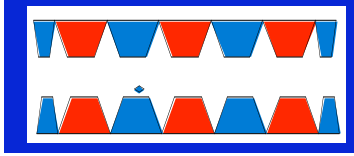
Beam measurements with wigglers at DA□NE

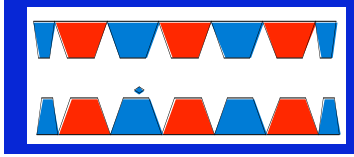
M.E. Biagini, INFN-LNF



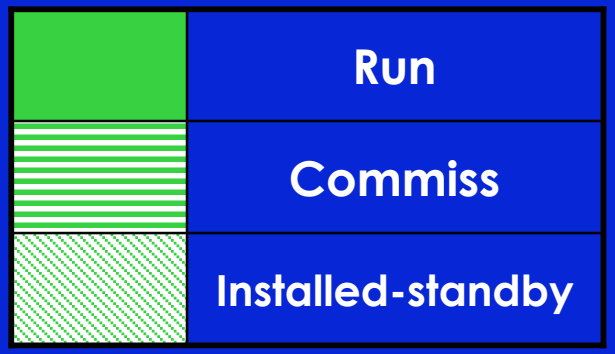
WIGGLE 2005, 21-22 Feb. 2005

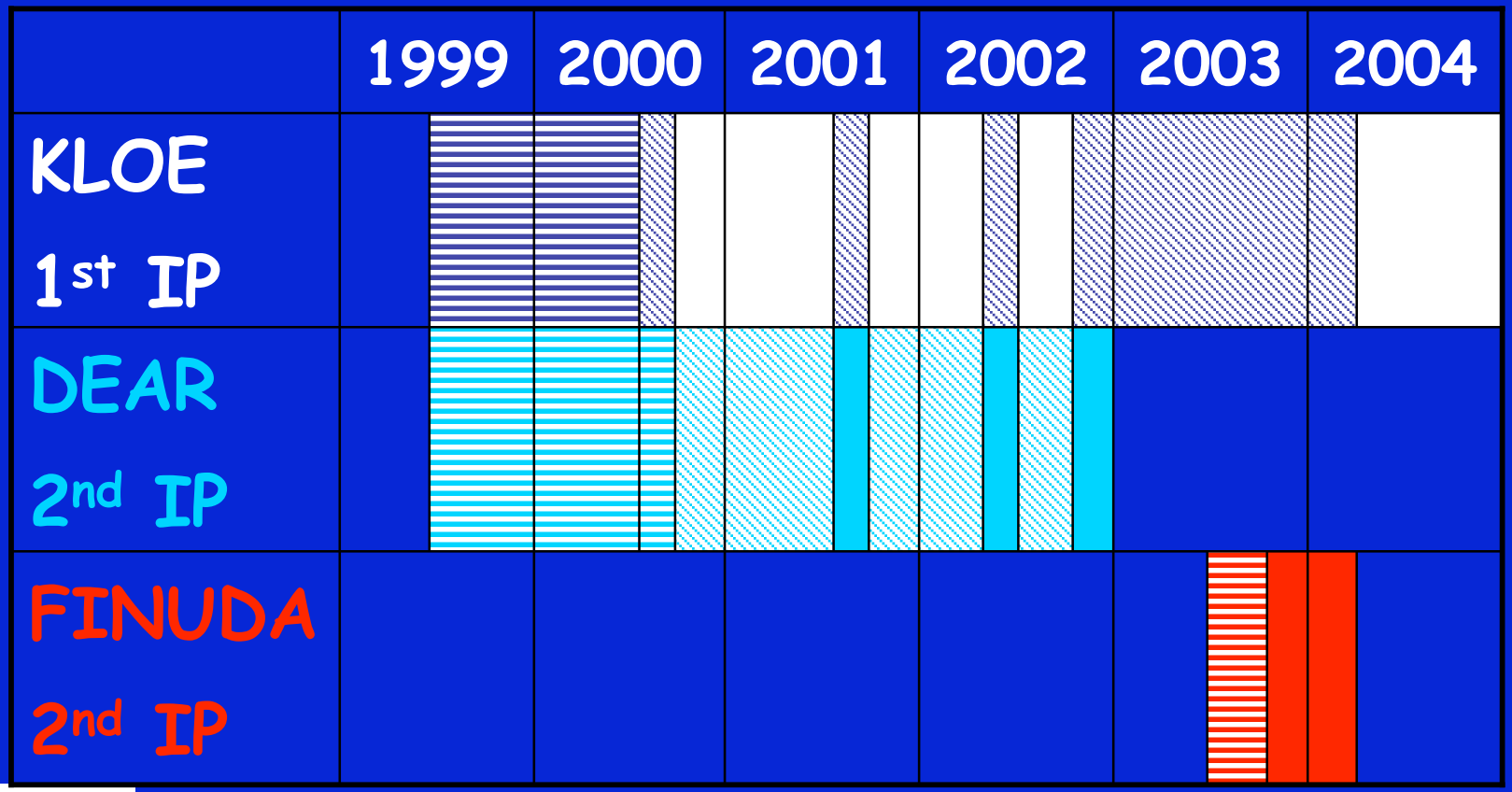
DA□NE

- DA□NE has 2 Interaction Regions hosting 3 detectors:
  - KLOE in IR1
  - DEAR and FINUDA sharing IR2
- 3 different lattice configurations
- Non linearities were first detected during KLOE operation
- First n.l. measurements in Dec. 2000

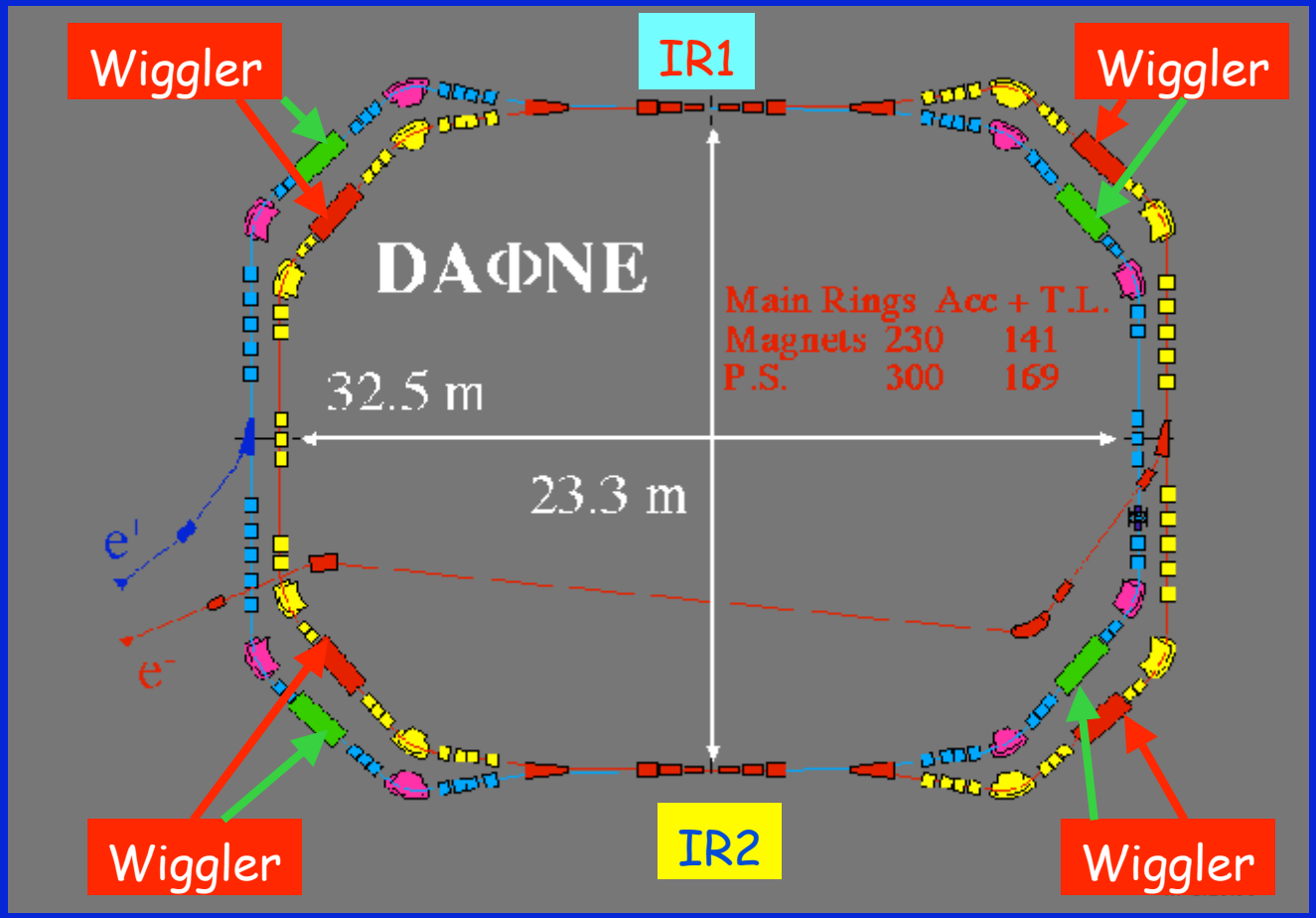


DA□NE experiments



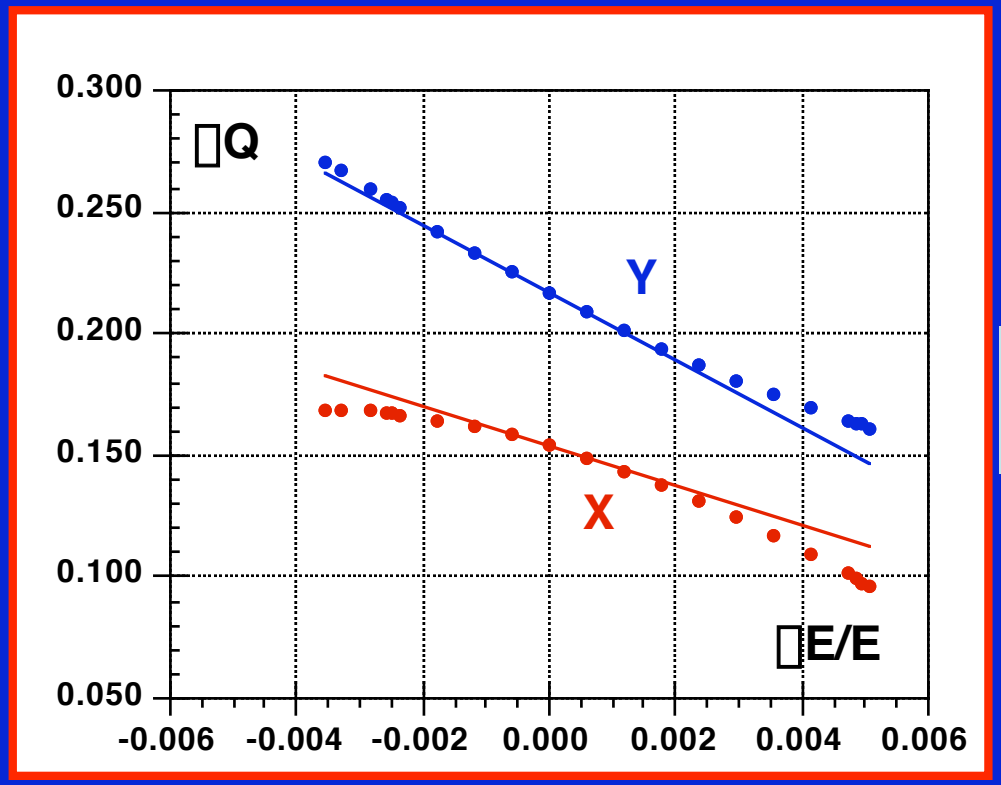


DA□NE


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

DA□NE non linearities

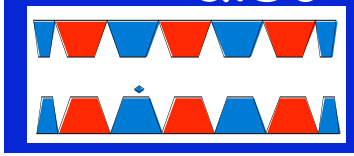
- Detected by measuring a non linear tune shift with energy without sextupoles
- Responsible for dynamic aperture reduction, also affecting beam-beam performances



Tune shift vs energy
Sextupoles OFF

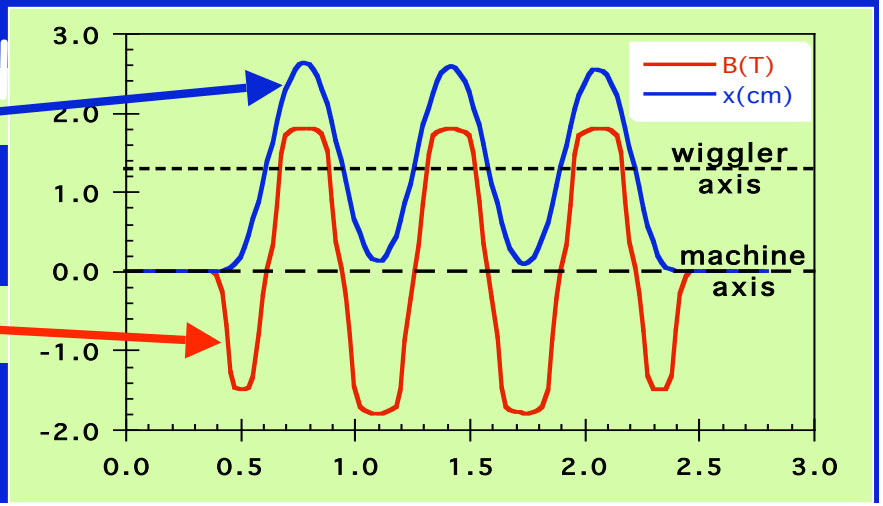
Investigations

- Known sources of non linearities: sextupoles, "C" correctors
- Wigglers, due to their limited pole width, can be also source of non linearity
- Checked wiggler effect by measuring tune shift vs beam position, with x-orbit bumps at the wiggler location (y aperture not sufficient)
- Beam decoherence and tune shift with energy also measured

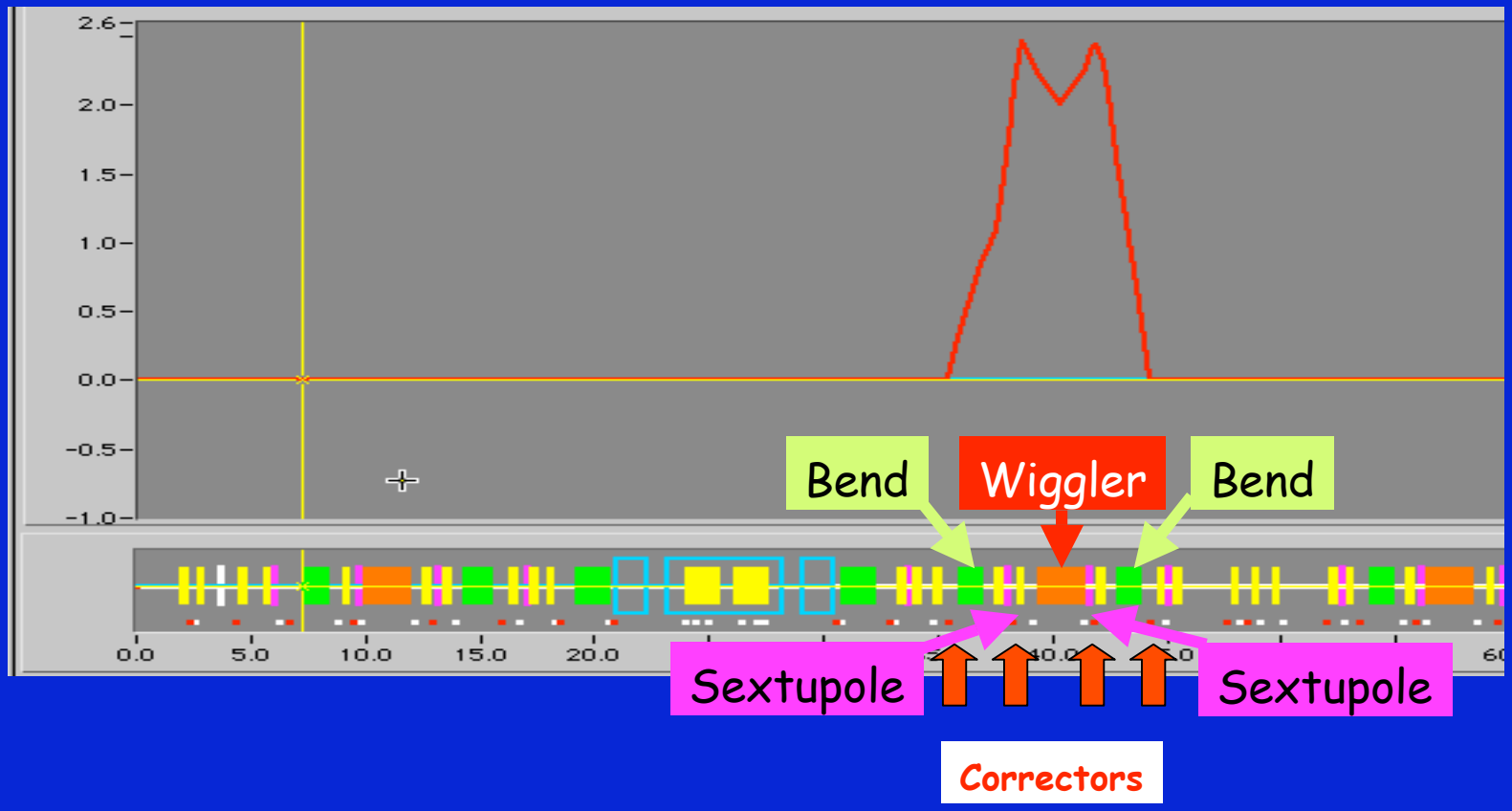


DA□NE Wigglers

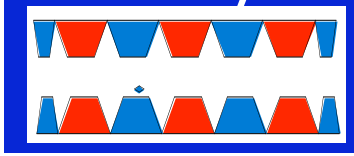
- 4 wigglers for each ring
- Used to increase radiation damping and quantum fluctuations
- B_{max} = 1.85 T, L_w = 2 m
- Beam trajectory: x = 2.5 cm peak-to-peak
- Wiggler axis displaced w.r.t. machine axis
- Optics designed with wiggl



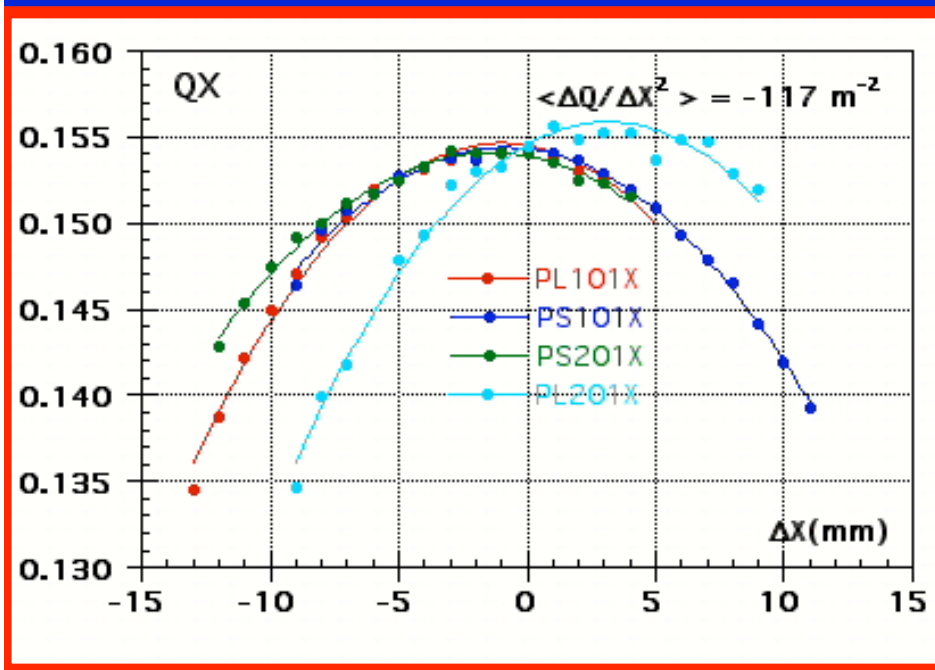
"Theoretical" closed orbit bump in wiggler with 4 horizontal correctors



The energy change induced by the correctors was corrected by changing the RF frequency. Sextupoles were OFF



Horizontal tune vs X amplitude

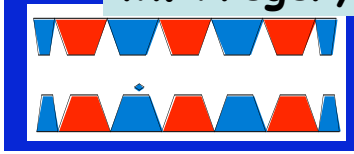


Horizontal tune fits well with a quadratic behaviour, typical of an "octupole-like" term. Slight displacement at x=0 due to residual orbit displacement at wigglers

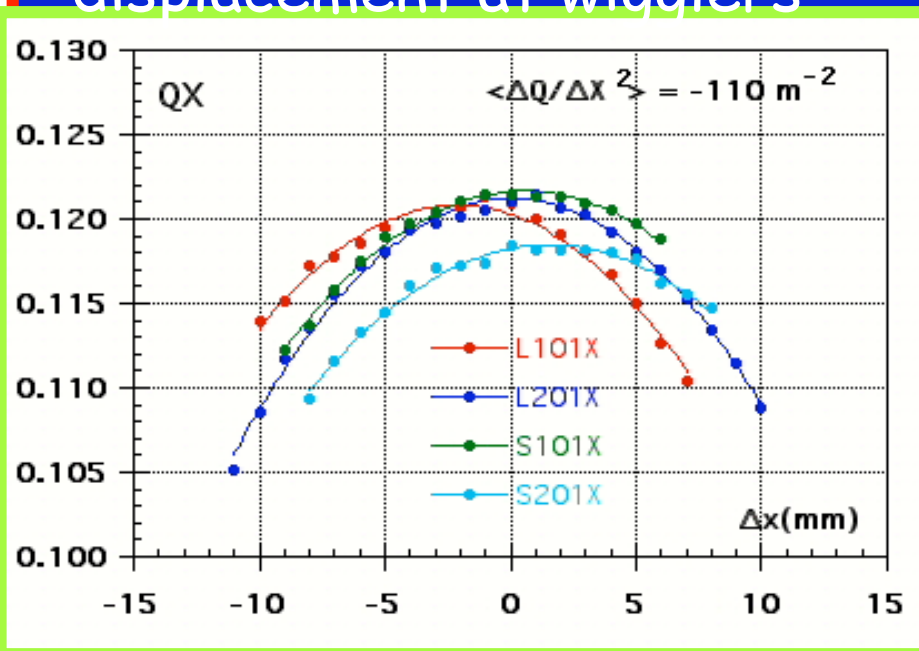
e^+ ring

Average □Q value is comparable in the 2 rings

M. Preger, DA□NE M.A.P., Jan. 2001

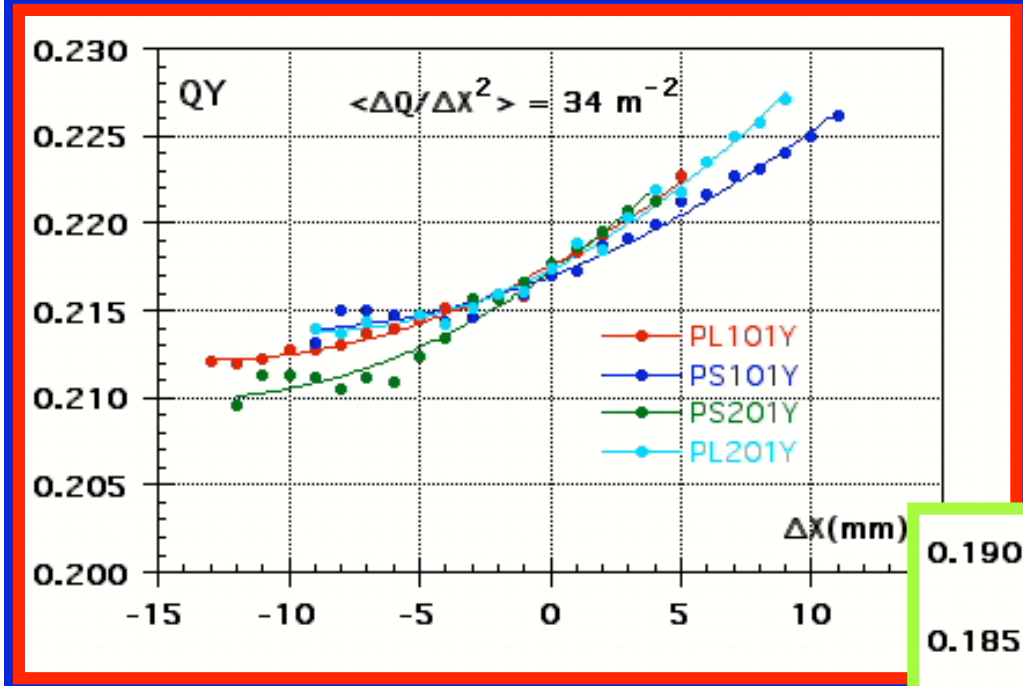


WIGGLE 2005, 21-22 Feb. 2005



e^- ring

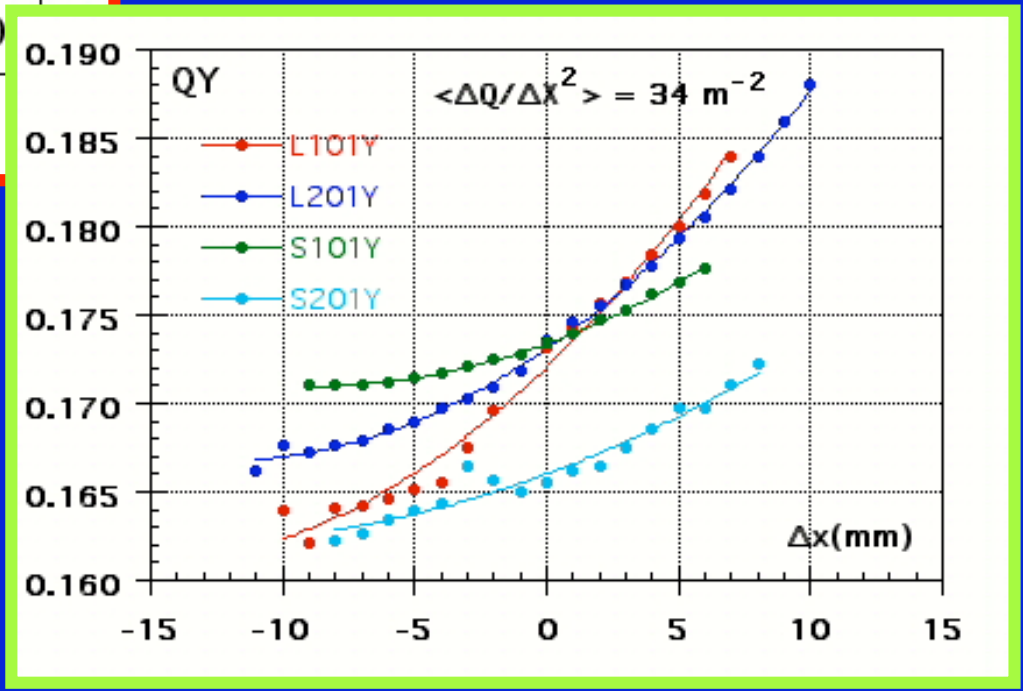
Vertical tune vs X amplitude



Vertical tune behaviour shows a small quadratic term + large linear term, due to c. orbit displacement in dipoles inside the bump

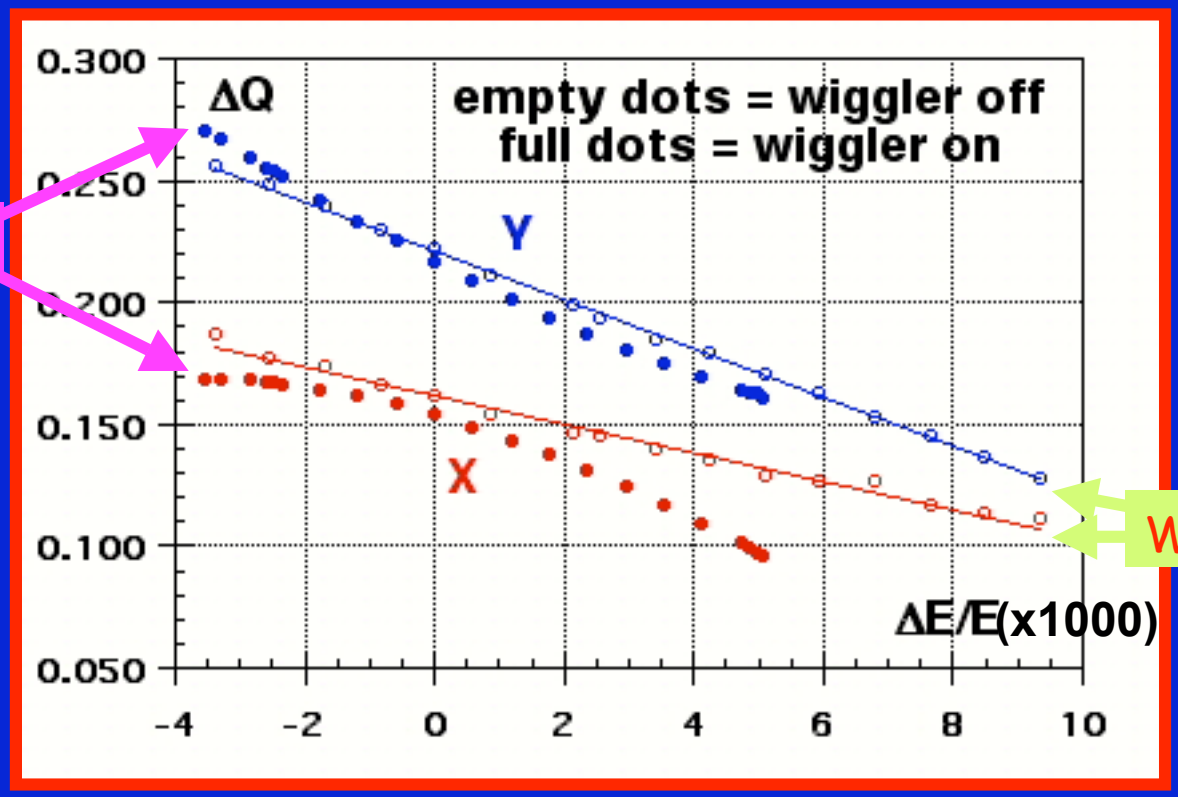
e^+ ring

e^- ring



- Strong octupole-like term measured in wigglers, coming from decapole term in wiggler field combined with oscillating trajectory
- Vertical tune showed a sextupole term. This may be explained by contributions from nearby bending magnets
- Designed lattice with wigglers OFF and similar optical functions in the arc to quantify wigglers contribution
- Wiggler OFF lattice more sensitive to transverse beam instabilities because Landau damping induced by wigglers was suppressed and damping time was 2-3 times longer

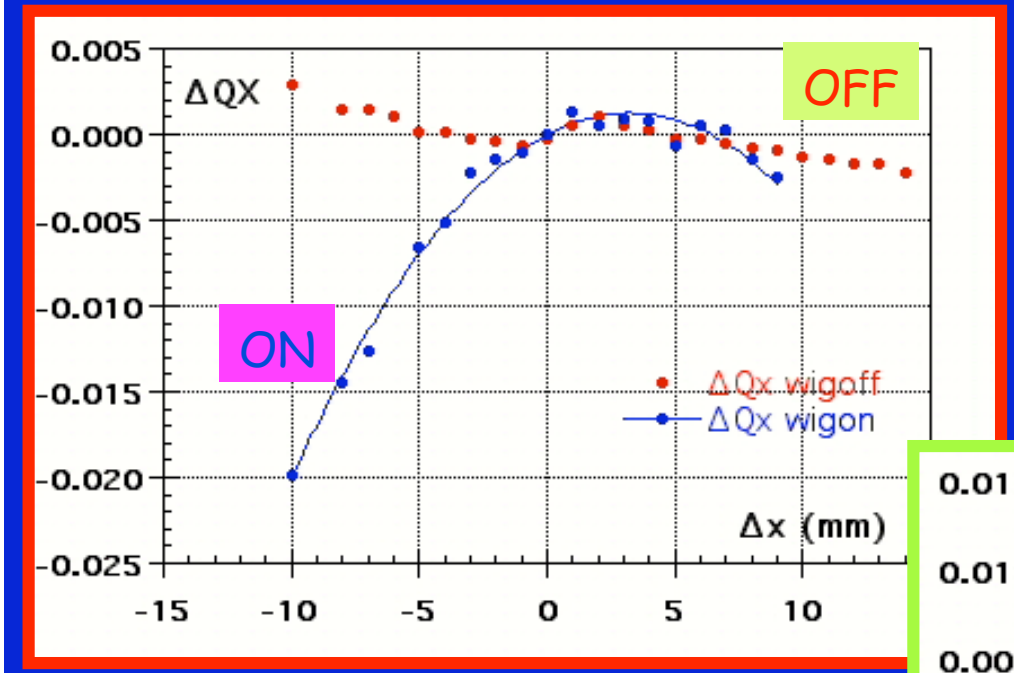
Tune shift vs energy with sextupoles OFF, wigglers ON & OFF



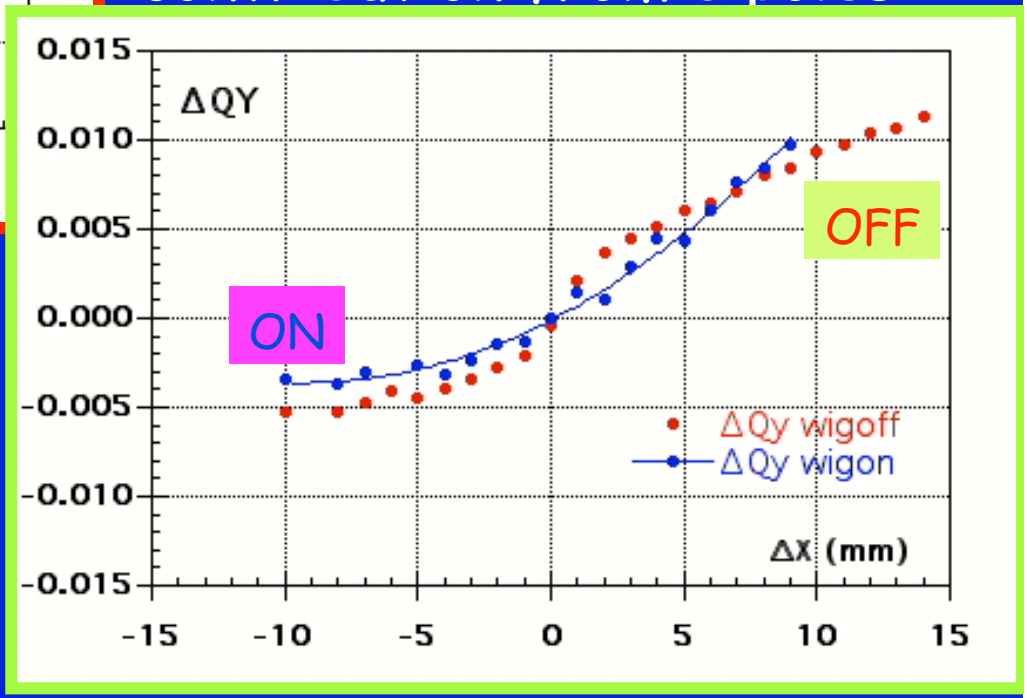
Wigglers ON

Wigglers OFF

Tune shift vs x-amplitude in one wiggler

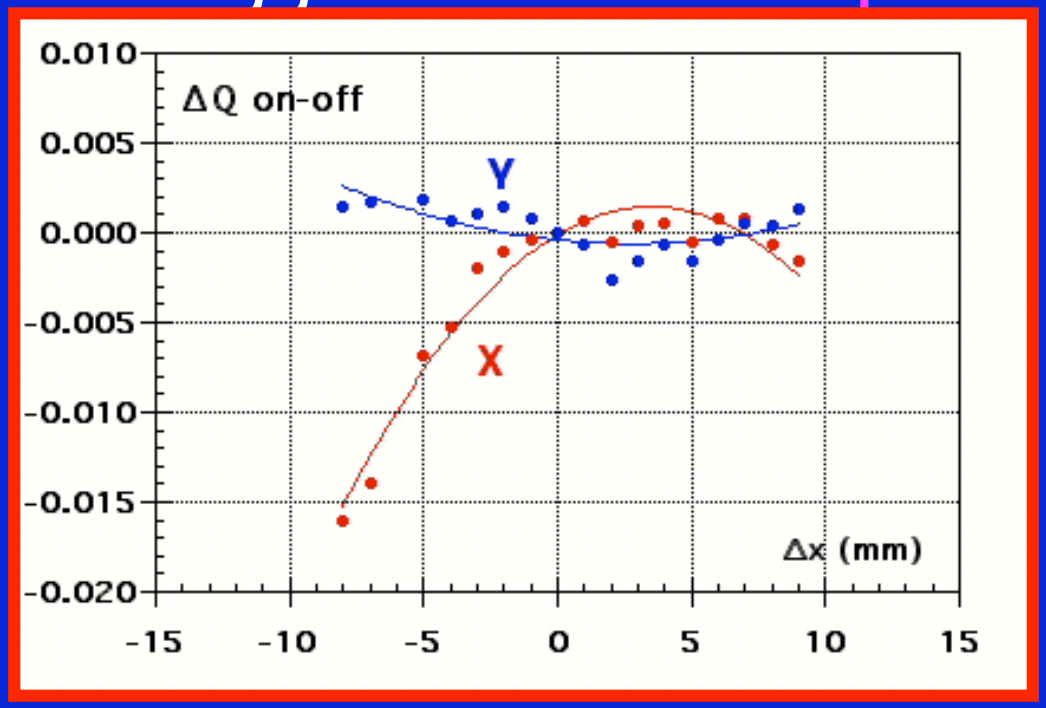


Horizontal tune, wiggler ON & OFF: mostly linear for wiggler OFF, with a small contribution from dipoles



Vertical tune, wiggler ON & OFF: small change, $\Delta\beta_y$ in wigglers is small, while $\Delta\beta_y$ in nearby dipoles is large

- Wiggler contribution isolated by subtracting measurement with wigglers OFF from the corresponding one with wigglers ON: octupole term



$\partial Q_x/\partial x^2 \approx -127\ m^{-2}$

$\partial Q_y/\partial x^2 \approx +28\ m^{-2}$

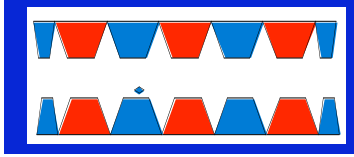
$(\beta_x/\beta_y \approx 3)$

MAD constant:

$k_3 \approx -1000\ m^{-3}$

(assuming $\langle\beta\rangle \approx 3m$)

for each wiggler

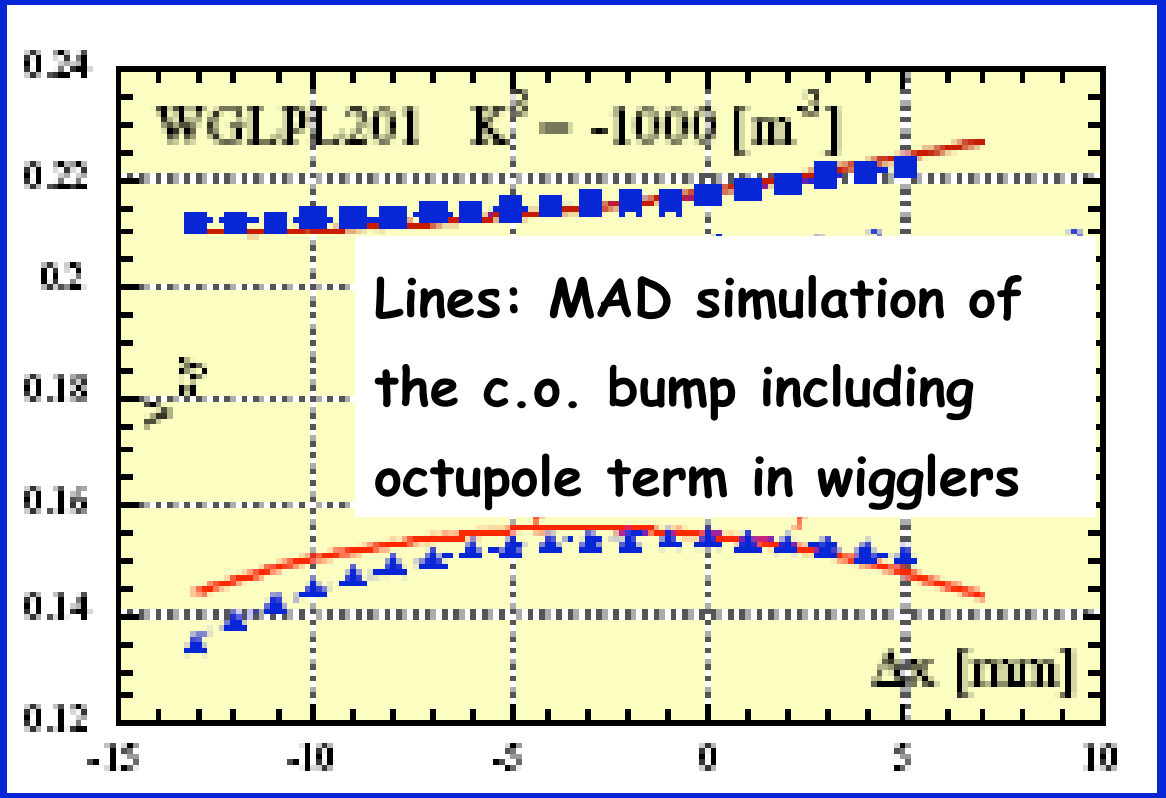


Simulation

	Meas	MAD	Meas	MAD
	x	x	y	y
□□/(□x)² (m^{-2})	-129	-122	+31	+38

Comparison with MAD model

Simulated x-bump in one wiggler



C.Milardi et al, PAC2001

Tune shift with amplitude

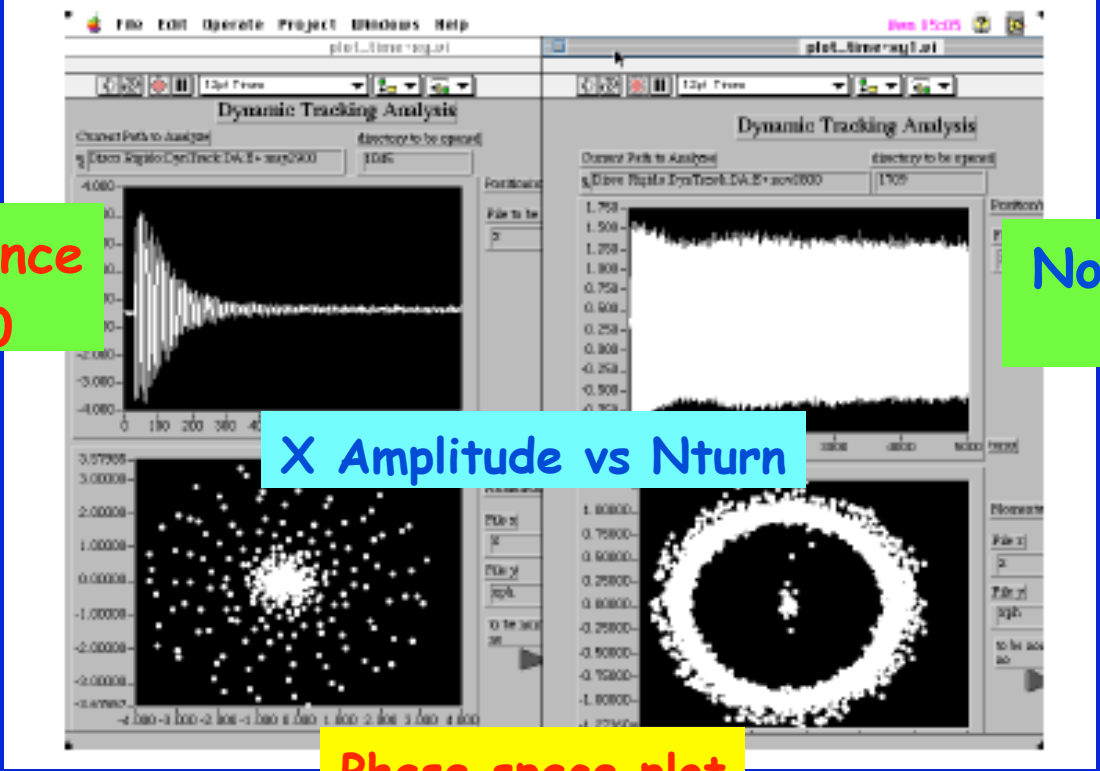
- Parameter c_{11}, measuring the horizontal tune shift with particle amplitude, gives cubic nonlinearity strength (M. Zobov, DA□NE Tech. Note G-57):

$$\Delta\nu_x = 2c_{11}J_x$$

- c_{11} can be computed by fitting the turn-by-turn signal envelope from beam tracking system
- c_{11} slightly negative is better for dynamic aperture and beam-beam interactions
- c_{12} negligible for flat beam and small β_y in wigglers

Beam decoherence

- Measured by a dynamic tracking system: coherent □-tron oscillation excited by kicking the beam with injection kicker and storing turn-by-turn displacement (A. Drago et al, DIPAC 2001)



Decoherence
$c_{11} < 0$

No decoherence
$c_{11} > 0$

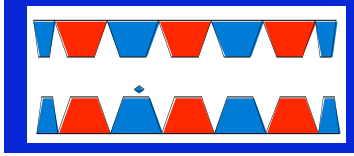
KLOE 2001

Wigglers ON

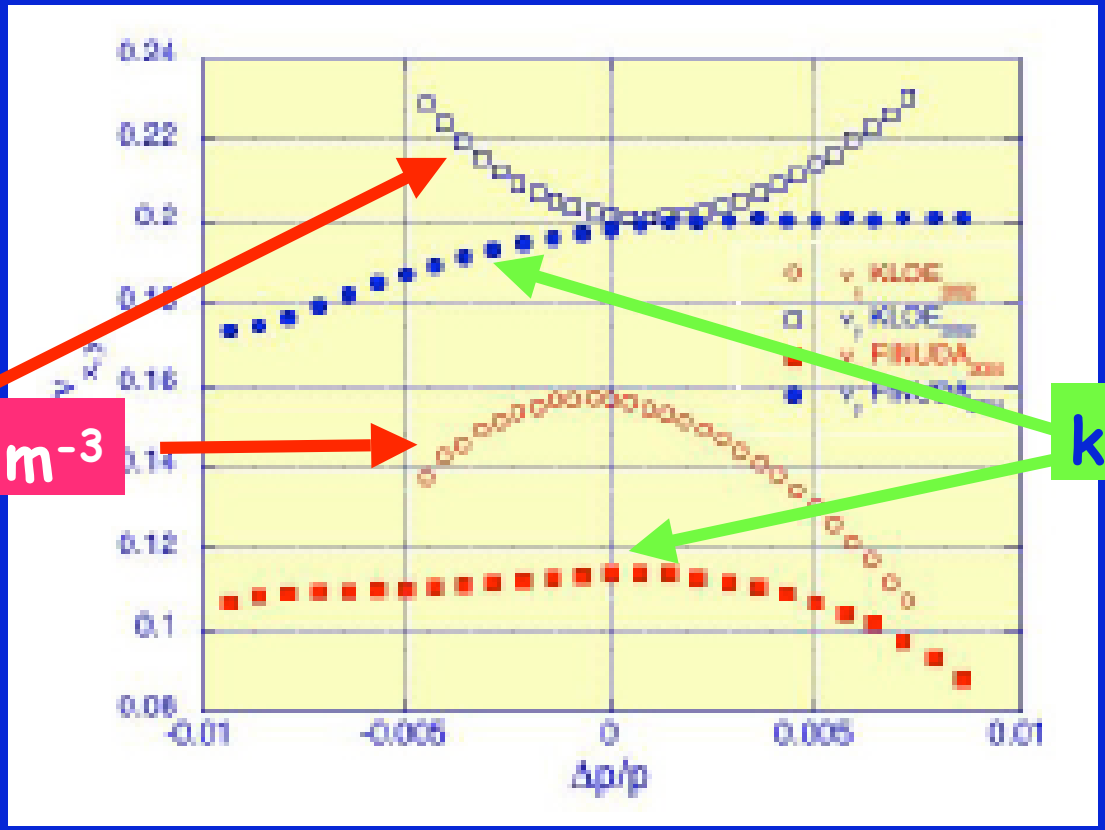
Wigglers OFF

Cures for non linearities

- Lowered β_x in wigglers
- Installed 3 octupole magnets/ring
- Optimized sextupole settings
- Modified wiggler poles (M. Preger's talk)



e+ ring tune shift vs energy before (KLOE) and after (FINUDA) wigglers upgrade (2003)

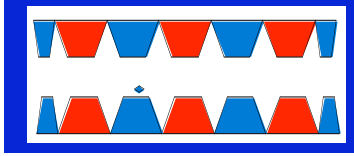


$k_3 = -840\ m^{-3}$

$k_3 = -180\ m^{-3}$

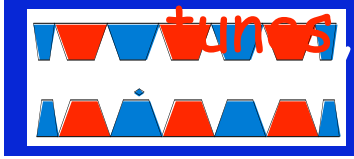
c_{11} for different configurations

CONFIG.	c_{11} (m^{-1})	Notes	CONFIG.	c_{11} (m^{-1})	Notes
KLOE 2000	-600	W ON, SXP ON	DEAR 2002	-450	W ON, SXP ON, OCT OFF
KLOE 2001	+400	W OFF, SXP OFF	DEAR 2002	-300	W ON, SXP ON, OCT ON
KLOE 2001	+200	W OFF, SXP ON	FINUDA 2004	-300	W ON, SXP ON, OCT OFF
KLOE 2001	-300	W ON -15%, SXP OFF	FINUDA 2004	-70	W ON, SXP ON, OCT ON
KLOE 2001	-170	W ON, Lower β_x^w	KLOE 2004	-140	W ON, SXP ON, OCT OFF
KLOE 2002	-80	W ON, SXP ON	KLOE 2004	-50	W ON, SXP ON, OCT ON
KLOE 2002	~0*	W ON, SXP ON, OCT ON	KLOE 2004	-10	W ON, SXP ON, OCT ON, high β_c



* Not used in collision

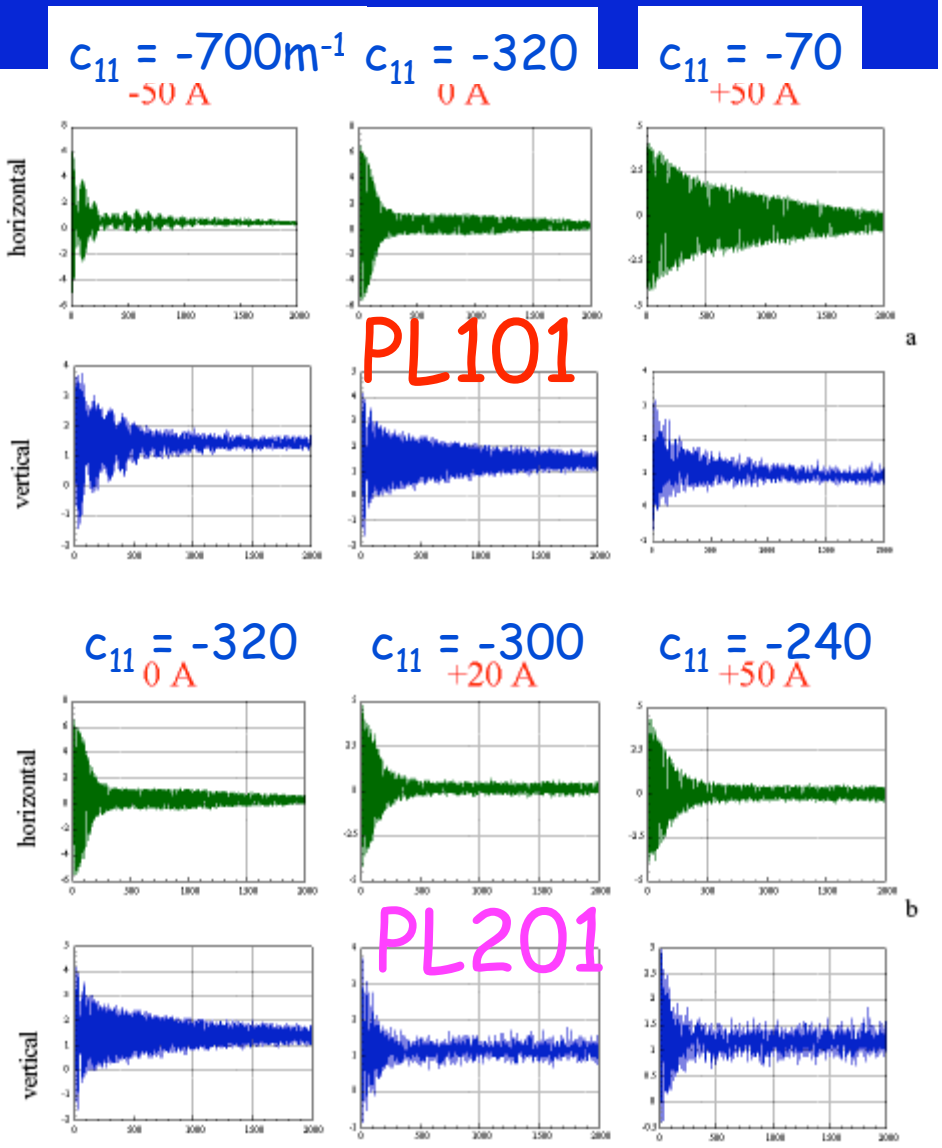
- Negative c_{11} provides Landau damping, beneficial to coherent beam instabilities
- Positive c_{11} affects BB causing beam blow-up and lifetime degradation
- The cubic non linearity changes widely, depending on functions and c.o.
- Larger negative contribution to c_{11} comes from wigglers
- Sextupoles contribution to c_{11} is also negative but smaller
- Octupoles give positive contribution to c_{11}
- Combined effect of cubic n. l. and bb depends on tunes, BB tune shifts, n.l. strength and sign of c_{11}



Decoherence with octupoles

FINUDA 2004

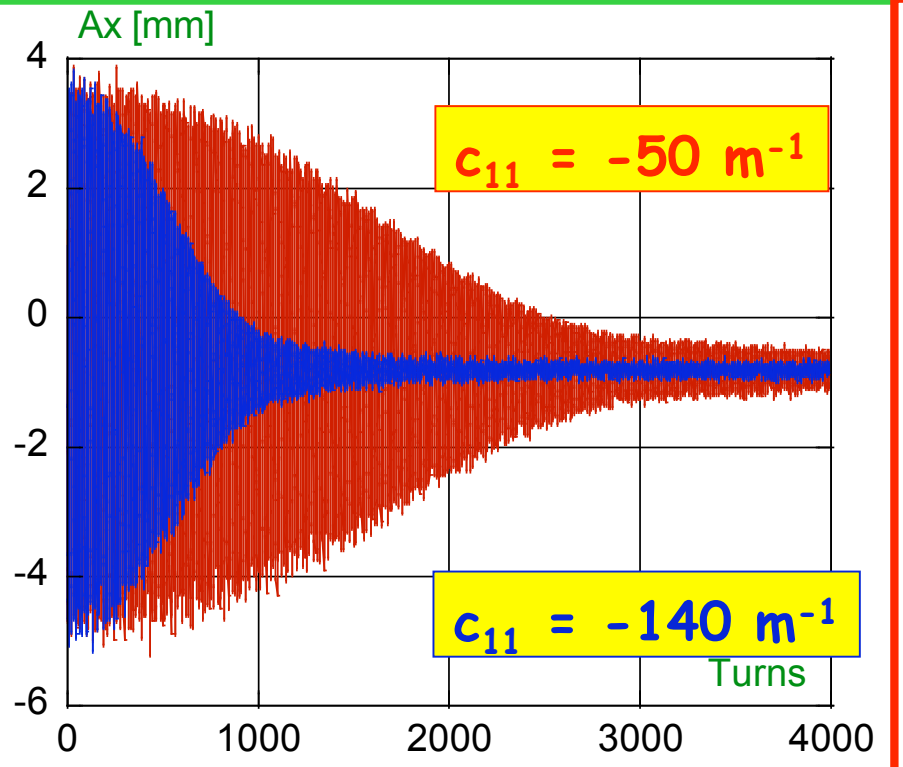
- 3 octupoles were installed in order to compensate for wiggler octupole-like effect, providing a knob to control c_{11}
- Octupoles are used in collision to optimize peak luminosity, lifetime and backgrounds
- Measurement of e^+ beam decoherence for different octupole settings →



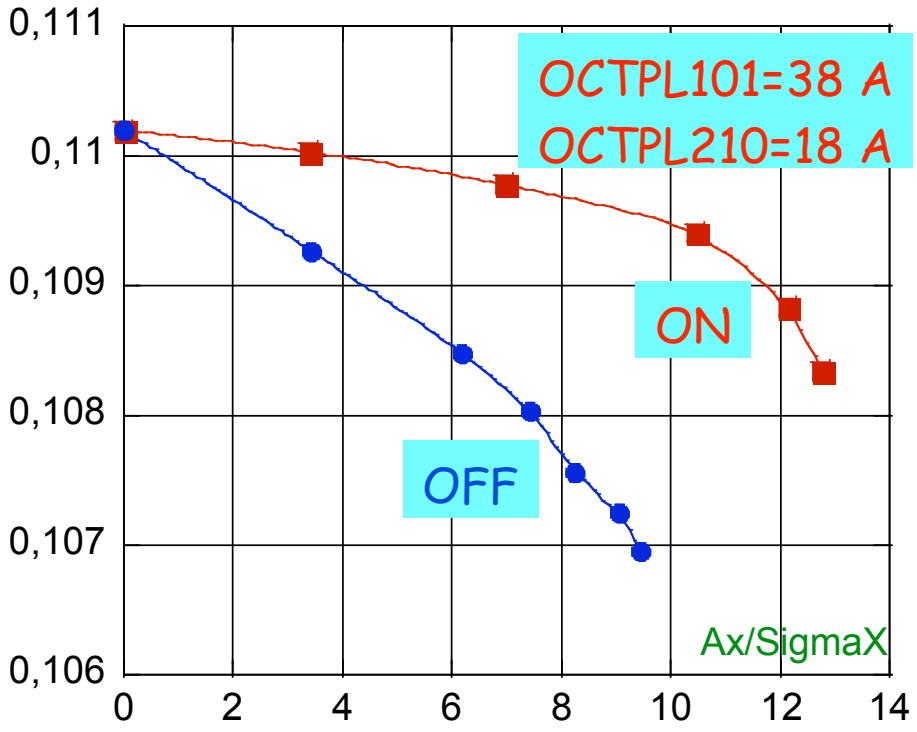
KLOE December 2004

Octupoles ON and OFF

Beam Decoherence



Tune Shift with Amplitude

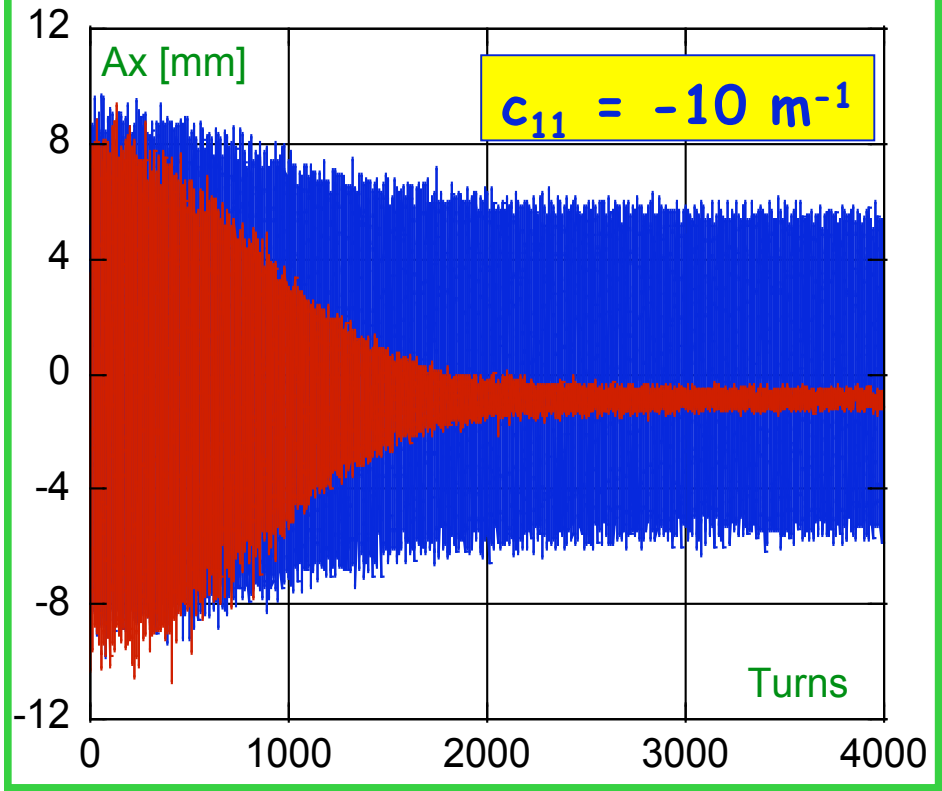


M. Zobov

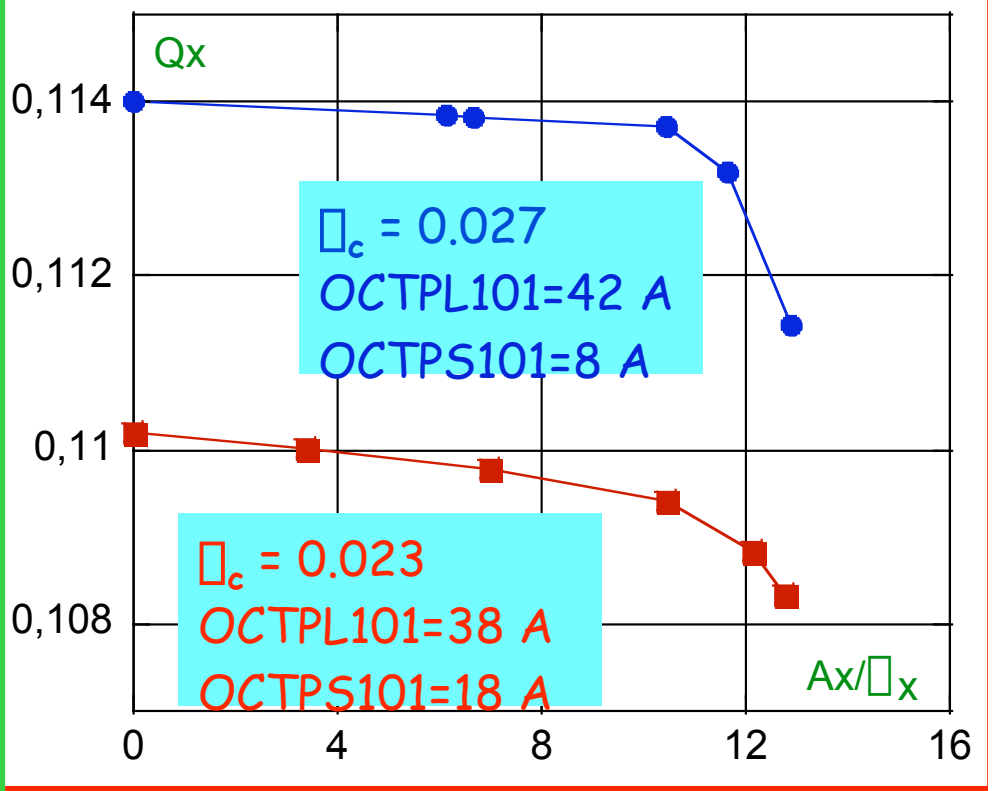
Comparison of 2 lattices

- Higher wiggler field, lower momentum compaction (0.023)
- Lower wiggler field, higher momentum compaction (0.027)

Beam Decoherence

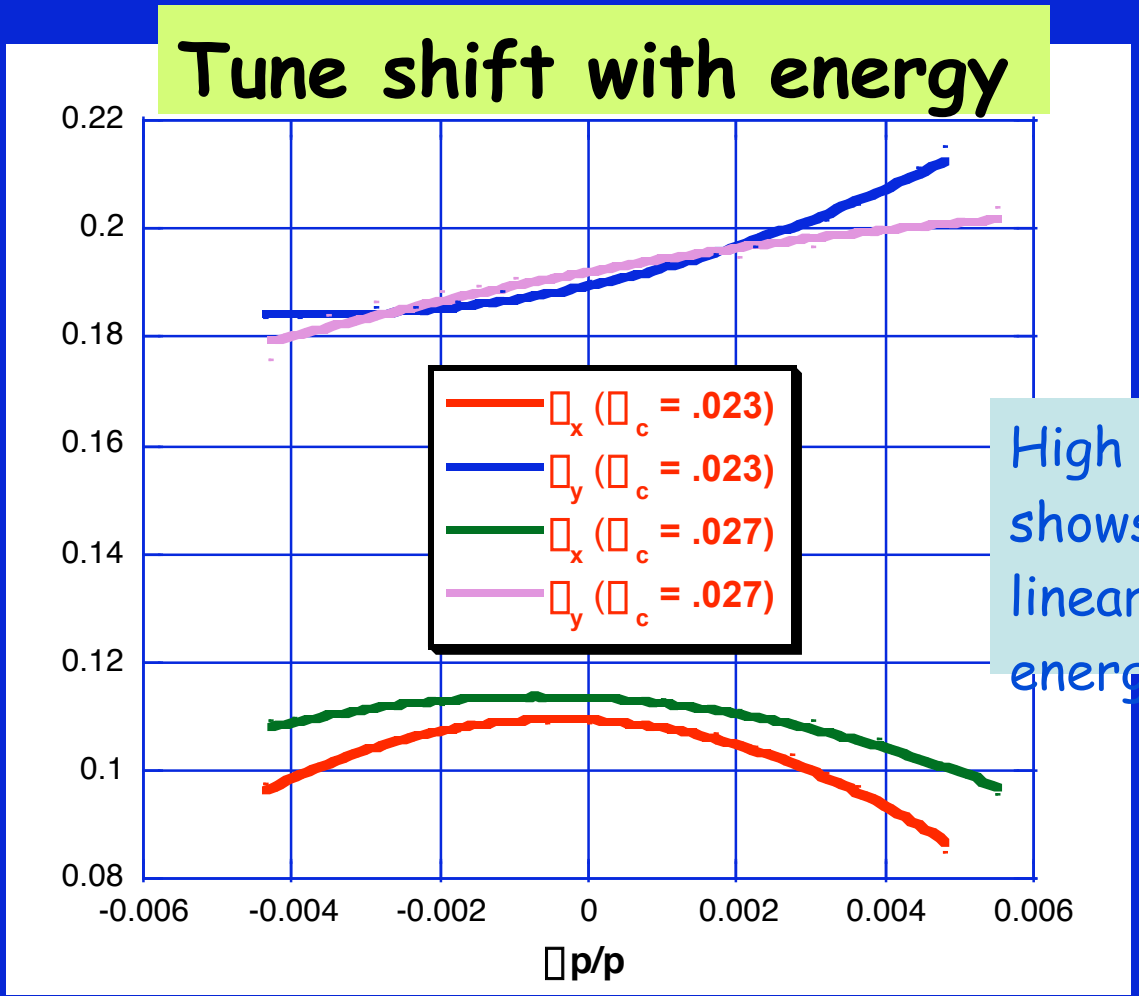


Tune Shift with Amplitude



M. Zobov

Comparison of 2 lattices



High Q_c lattice shows less non linearity and larger energy acceptance

Conclusions

- The 8 wigglers turned out to be the main source of DA□NE non linearities
- Lattice modifications and insertion of octupoles have been beneficial
- Wiggler pole modification strongly reduced non linearities
- Non linearities are smaller and under control for the present operation