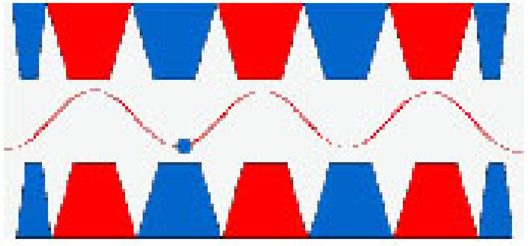
Wiggle 2005

Mini-Workshop on Wiggler Optimization for Emittance Control
INFN-LNF, Frascati 21-22 February 2005

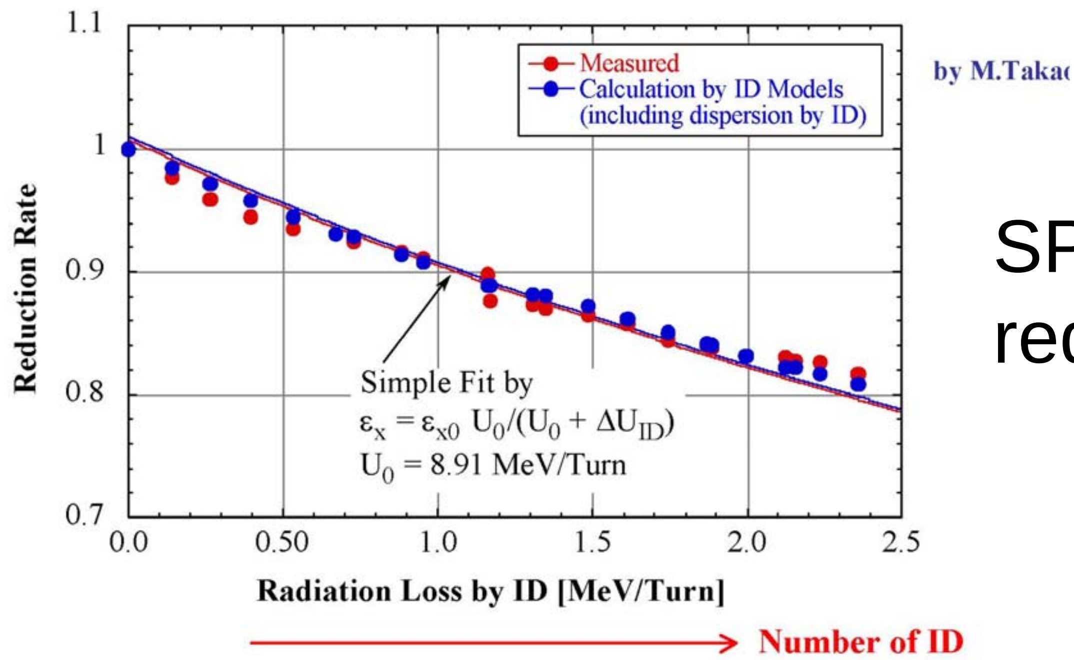


operational experience
& beam observation:
CESR, ATF, DAFNE, SPring-8, BESSY, BINP,…

Spring-8

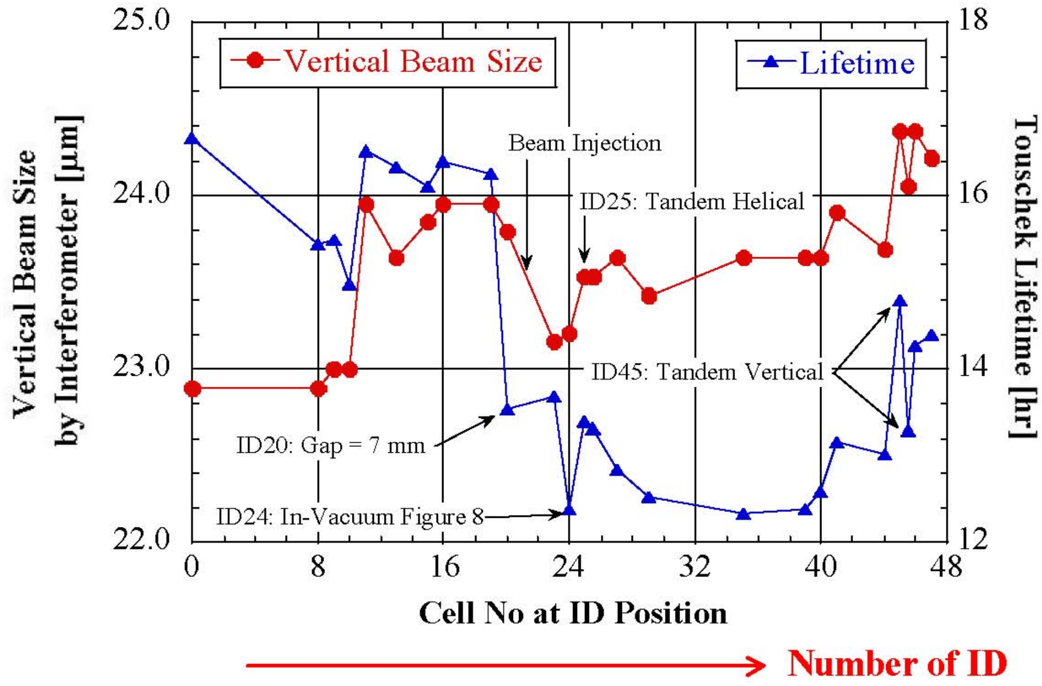
- 26 insertion devices: 20 in-, 6 out-vacuum;
  typically 3.2 cm period, K_{max}=2.5 (0.84 T); 25-m long planar, figure-8, ellipt., revolver, perm.–el.magnet–Fe combined, helical, tandem,10-T wiggler …
- minimum vertical full gaps: 7 mm – 15 mm
- several optics (achromat, non-achromat)
- emittance measurements: 2D visible-light interferometer, X-ray monitors (zone plate & int. interfer.), D_y, Touschek lifetime, pulsed bump & scraper
- **wigglers reduce ε_x by 20%, little effect on ε_y**
- wigglers **cause tune shift of ~0.02 (impedance)**
- **bunch lengthening** smaller than expected
- lifetime factor 2 smaller; injection efficiency 85->65%
- damping beam has tail distribution $\sim y^{-2}$
- combined wiggler & 10-T wiggler more difficult

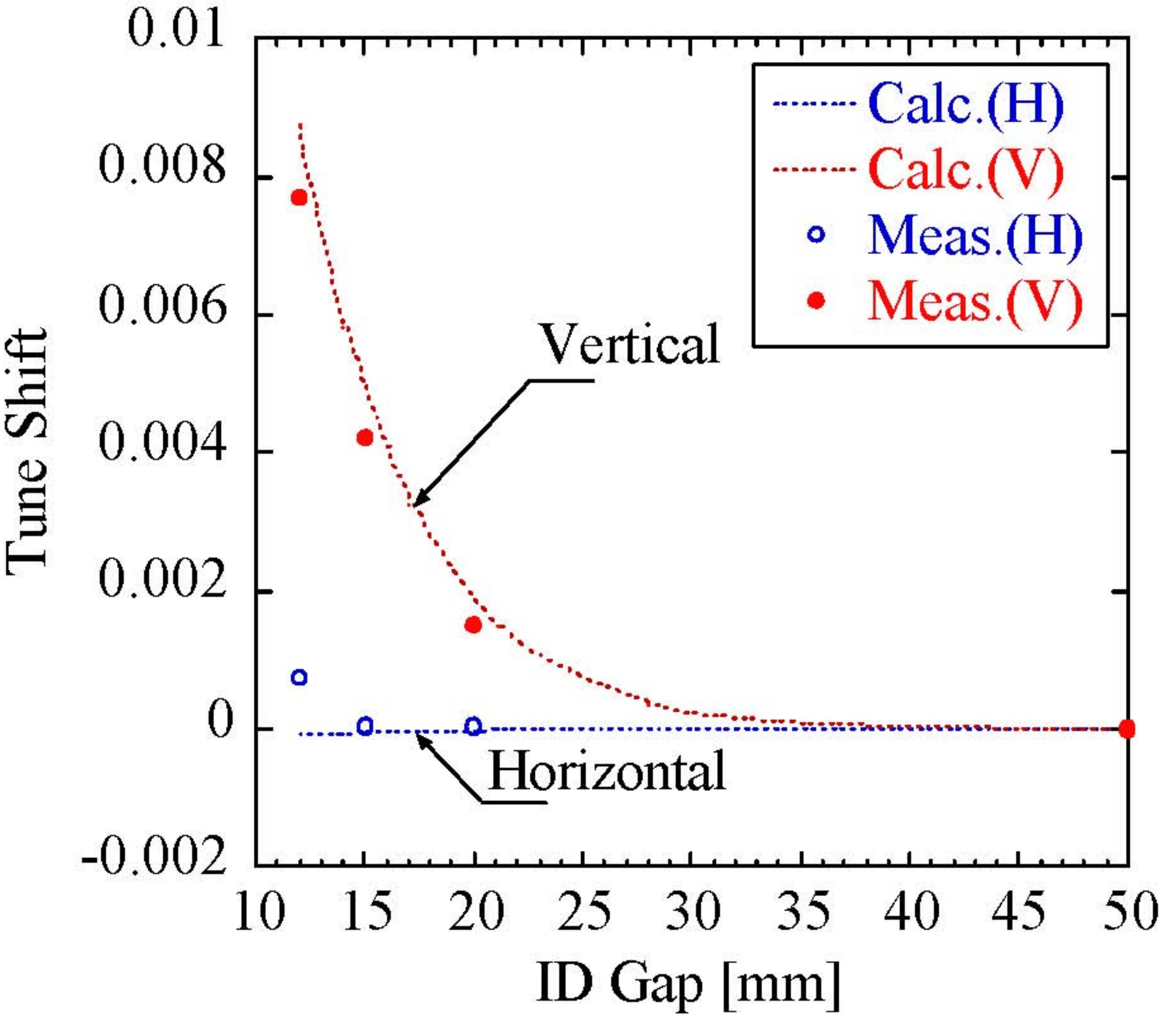
K. Soutome



SPring-8 wigglers reduce ε_x by 20%...

... and have little effect on ε_y





β tune shift when closing Spring-8 25-m long planar undulator;

total tune shift from all insertions is about 0.02

BESSY-II

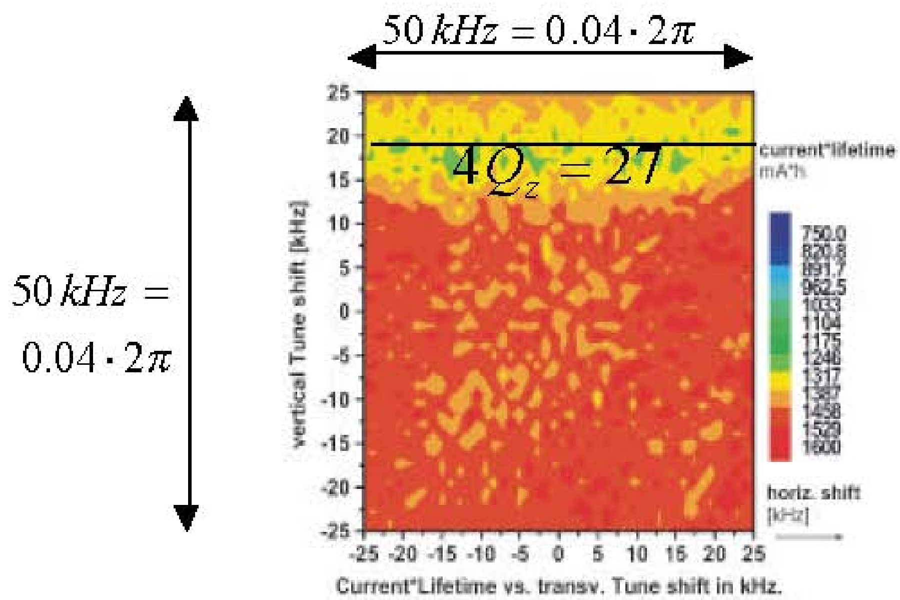
- 15 insertion devices
- wiggler effects:
  - **skew 8-pole resonance,**
  - **beta and phase beating,**
  - **factor 2 lifetime reduction**
- strong linear distortions detune nonlinear ring optics
- beta and phase-beat correction required

G. Wuestefeld

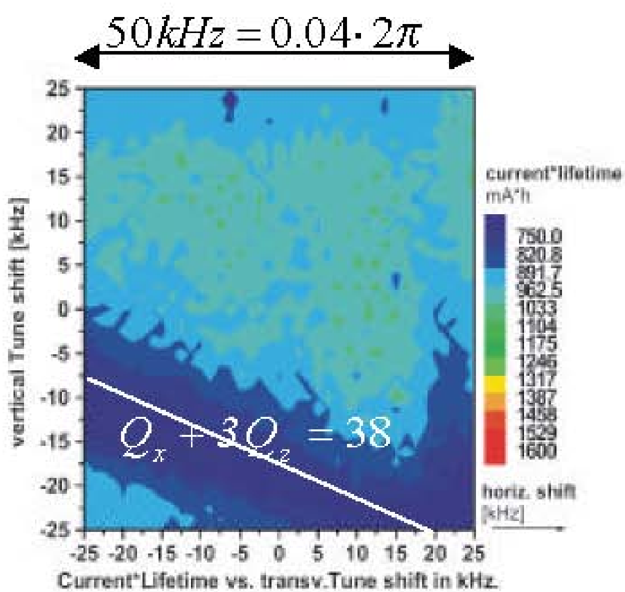
wiggler effect on the beam at BESSY-II

excitation of skew octupole resonance by UE56

vertical tune scan



gap open



gap closed

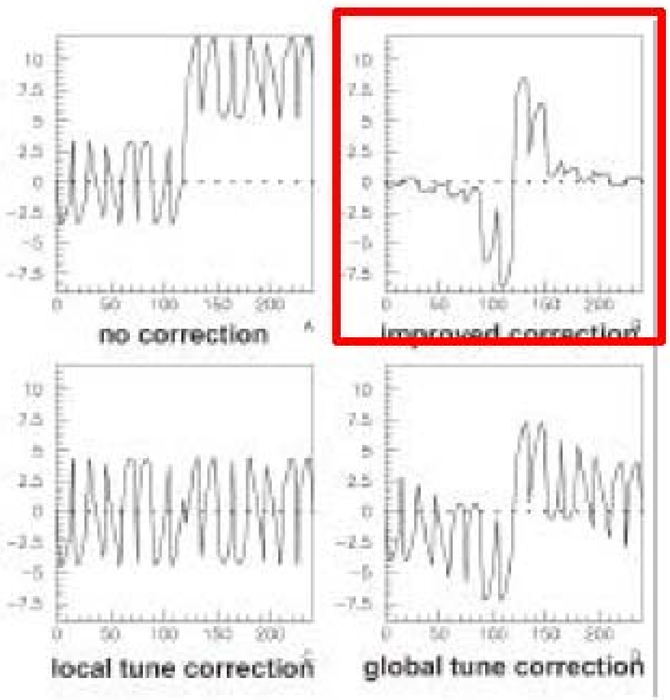
scan of lifetime in the tune diagram

G. Wuestefeld

wiggler distorts linear optics, requiring correction

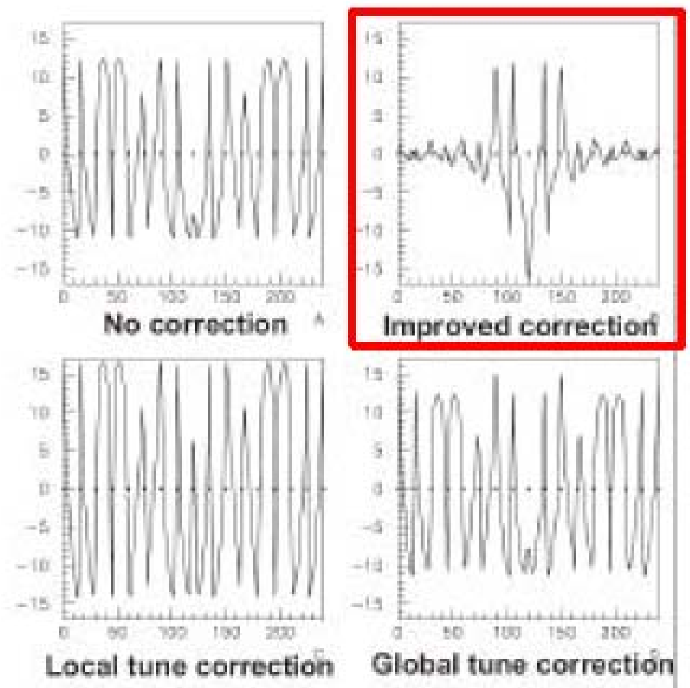
optics correction of U-125, tune shift 0.02

phase beat correction



vertical phase beat in degrees

beta beat correction

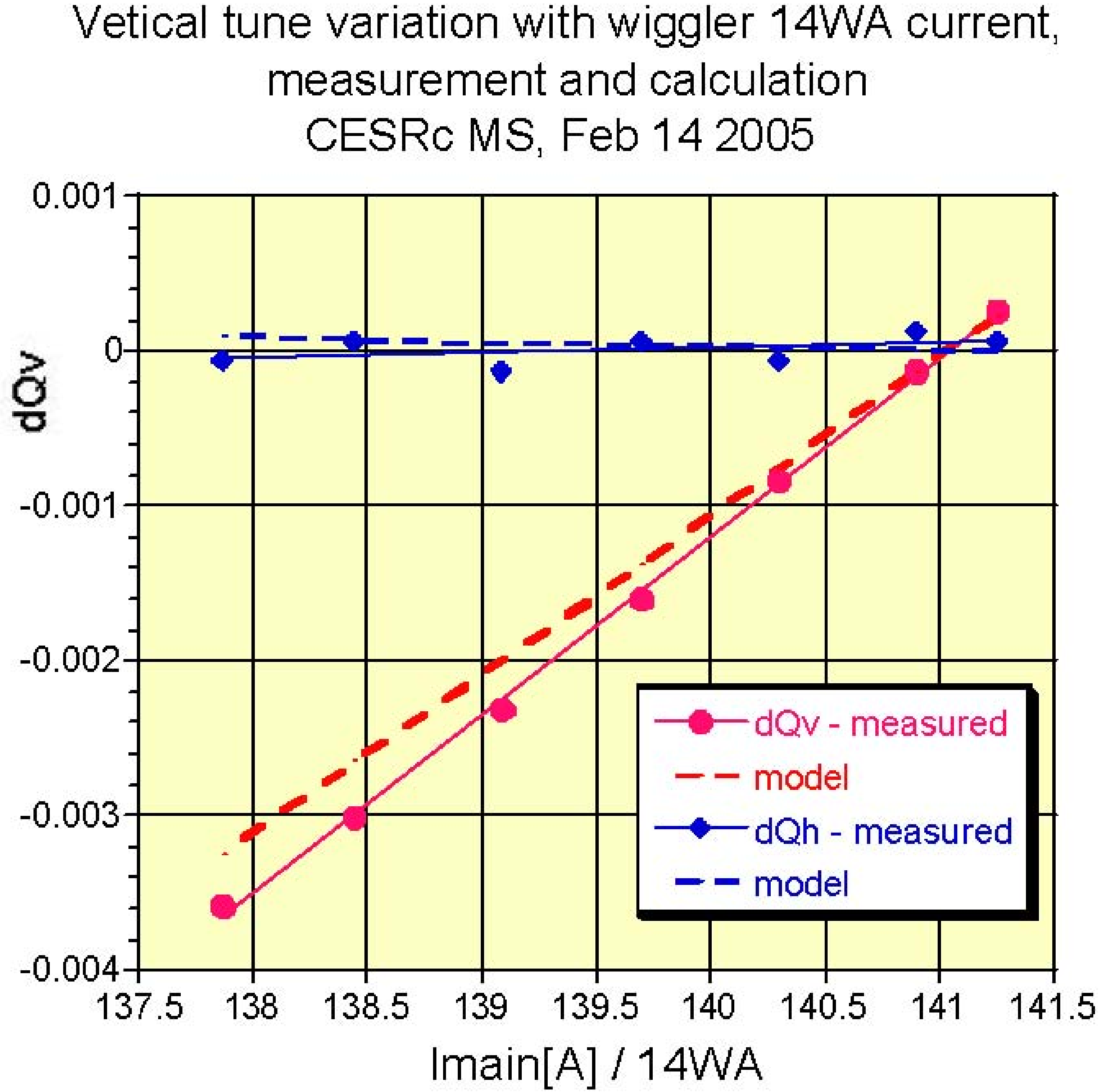


vertical beta beat in %

CESR-c

- 12 superferric wigglers installed, 2.1 T, 40 cm, 1.5 m
- needed to recover luminosity at lower energy; enhance damping, control emittance
- symmetric & asymmetric designs
- beam-based characterization agrees with model (based on BMAD subroutine):
  - coupling (no source, from wave analysis)
  - energy spread inferred from bunch length within 2% from model (72% due to wigglers)
  - **tune vs. wiggler field**
  - **tune vs. horizontal & vertical orbit in wiggler**
  - **tune vs. oscillation amplitude**
- did not observe any performance degradation

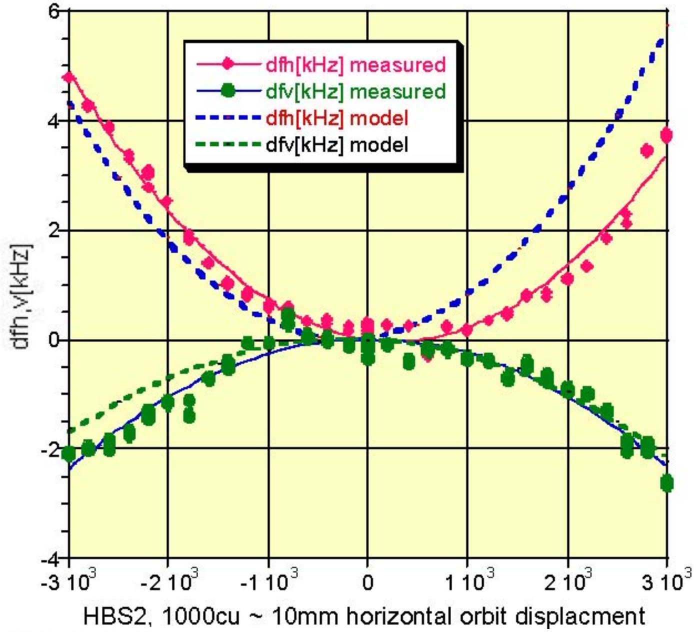
A. Temnykh



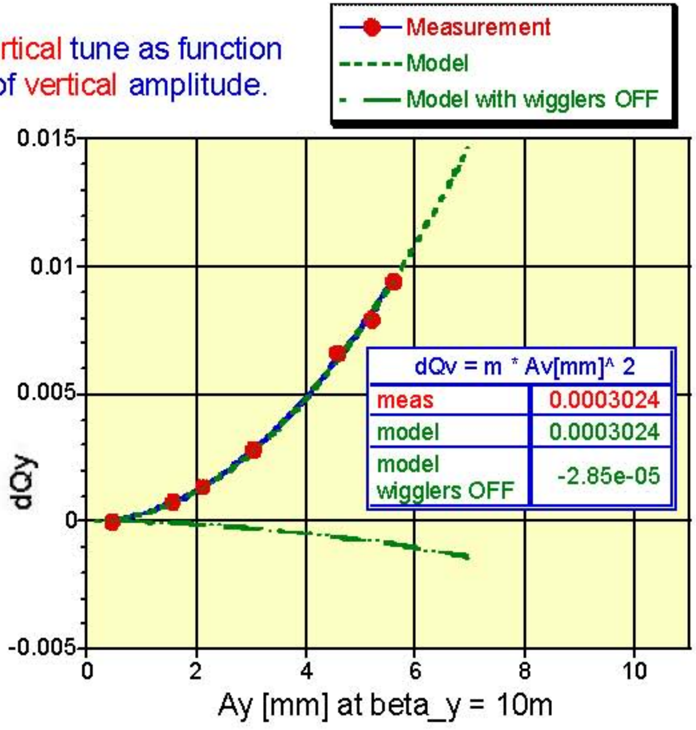
tunes vs. wiggler excitation

A. Temnykh

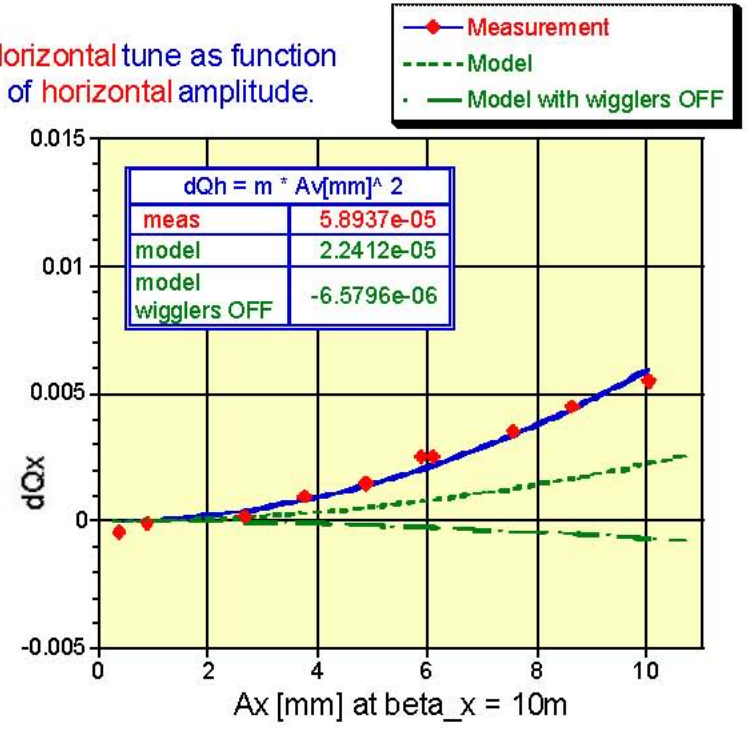
tune vs. vertical orbit in wiggler



Vertical tune as function of vertical amplitude.



Horizontal tune as function of horizontal amplitude.

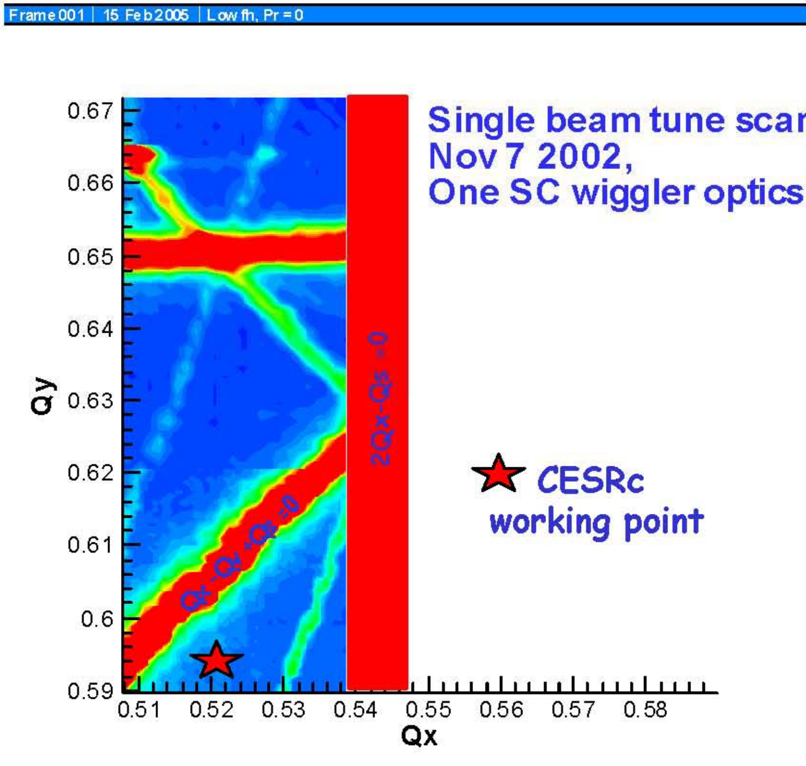


tunes vs. oscilla-tion ampli-tude

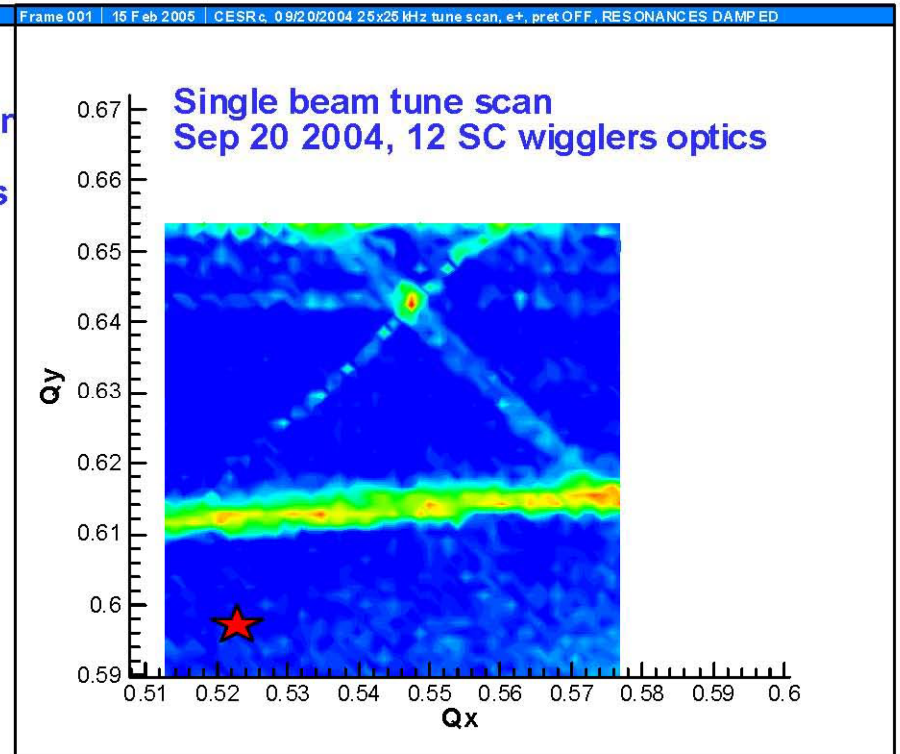
A. Temnykh

ring characterization with beam: tune plane mapping

Vertical beam size (vertical beam emittance) versus tune



Nov 2002, One wiggler optics



Sept 2004, 12 wigglers optics with better tuned nonlinearities (Sextupoles and skew sextupoles)

ATF

- in summer '04 DC loads were connected to control end-pole fields; wiggler operation could resume
- damping times, final emittances, and energy spread measured with wigglers on & off in all 3 planes
- agreement of measurement with calculation comparable to agreement between 2 calculations
- IBS effect is visible in horizontal and longitudinal plane
- **wigglers reduce ε_x by 20%, little effect on ε_y**
- beam lifetime and its tune dependence similar to case without wiggler
- extensive beam tuning:

  (1) correction of orbit, D_y, coupling, and iteration

  (2) ORM measurement & correction

  both schemes achieved ε_y=4 pm (how to go to 2 pm?)

J. Urakawa

measured and calculated damping times at ATF

wiggler OFF wiggler ON wiggler OFF wiggler ON

Damping Time	Cal.,wiggler off	Cal.,wiggler on	Meas.wiggler off	Meas.wiggler on
Horizontal damping time τ_x	17.5 ms (17.0 ms)	15.0 ms (13.8 ms)	19.3+/-0.63 ms	15.7+/-0.38 ms
Vertical damping time τ_y	28.5 ms (28.5 ms)	23.0 ms (20.5 ms)	28.8+/-1.5 ms	25.4+/-0.67 ms
Longitudinal damping time τ_z	20.5 ms (21.5 ms)	15.5 ms (13.6 ms)	21.4+/-3.9 ms	14.2+/-2.4 ms

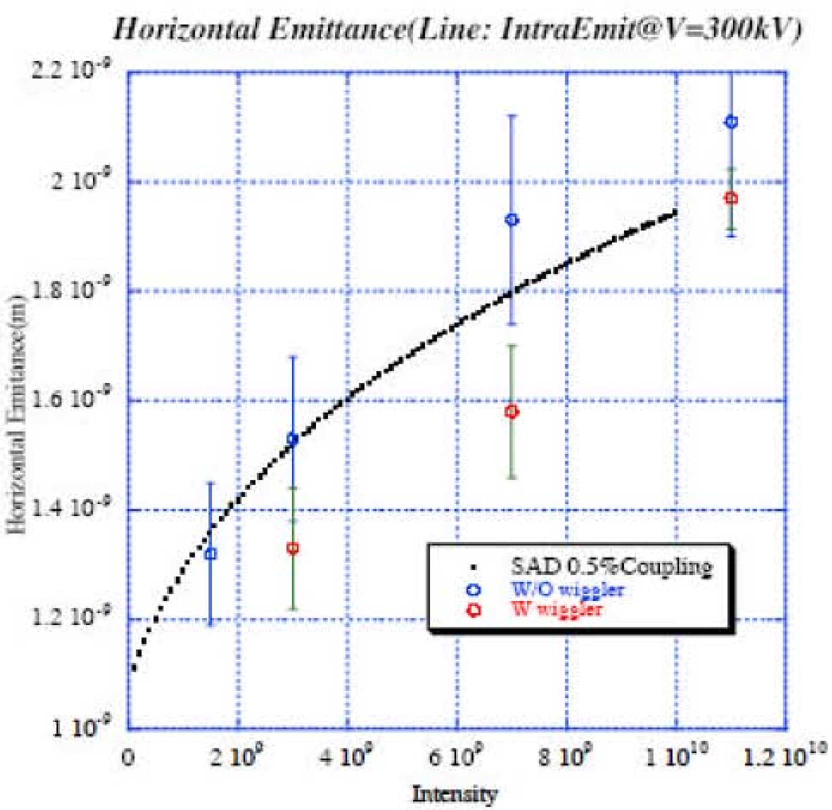
calculated measured

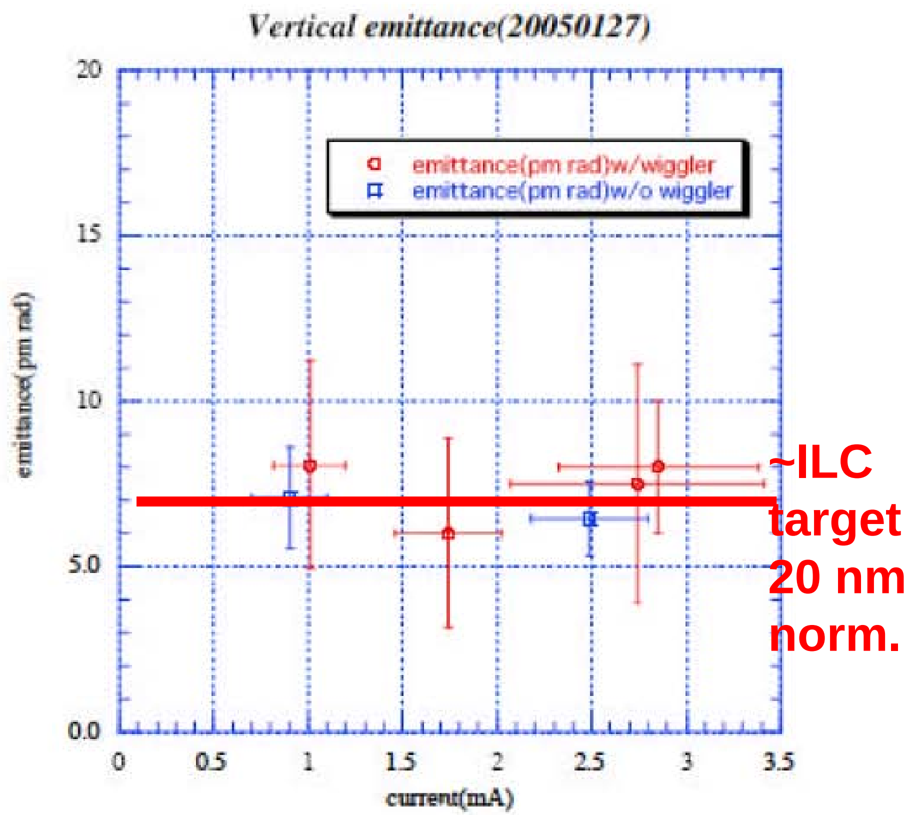
two calculations were performed by S. Kuroda (SAD) and A. Wolski (MAD); second set is shown in parentheses

equilibrium emittances at ATF

J. Urakawa

Emittance measurements

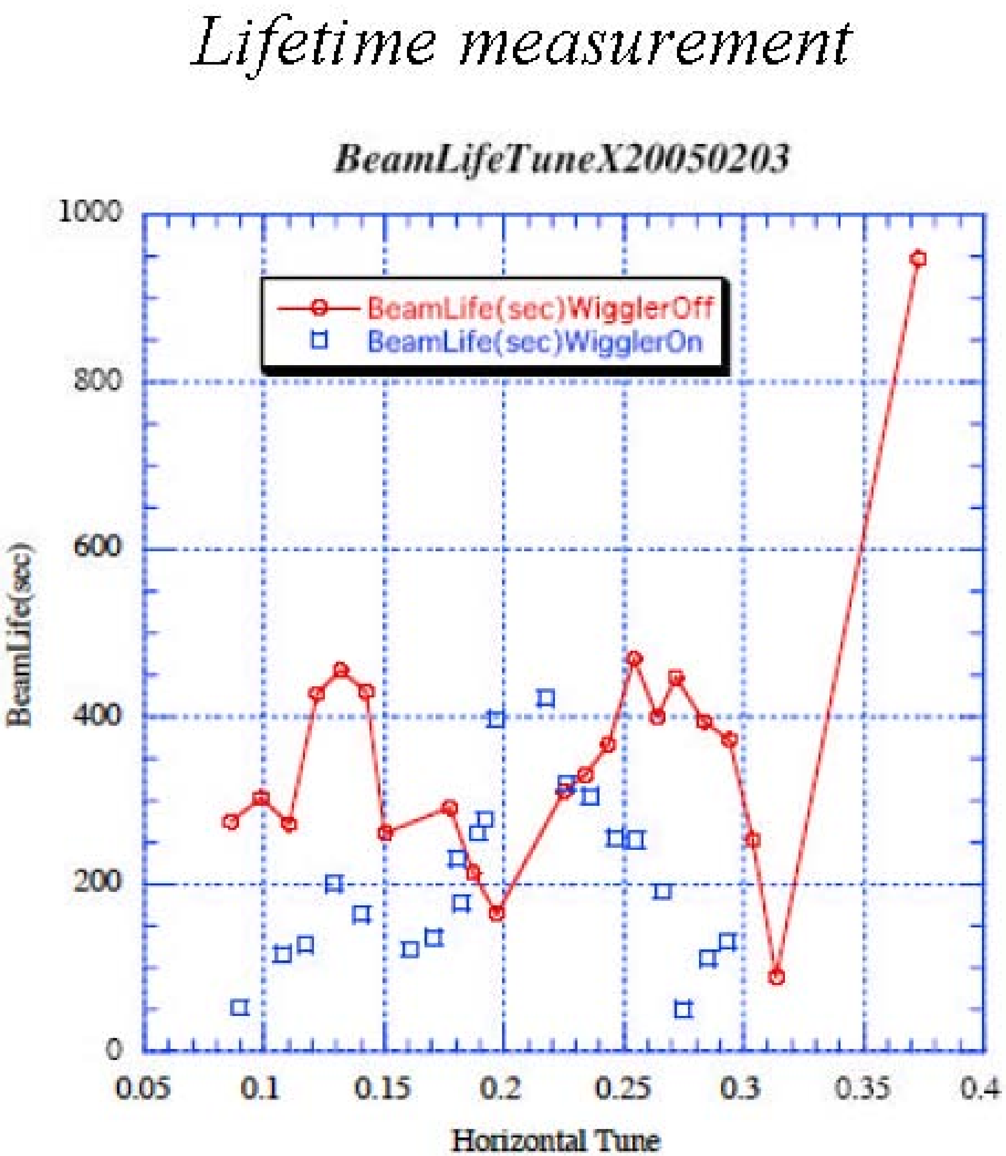




Natural emitt.	Cal.wiggler off	Cal.wiggler on	Meas.wiggler off	Meas.wiggler on
ε_0	1.03×10^{-9} m (1.1 nm)	0.87×10^{-9} m (1.0 nm)	$(1.1+/-0.2)\times10^{-9}$ m	$(0.9+/-0.2)\times10^{-9}$ m 17

ATF beam lifetime and tune dependence

J. Urakawa



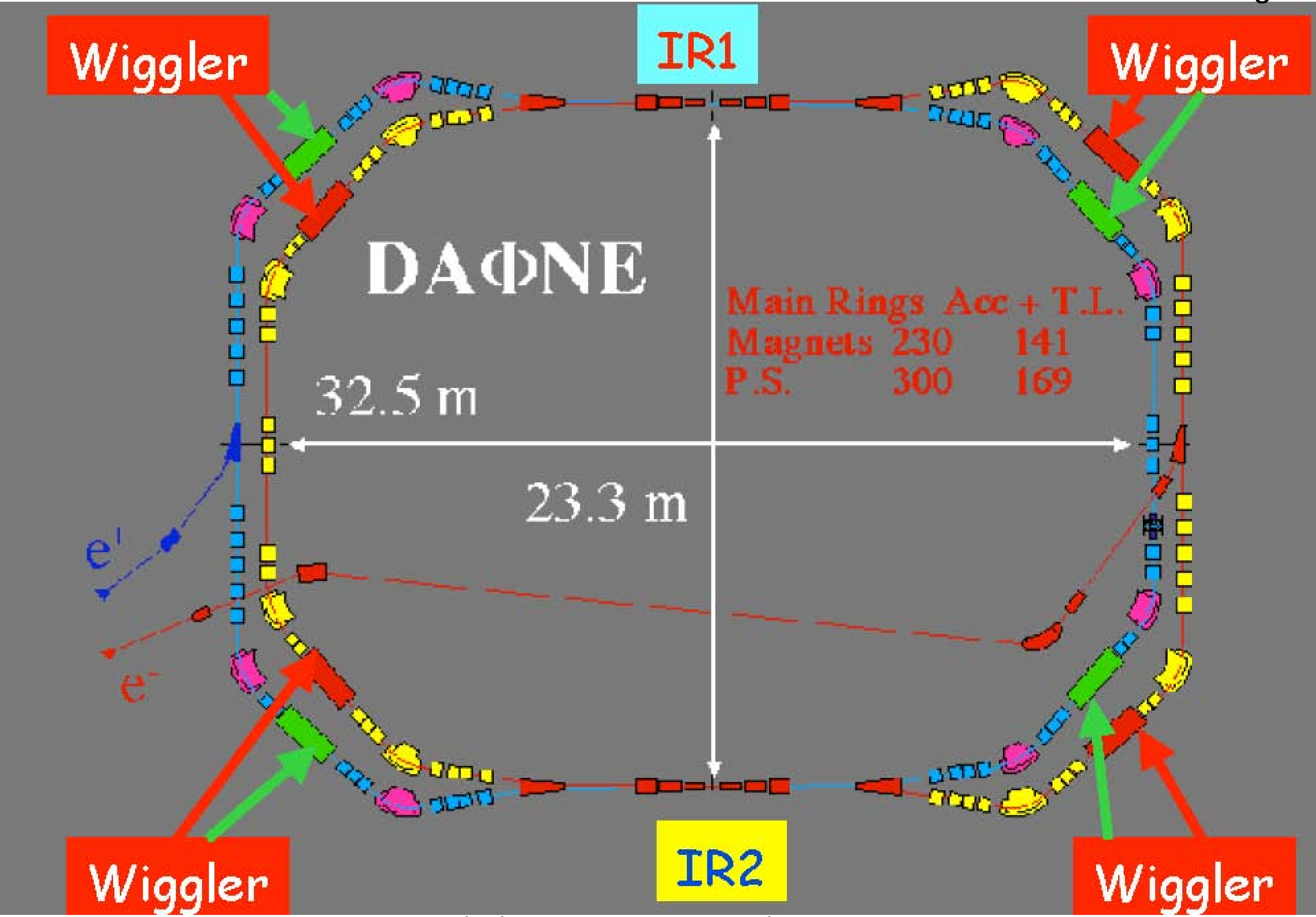
wiggler ON

wiggler OFF

DAFNE

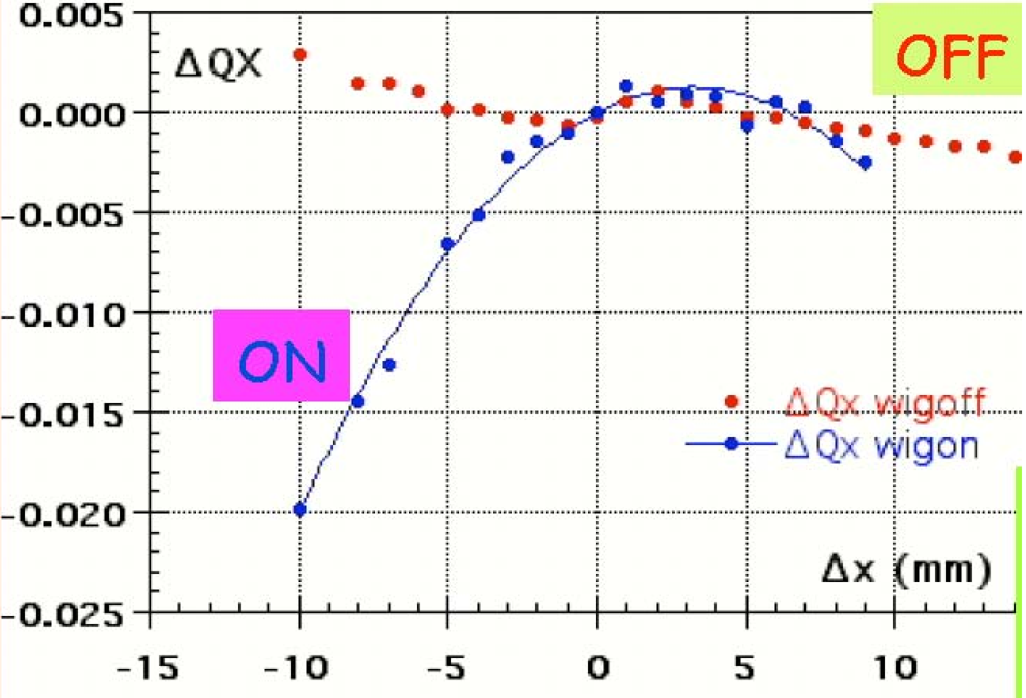
- 4 wigglers / ring, B=1.85 T, L_w=2 m,
  trajectory in wiggler 2.5-cm peak-to-peak,
  wiggler displaced from machine axis
- wigglers **main source of nonlinearity**
- responsible for **dynamic aperture limit**
- also affected beam-beam performance
- measured: *- nonlinear tune shift with energy,*
  - tune shift vs. orbit in wiggler,
  - beam decoherence
- fitted octupolar component k_3=-1000 m^{-3} (β_x=3 m)
  for each wiggler
- cures: lowered β_x in wiggler, installed 3 octupoles
  per ring, optimized sextupoles, modified w. poles
- afterwards **"e-cloud instability"** appeared in e+ ring

M. Biagini



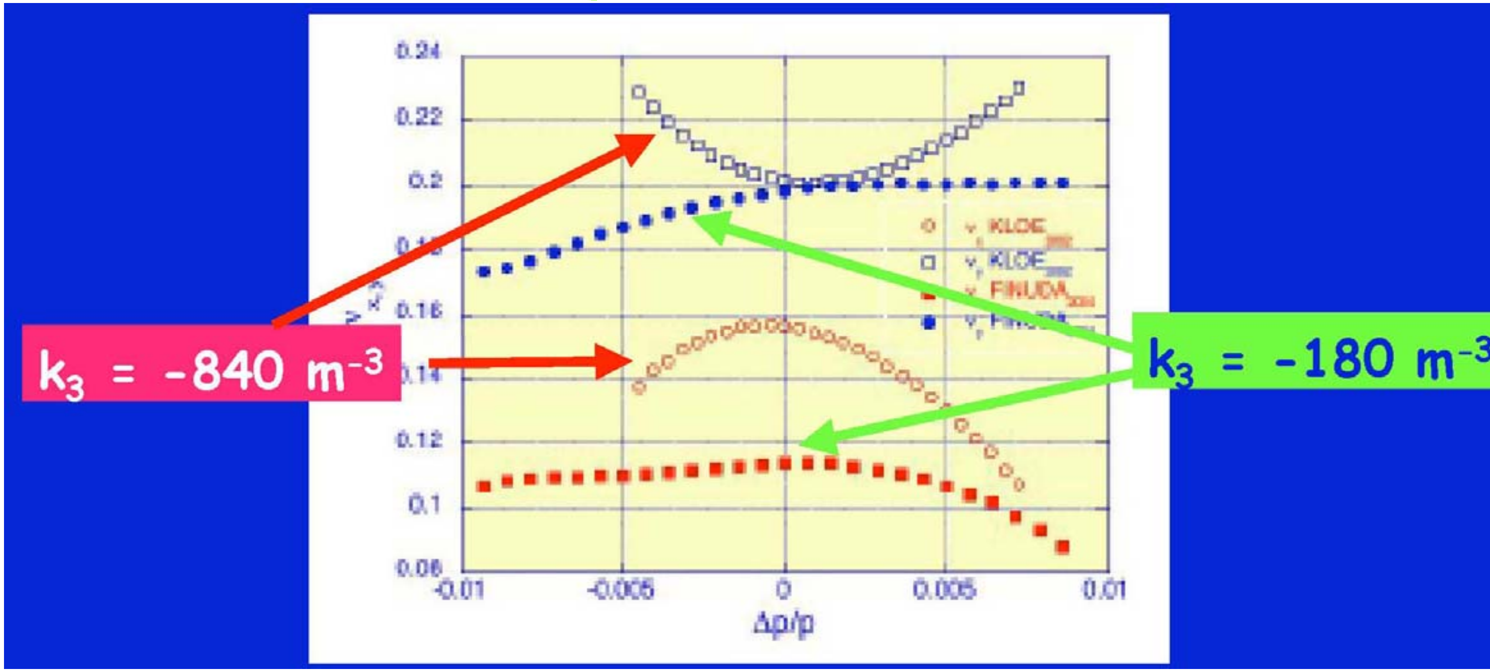
Wiggler
IR1
Wiggler
DAΦNE
Main Rings Acc + T.L.
Magnets 230 141
P.S. 300 169
32.5 m
23.3 m
e+
e-
Wiggler
IR2
Wiggler

M. Biagini

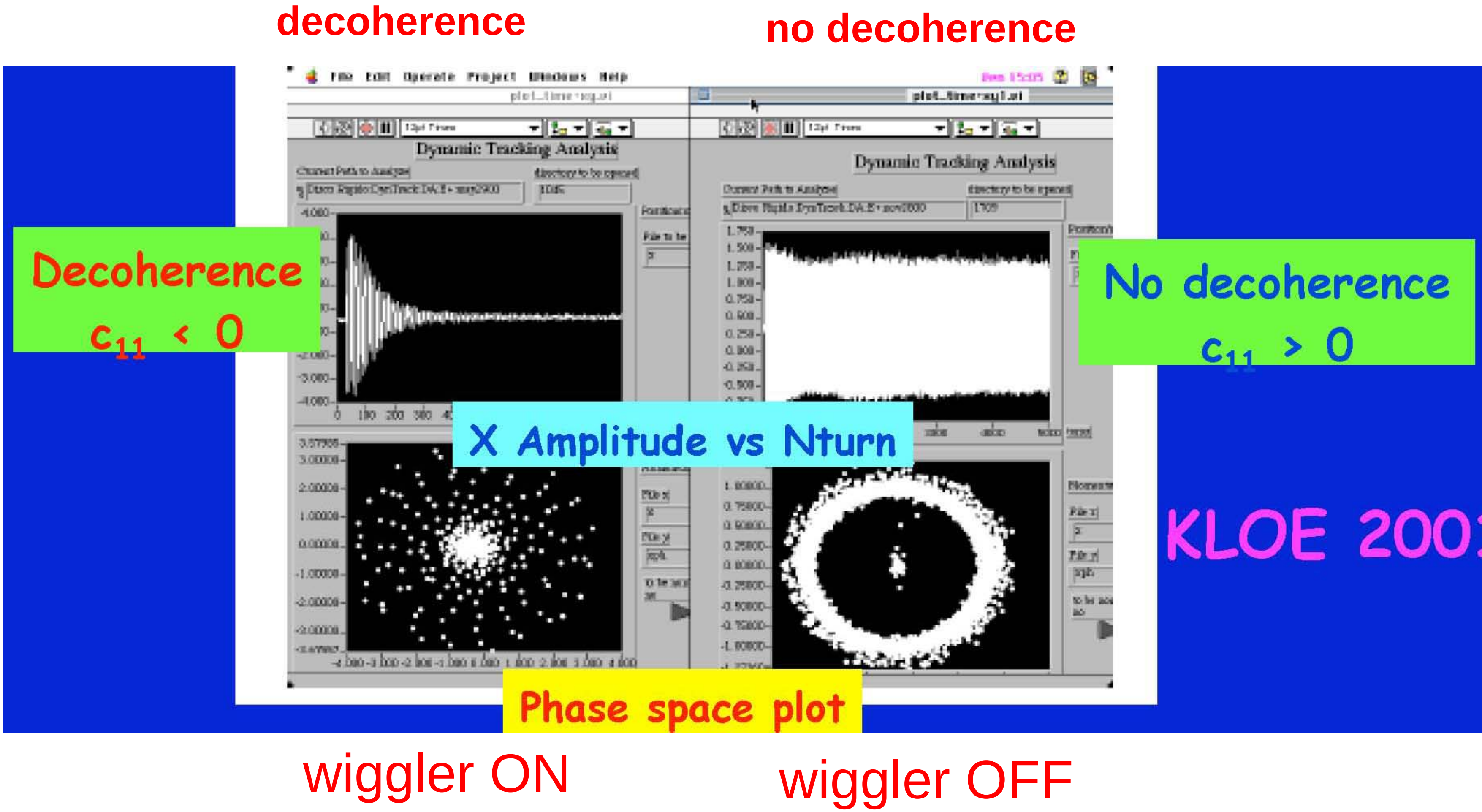


DAFNE horizontal tune vs. horizontal orbit offset with wiggler ON & OFF: *tune change 0.02 for orbit shift of 1 cm*

tune shift vs. energy before and after wiggler upgrade



effect of (original) wiggler on beam decoherence



small negative c_{11} is optimum for dynamic aperture & beam-beam

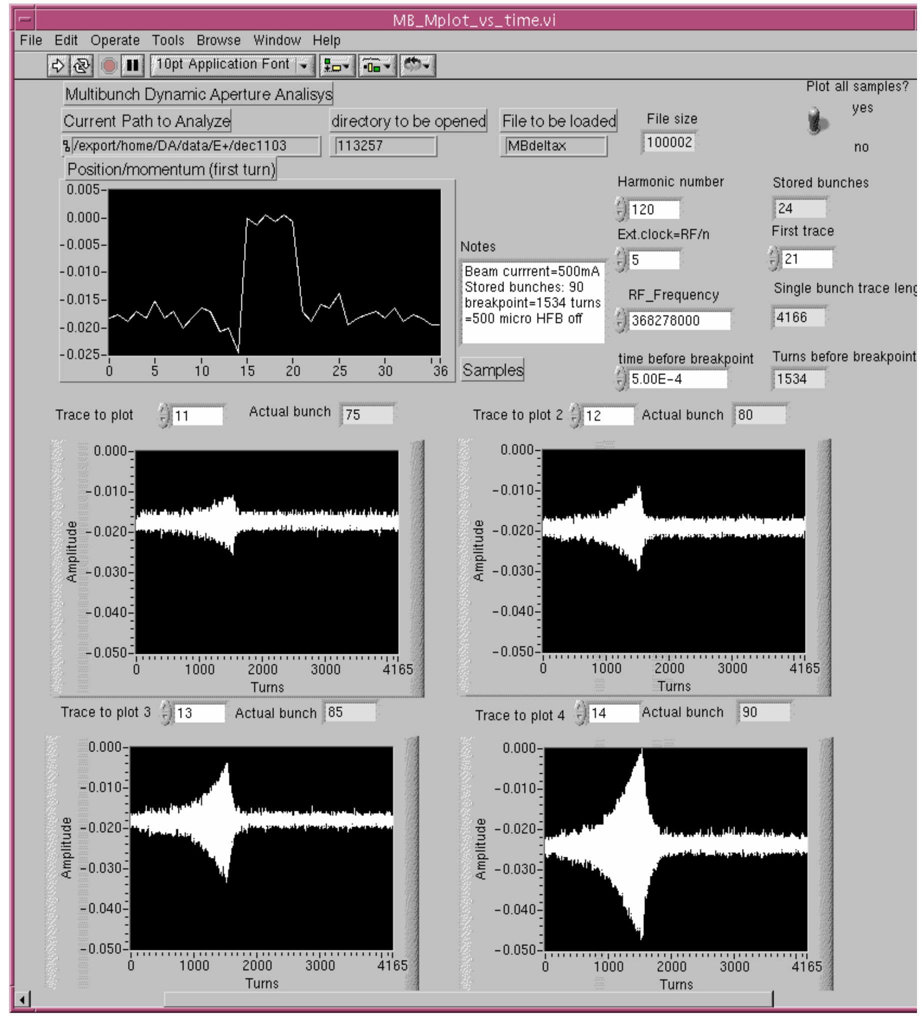
F. Z.

transverse e+ “e-cloud” instability in DAFNE

- o **I_e+ limited to 1.2 A** in collision by strong instability (τ~10 ms rise); in previous years reached 2.5 A
- o large **positive tune shift with current in e+** ring, not seen in e- ring
- o wound solenoids in field-free sections w/o any effect
- o main change for 2004 was wiggler field modification; suspicion that e- are created & trapped by wiggler field
- o instability **sensitive to orbit in wiggler** (few mm)
- o instability depends on bunch current (not total current)
- o instability strongly increases along the train
- o rise time is faster than the synchrotron period
- o sensitive to injection conditions
- o threshold scales w. transverse emittance

grow-damp measurement (A. Drago)

bunches at the train end: 75, 80, 85,90



conclusions

- dominant wiggler effects are different for different storage rings
- issues are linear optics, nonlinearities, physical aperture limitation, impedance, injection efficiency, lifetime, instabilities
- cures were developed for many of these