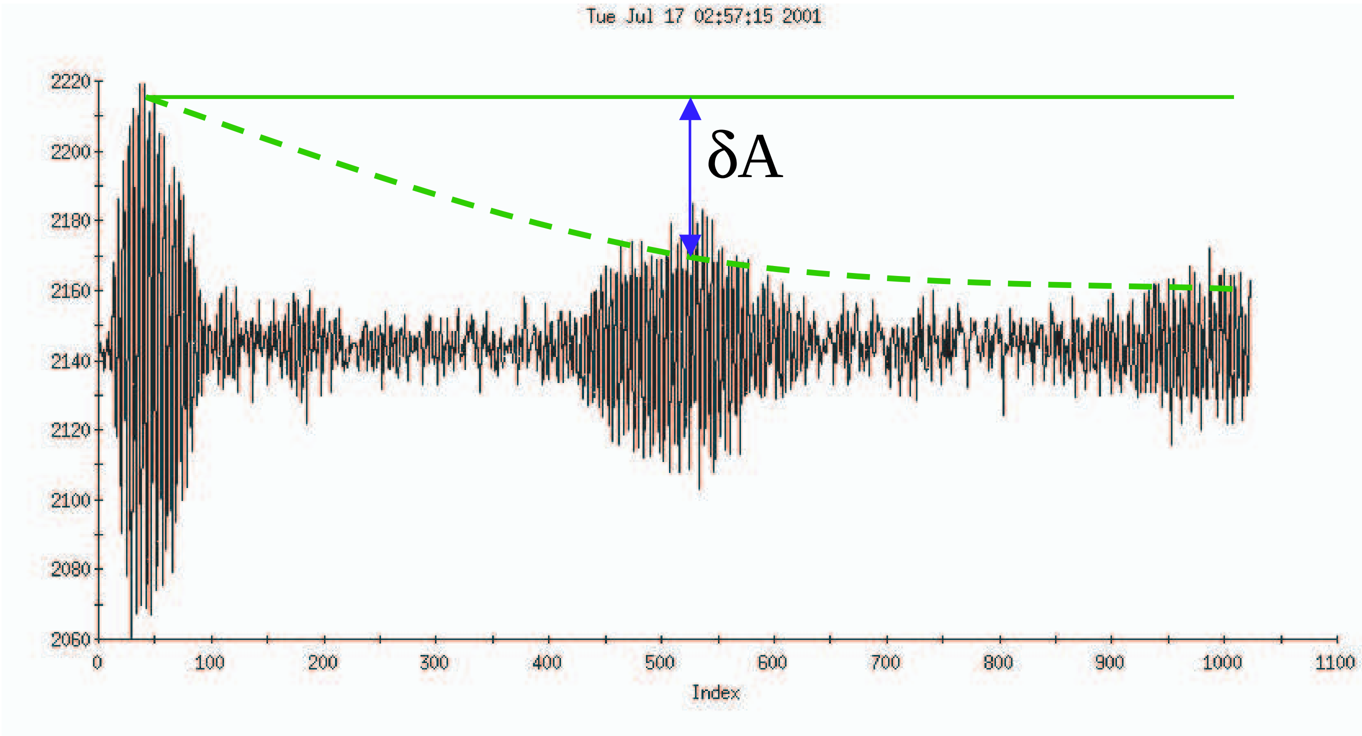


Tune footprints from tracking
Design lattice

- Studies should evaluate the possible techniques:
  - Schottky signal
  - Beam transfer function
  - AC dipole: oscillation amplitude versus dipole field curve
  - TBT signal information

Beam recoherence

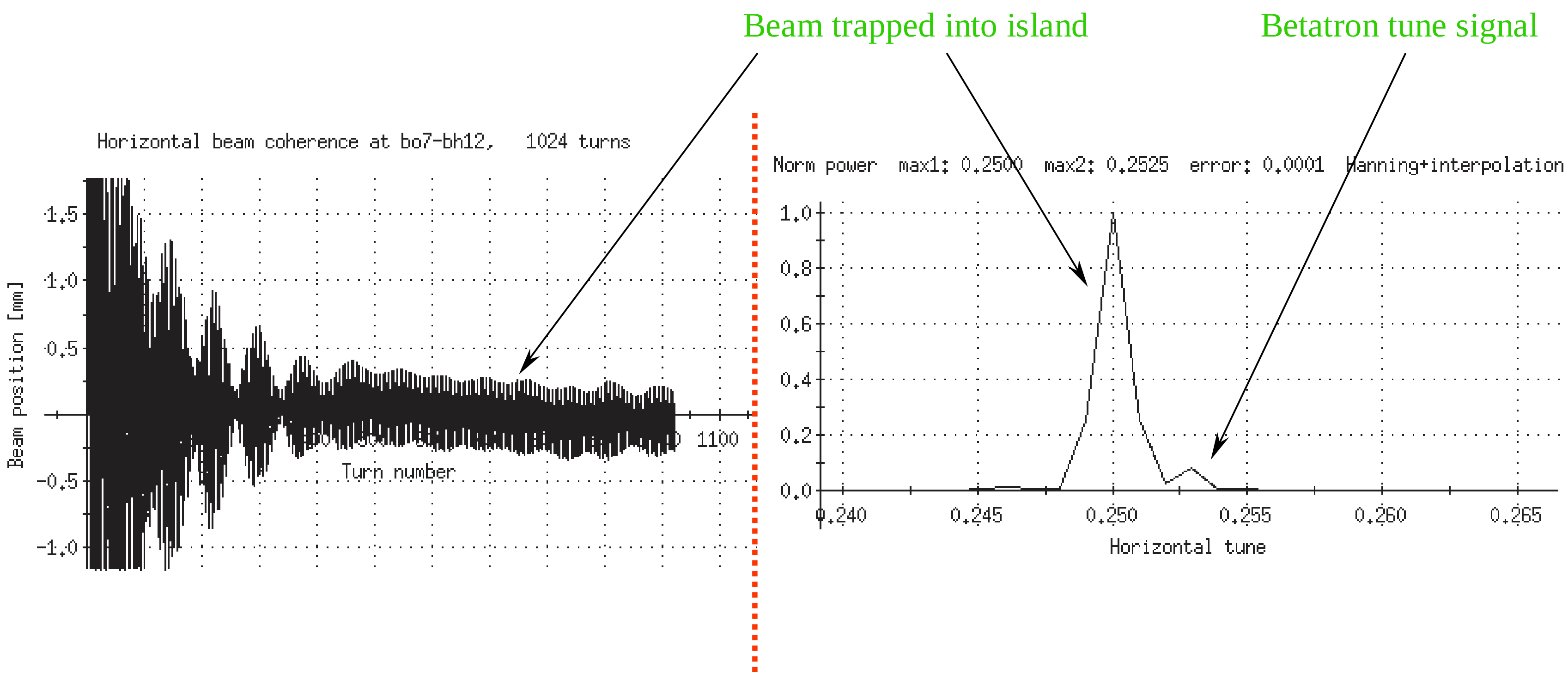
- Decrease in amplitude (δA) is due to combined nonlinear tune spreads in transverse and longitudinal planes
- Large chromaticity, good decoupling are required to observe the effect



$$y = A \cdot \cos(\nu_y \theta) = \exp\left[-\frac{\sigma_E^2 \zeta}{\nu_s^2} \cdot (1 - \cos(\nu_s \theta))\right] \cdot \cos(\nu_y \theta)$$

Resonance studies

- Beam trapped into resonance islands was observed during the operation
- 0.20, 0.25 resonance islands were observed and studied at injection
- Octupole or decapole corrections was used to eliminate resonance signal



Resonance measurements and correction

- The method used the last run can be applied only at injection (it is based on creating large injection error)
- The real points of interest for resonance correction are flattop and transition
- The resonance measurement methods should be evaluated:
  - Beam Transfer Function: beam response at various excitation frequencies (P.Cameron)
  - Measuring resonance driving terms from TBT data (SUSSIX method, F.Schmidt)
- IR octupole and decapole correctors can be used for 0.25 and 0.2 resonance corrections

Other studies

– Action-angle jump technique (J.Cardona) ;

Fast diagnostic of IR nonlinearities (possibly sextupole and octupole)

– Tune dependence on closed orbit;

Two corrector scan, tune shifts versus amplitude and phase of the orbit. (top, injection)

– AC dipole experiments:

- driving resonance terms; SUSSIX (M.Bai, F.Schmidt)
- smear measurements (T.Satogata)

– Tune scans, working point studies;

Lifetime versus working point.

Tracking studies

- Theoretical/tracking studies were done for a lattice with β^* configuration: 4x10m + 2x1m
- Lack of detailed studies for the present lattice (5x2m+1x1m) and for the lattice: 4x2m + 2x1m
- The tracking studies must be done as soon as possible.

Conclusion. List of possible studies.

- Tracking studies
- Nonlinear chromatism
- Dynamic aperture measurement
- Resonance measurements and correction
- Nonlinear tune spread/detuning measurement
- Tune scans, working point studies
- Action-angle jump technique
- Tune dependence on closed orbit
- AC dipole experiments