SLS acceptance and lifetime

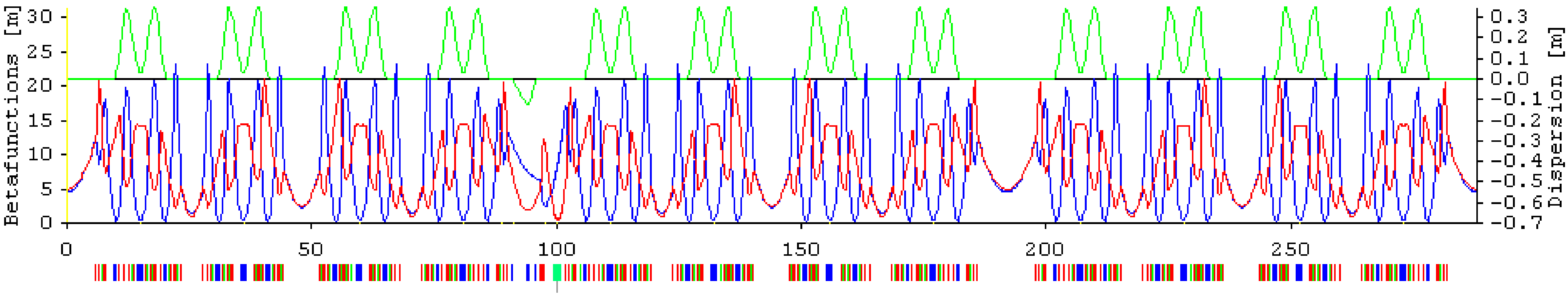
Andreas Streun
PSI Villigen, Switzerland

ESRF workshop
Nonlinear dynamics in storage rings:
from modelling to experiment
Grenoble, May 26-28, 2008

Contents

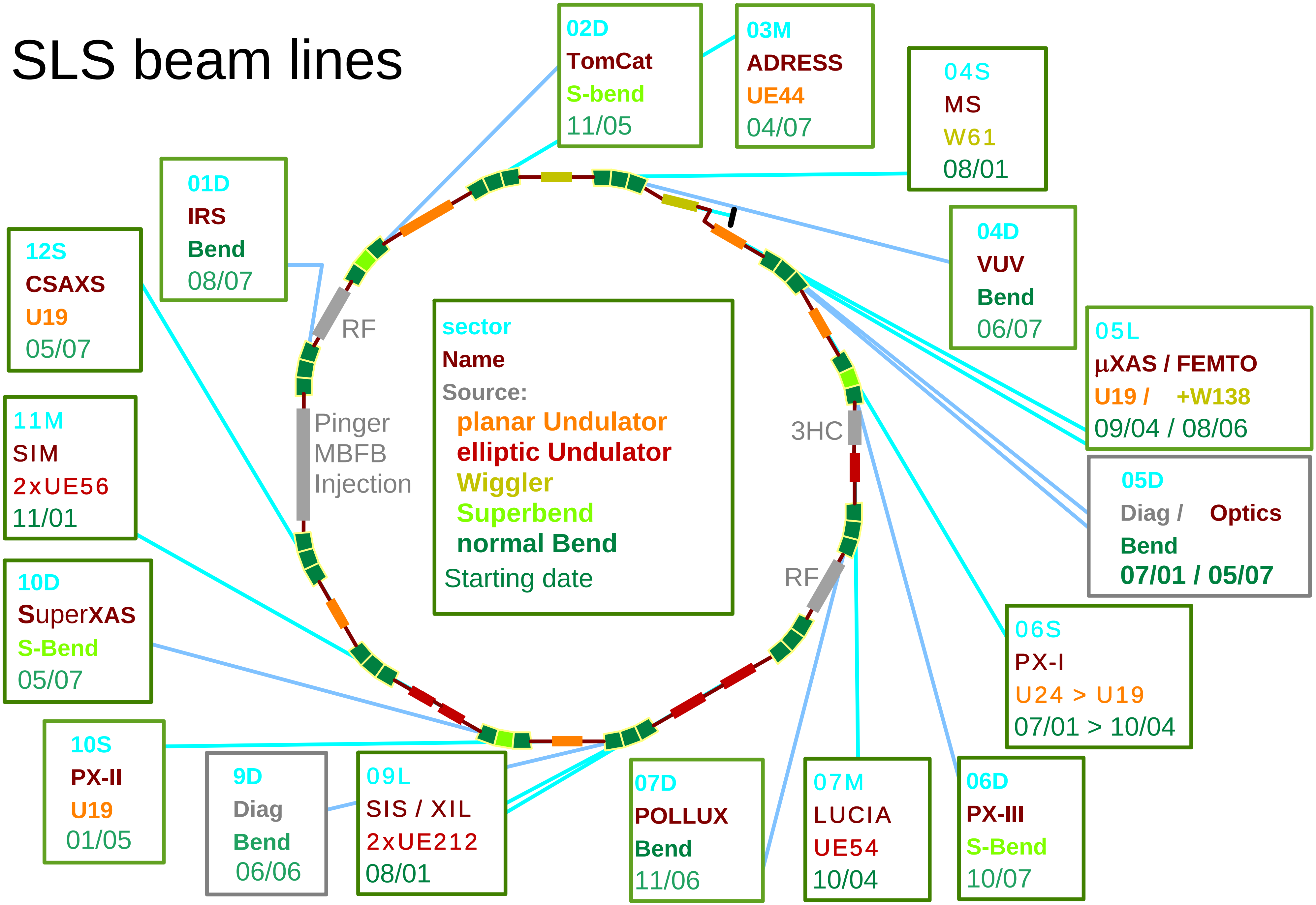
- Status and parameters of the SLS
- Vertical acceptance and elastic scattering lifetime
  - residual gas composition
- Horizontal acceptance
  - amplitude dependant tune shifts
- Momentum acceptance and Touschek lifetime
  - problems of large chromaticity
  - dangerous resonances and how to suppress
  - coupling and scraper experiments
  - conclusions
- Summary

The Swiss Light Source SLS



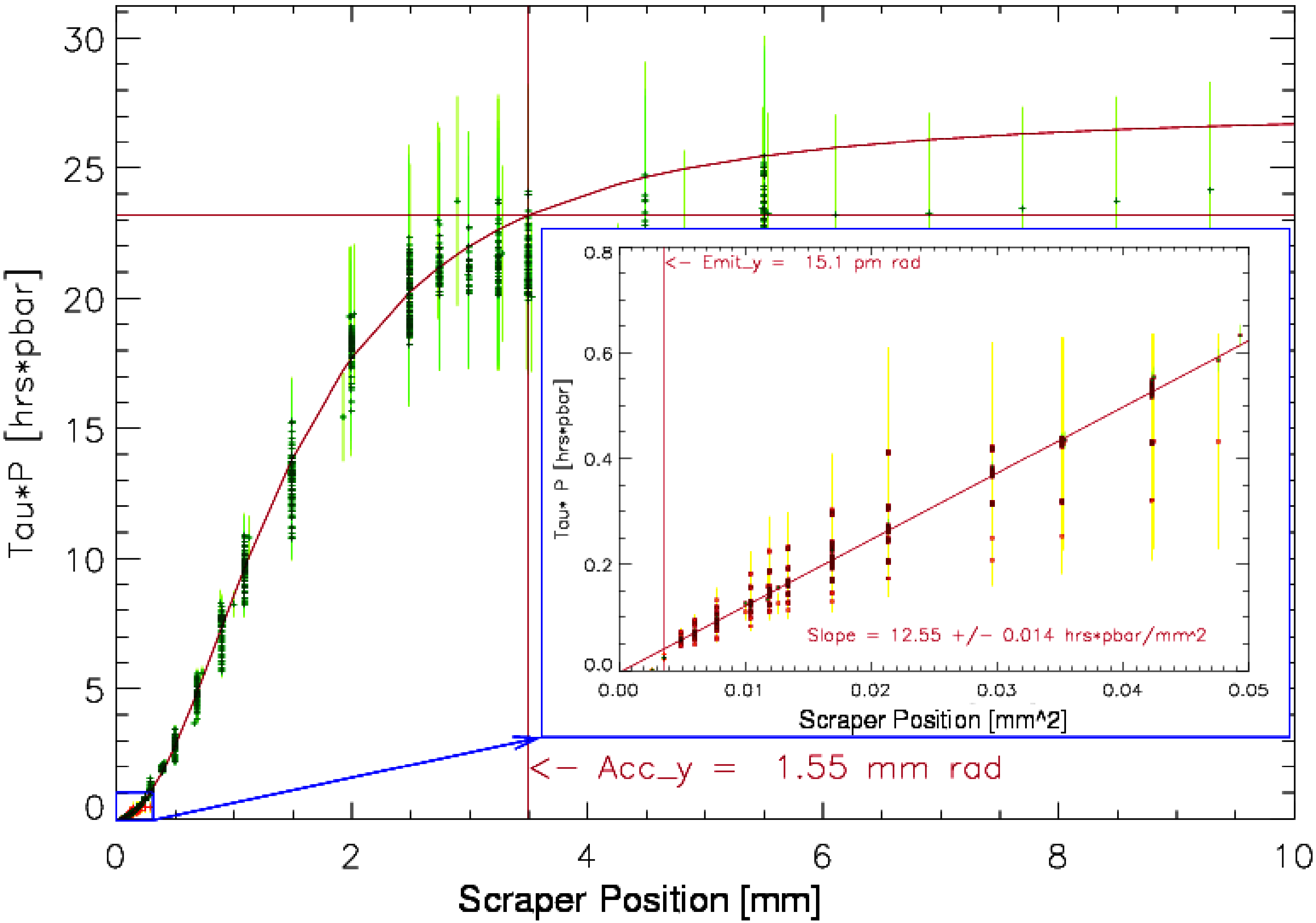
- 12xTBA lattice, 288 m circumference, 2.4 GeV
- 5.0...6.8 nm emittance (dep. on ID status)
- 400 ±1 mA top up operation
- User operation since 7 years, 98% availability
- Upgrades: Femto laser slicing & 3 superbends
- 1 micron photon beam stability at front end
- 3 pm rad vertical emittance (0.05% coupling)

SLS beam lines



Vertical acceptance

Measurement (T·P) vs. scraper to determine acceptance and residual gas composition and to estimate coupling:



Vertical acceptance and elastic scattering lifetime

- Aperture limitation before 2006:
  W61 chamber (2 m x 5 mm, β_y= 2 m): A_y = 3 mm mrad
- Measurement: $A_y \approx$ 1.0 mm mrad
  chamber realignment $\Rightarrow$ $A_y \approx$ 1.5...1.8 mm mrad - ?
- Aperture limitation since 2006:
  FEMTO wiggler (2.4 m x 8 mm, β_y = 7.7m): A_y = 2 mm mrad
- Measurement: $A_y \approx$ 1.5...1.8 mm mrad
- Residual gas:
  no beam: 0.6 pbar, ~ 20% CO
  400 mA: 4.0 pbar, ~ 10% CO

◆ Lifetime not limited by vertical acceptance

$\Rightarrow$ Lower gaps (4 mm), rounder beams ($\beta_y \uparrow$)

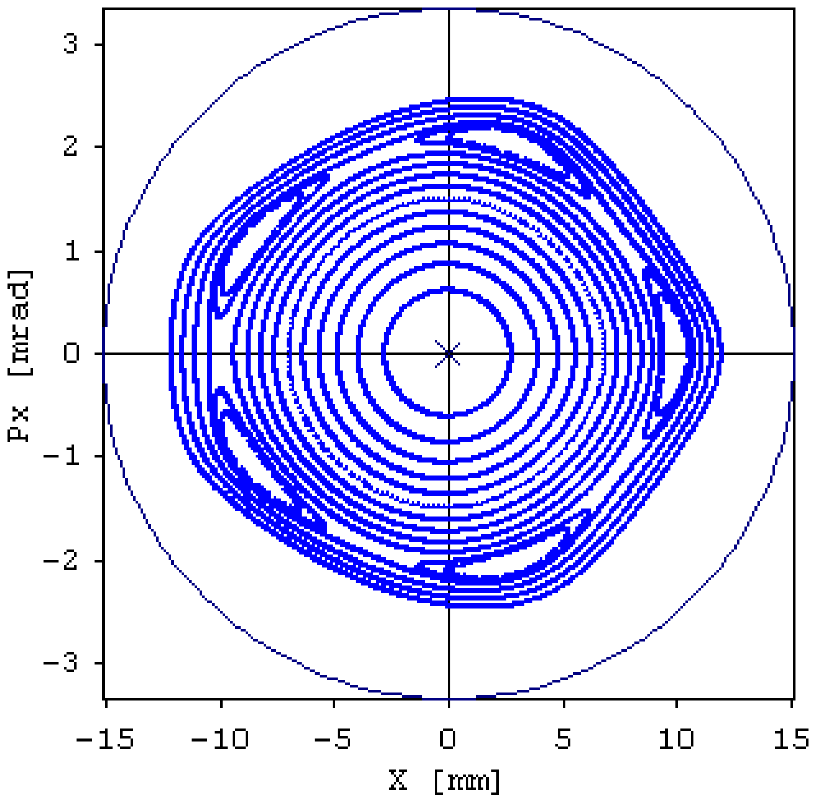
$\Rightarrow$ W61 chamber will be removed $\Rightarrow$ dedicated scraper.

Horizontal acceptance

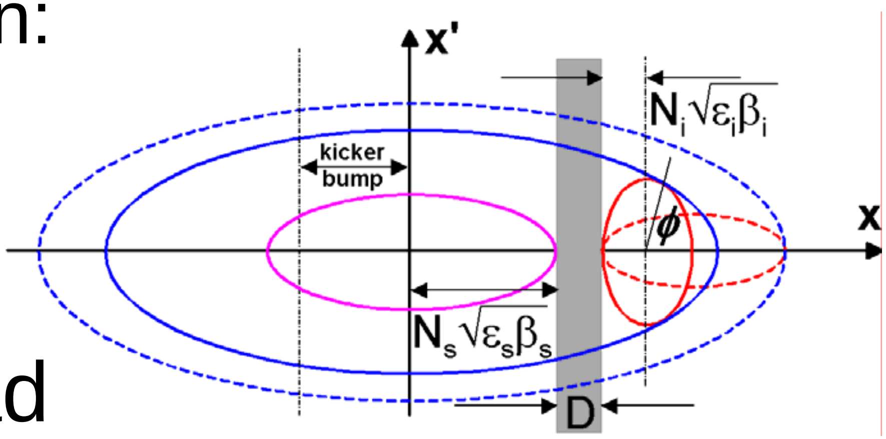
Simulation (ideal lattice):
Ax = 30 mm mrad

break up at 5Qx=102 resonance?
Ax = 18 mm mrad

Maximum excitation from pinger:
Ax = 11 mm mrad.
Acceptance limit not reached



Minimum requirement for injection:
Ax > 8 mm mrad
100% efficiency possible
(usual 90..95%), but little margin



Conclusion: Ax > 11 mm mrad

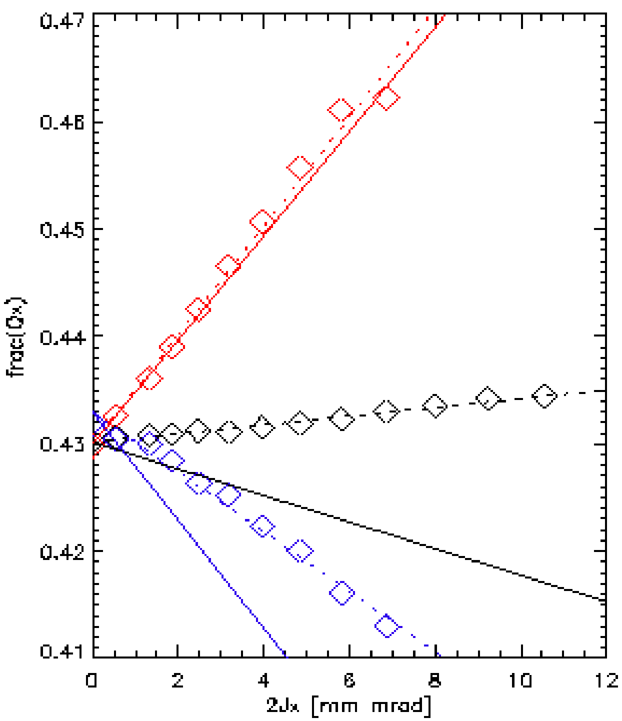
Amplitude dependant tune shift measurements

-------Theory: dQx/dAx = -1200/m (nominal) / set to +5000;-5000/m

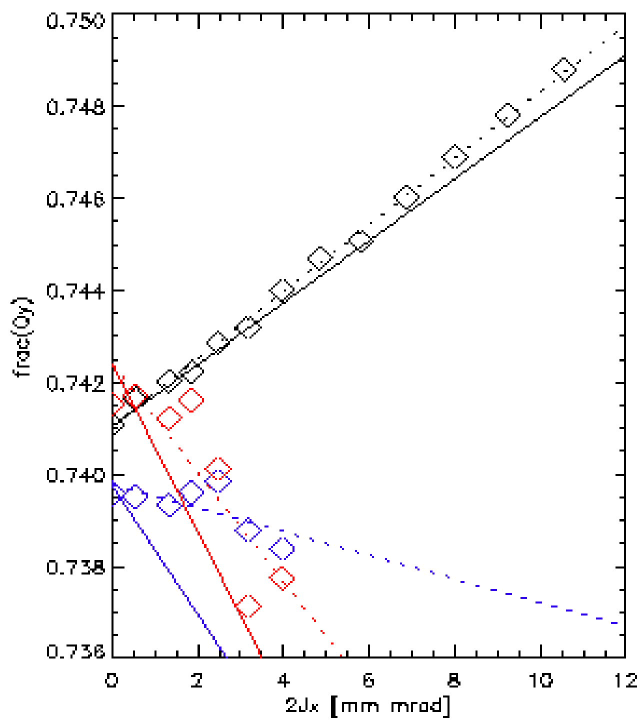
◊···◊···◊ measurement and fit

dQx/dAx	max. Ax theory / reached [mm mrad]		
-1200	30 [18] / 11		limit not reached by pinger
+/- 5000	16 / 7		no injection

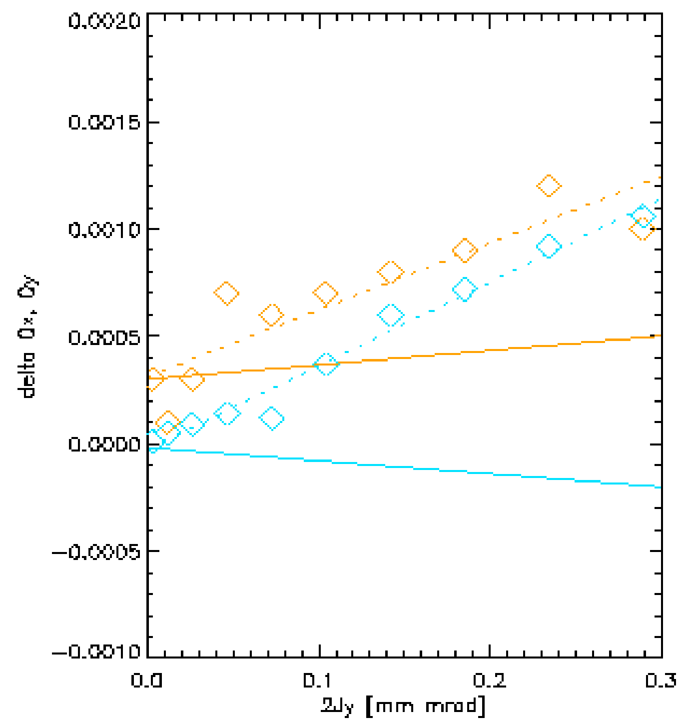
Qx vs. Ax



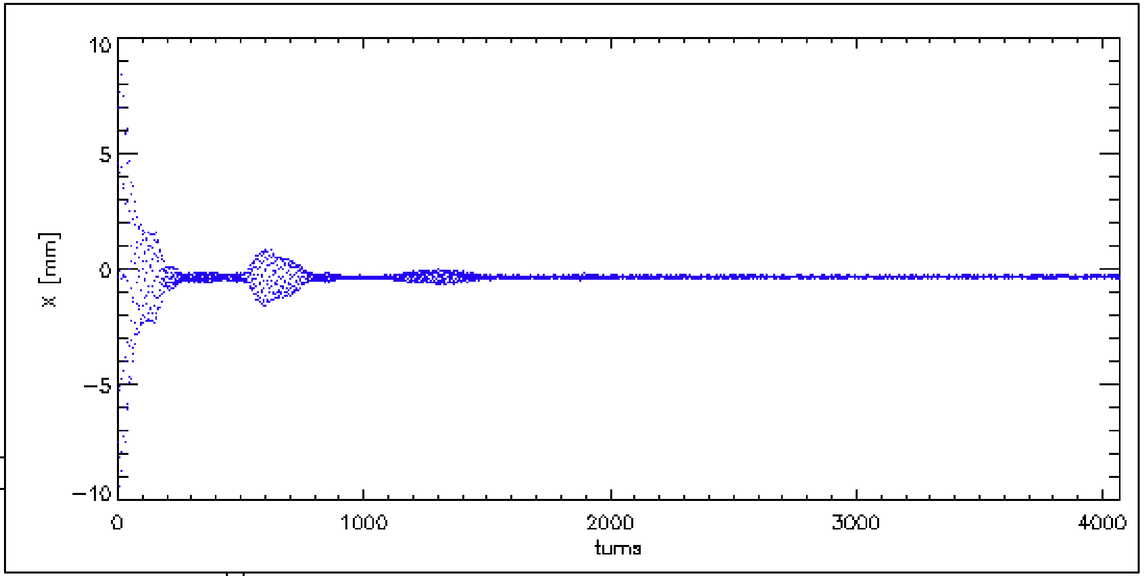
Qy vs. Ay

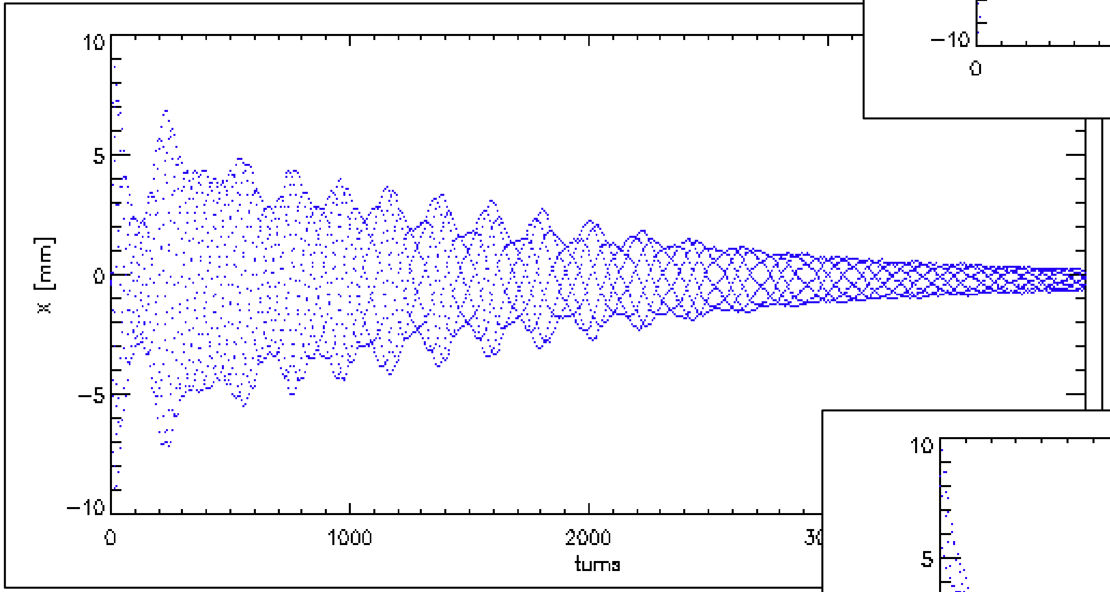


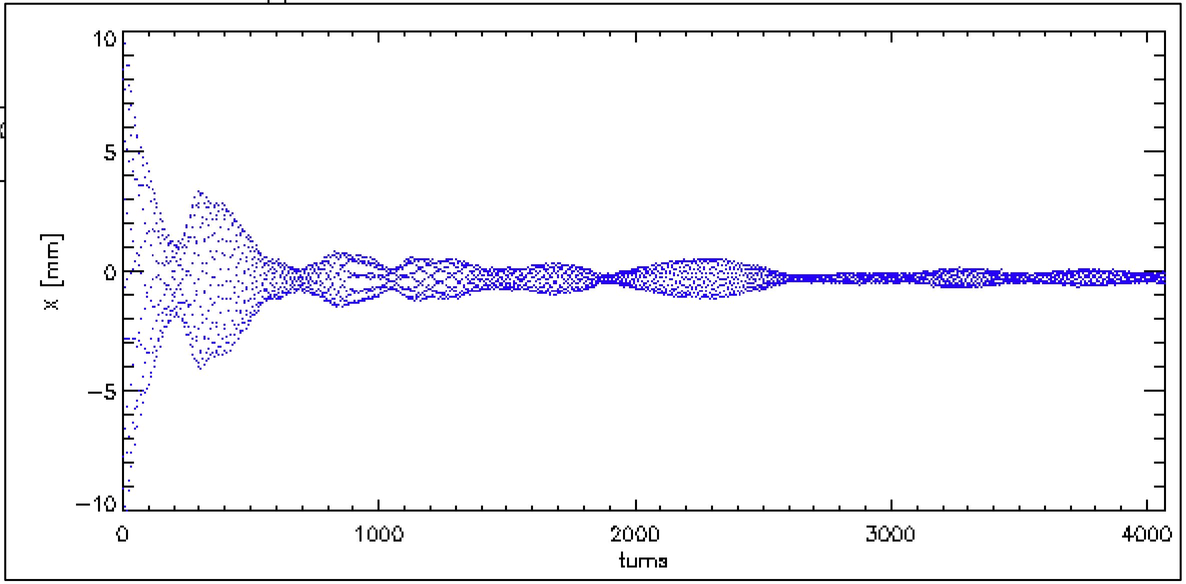
dQx, dQy vs. Ay



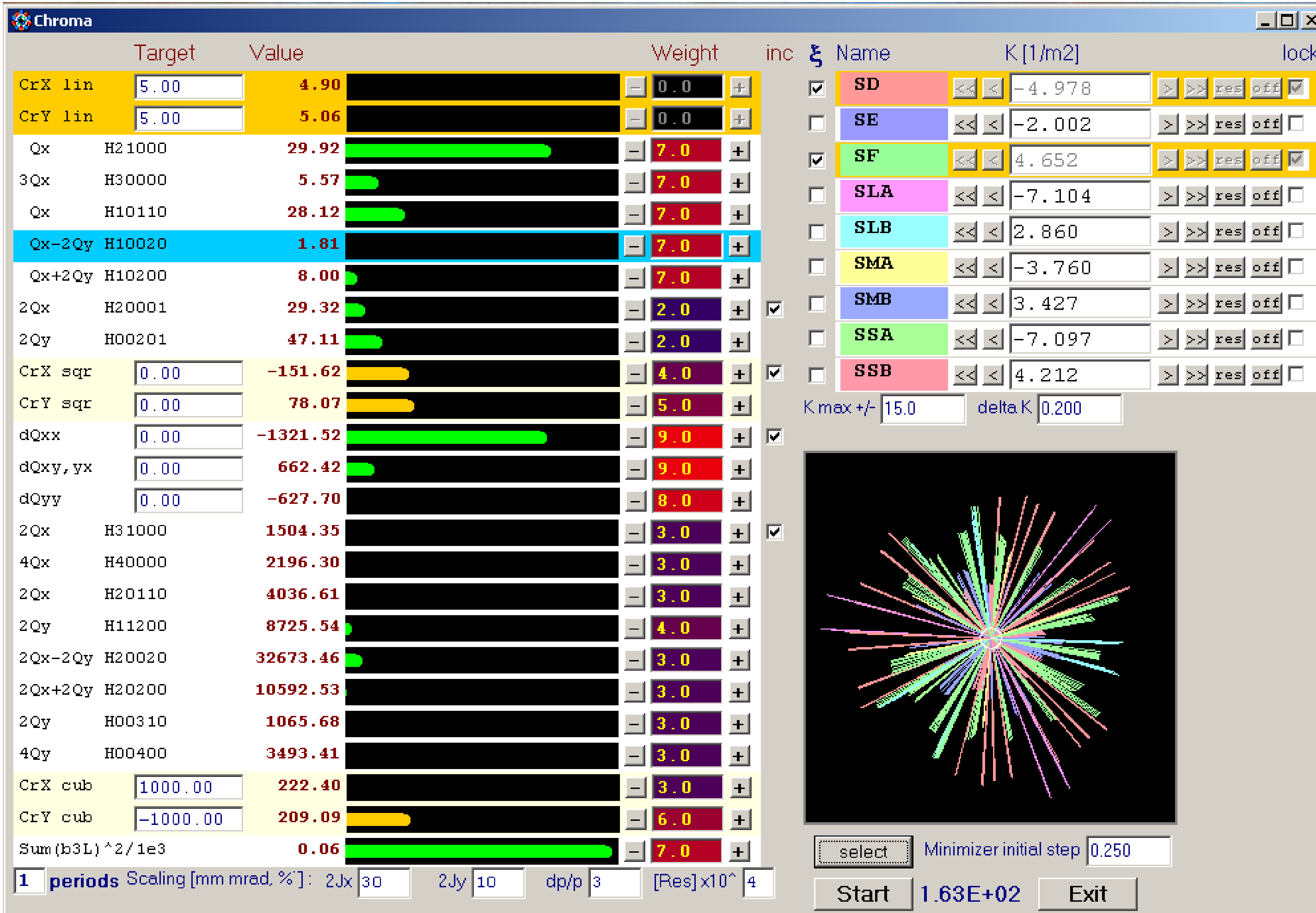
Decoherence
of beam kick for
dQx/dAx (set)
-5000; -1200; +5000/m.



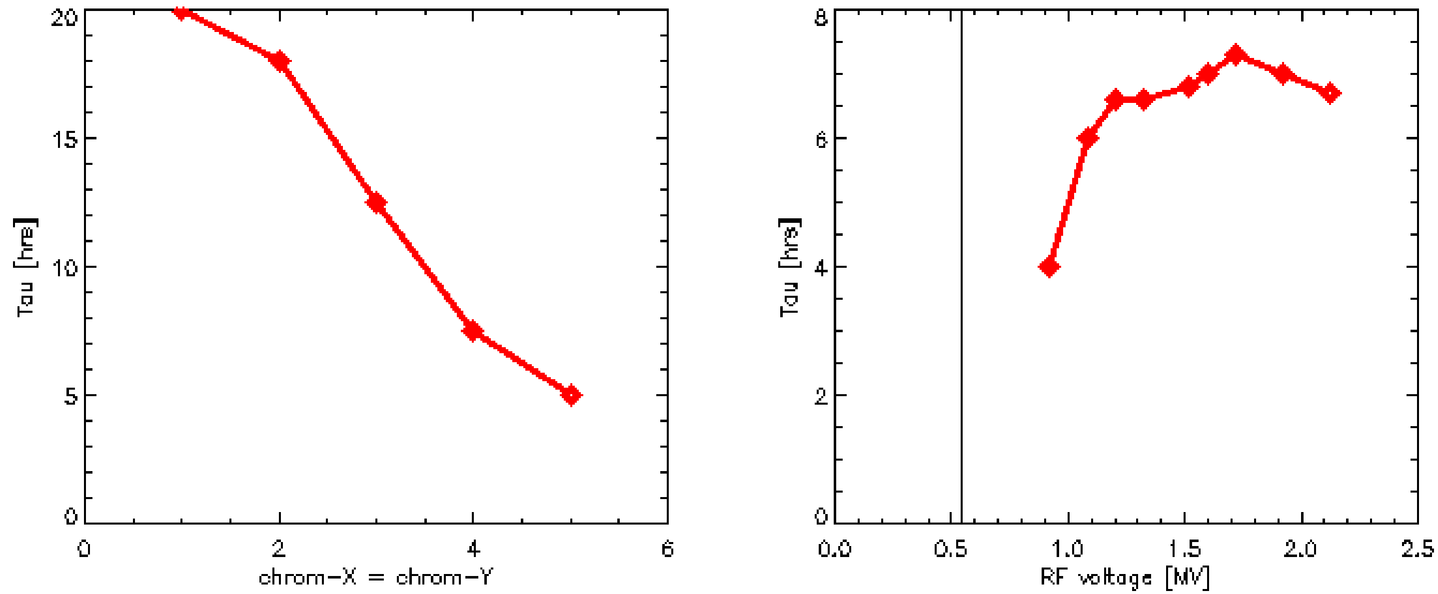




Panel for sextupole optimization



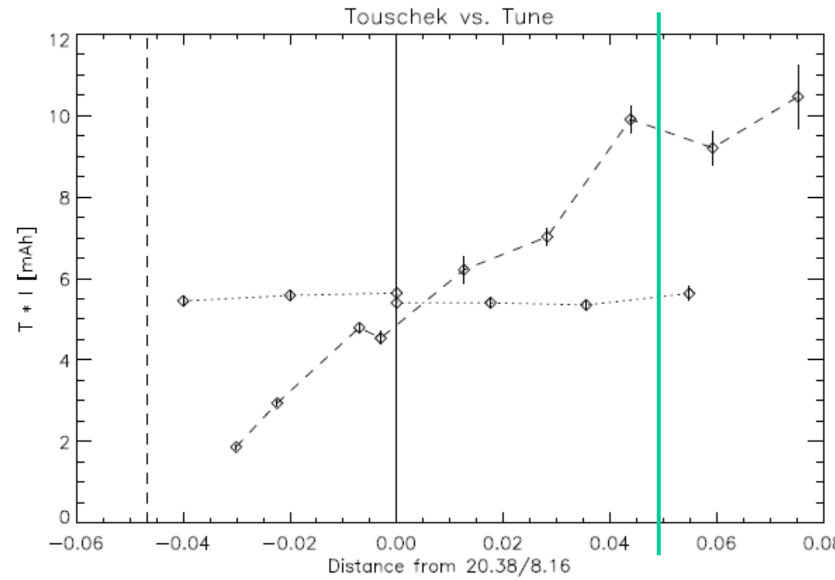
Momentum acceptance and Touschek Lifetime



- Lifetime strong function of chromaticity:
  [set] chromaticity: +1 $\rightarrow$ +5 $\Rightarrow$ Lifetime: 20 hr $\rightarrow$ 5 hr
- Early saturation of lifetime vs. RF voltage:
  little gain > 1.1 MV, i.e. for dp/p > 1.8%

$\Rightarrow$ Lattice dp/p acceptance < RF acceptance (3%)

Lattice acceptance limitation: prime suspect $3Q_x$=61



Touschek Lifetime vs. distance to 3Qx=61 resonance:

move Qx 20.38 → 20.43 (2001)

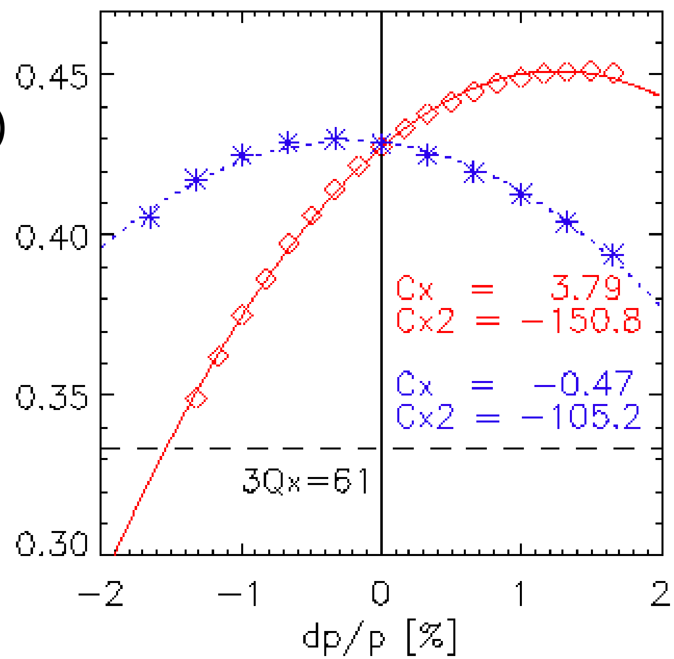
Ref.: A.Streun, SLS-TME-TA-2001-0191

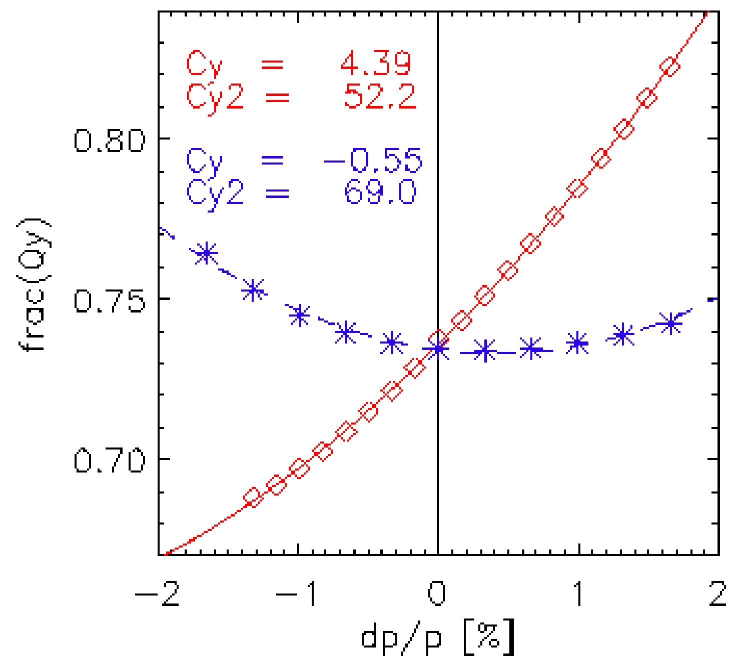
Chromaticity Measurement (2008):

High (= operational) and **low** chromaticity.

Theory:

Cx = +5
Cx2 =-152
Cy = +5
Cy2 = +78





Beam spectra

Excitation by pingers

Betatron amplitudes:
 Ax = 1.1 mm mrad
 Ay = 0.1 mm mrad

Peaks in spectra

clear:

Fundamental: Qx, Qy [±Qs]

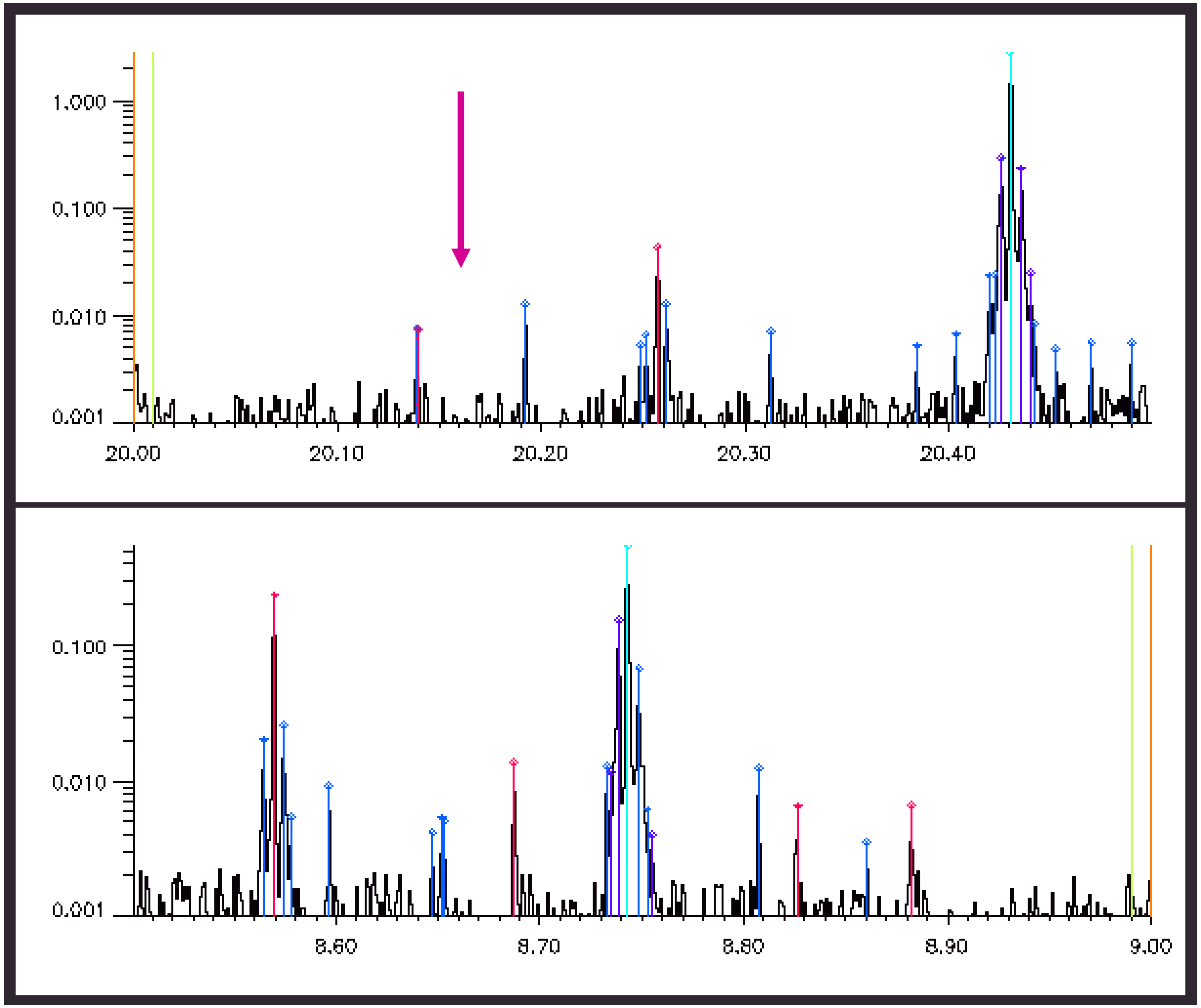
Coupling: Qx ± Qy

doubtful:

1st order sextupole:
 3Qx
 Qx ± 2Qy

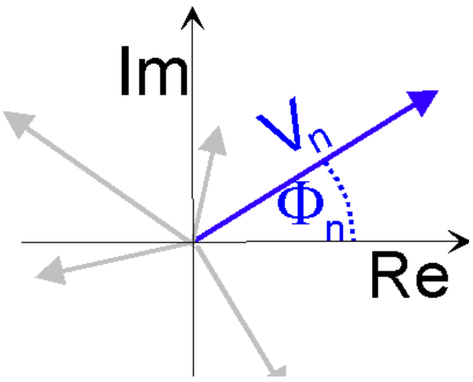
2nd order sextupole (octupole):
 2Qx – 2Qy
 ⇒ has a contribution from crosstalk 3Qx ↔ Qx + 2Qy

Ref.: J.Bengtsson, CERN 88-05



	peak[mm]	Tune	Guess	min.dist.	[a	b	n]
X	2.78305	20.43029					
0	0.04315	20.25698	20.25698	-0.000000	[1	-1	12]
6	0.00750	20.13921	20.13943	-0.000054	[3	0	61]
Y	0.54726	8.74302					
0	0.23546	8.56972	8.56971	0.000000	[1	-1	12]
4	0.01388	8.68710	8.68727	-0.000041	[1	-2	3]
8	0.00657	8.88231	8.88245	-0.000026	[2	-2	23]
9	0.00652	8.82634	8.82669	-0.000088	[1	2	38]

Optimization of sextupole Hamiltonian

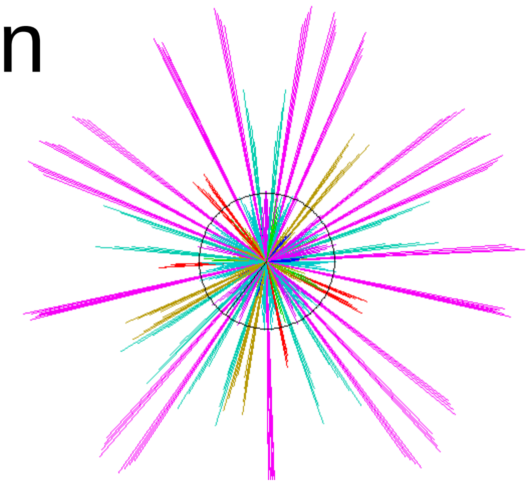


$$h = \sum_{n}^{N_{\text{sext}}} V_n e^{i\Phi_n}$$

Sextupole$_n$ $\leftrightarrow$ complex vector:

Length $V_n = V_n\left(b_3, L, \beta_x, \beta_y, D\right)$

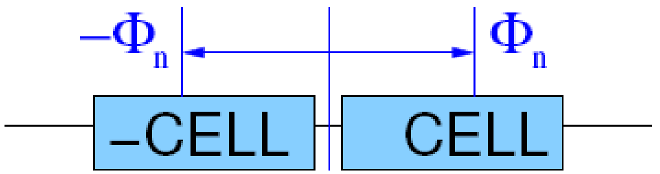
Angle $\Phi_n = \Phi_n\left(\phi_x + \phi_y\right)$



Ref: J Bengtsson, SLS-Note 9/97

Systematic first order optimization:

9 terms h_{jklmp} (7 complex, 2 real) $\Longrightarrow$ Symmetry:

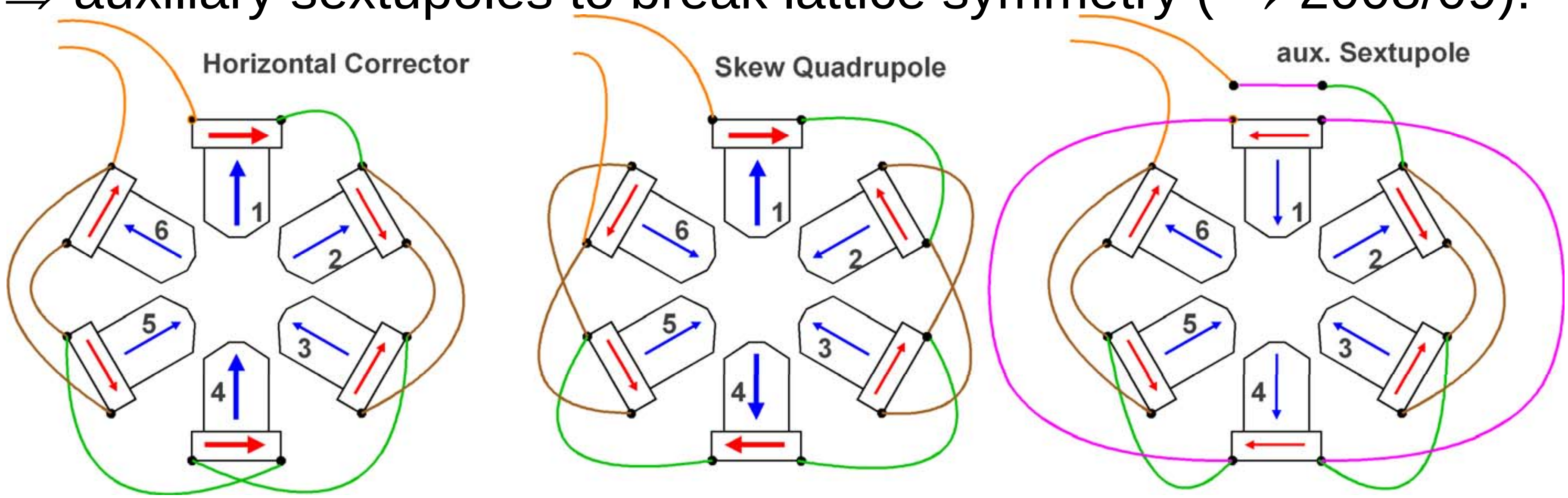


$\rightarrow$ **16** sextupole families

$Im(h_{jklmp}) = 0 \rightarrow$ **9** sextupole families.

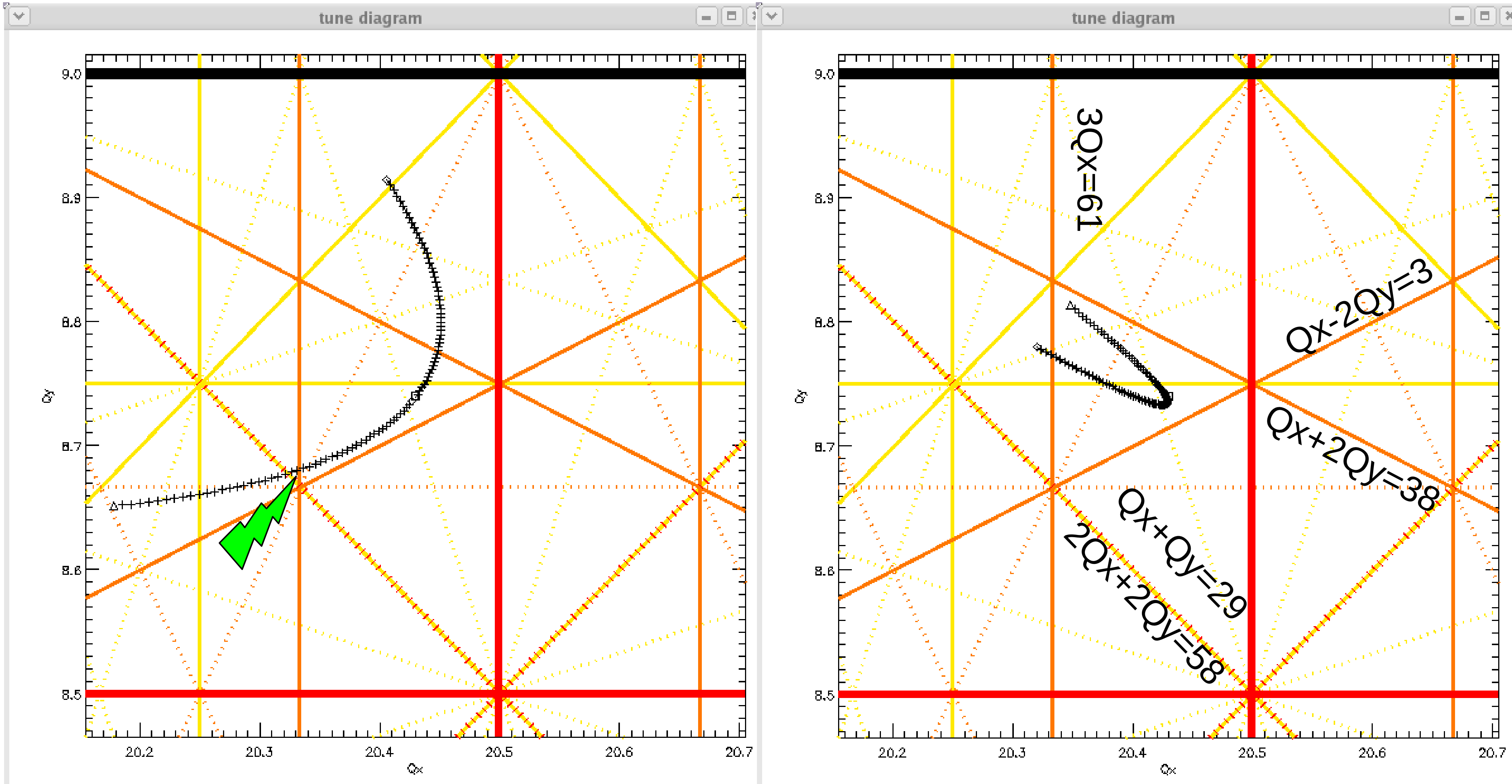
Problem: Sextupoles in ***families*** can't access h_{jklmp}-phases

$\Rightarrow$ auxiliary sextupoles to break lattice symmetry ($\rightarrow$ 2008/09):



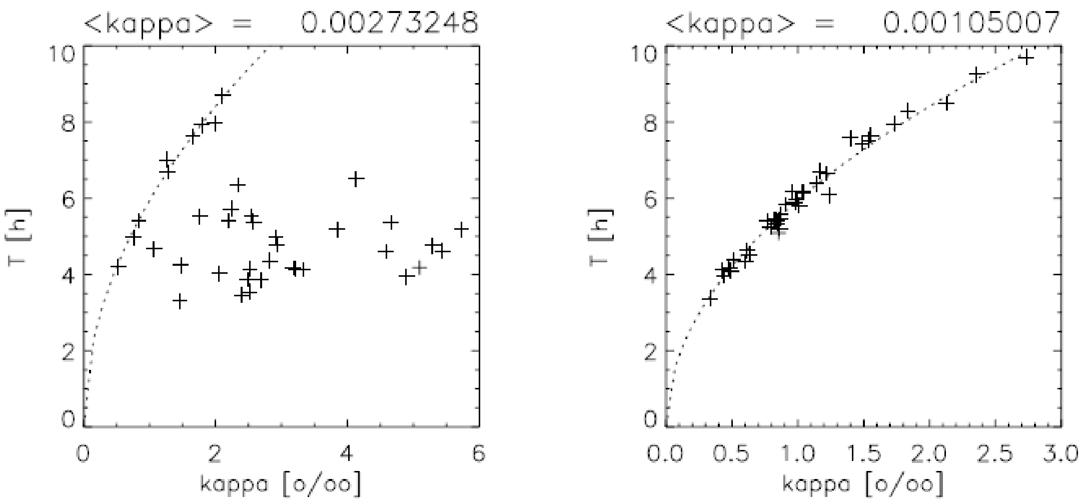
Tune Diagram for
high chrom.+3.8/+4.4 ↔ ≈ zero chrom. -0.5/-0.5

dp/p = -3%...0....+3% (Δ +++ ☐ +++ ◊); order **1,2,3,4;** regular____ skew.......



⇒ Is the main coupling (Qx+Qy=29) the culprit and 3Qx=61 innocent?

Touschek lifetime and coupling



Simulation:

T vs. coupling for 50 misalignment seeds with and without coupling suppression using 6 skew quads.

Ref. M.Böge & A.Streun, PAC-1999

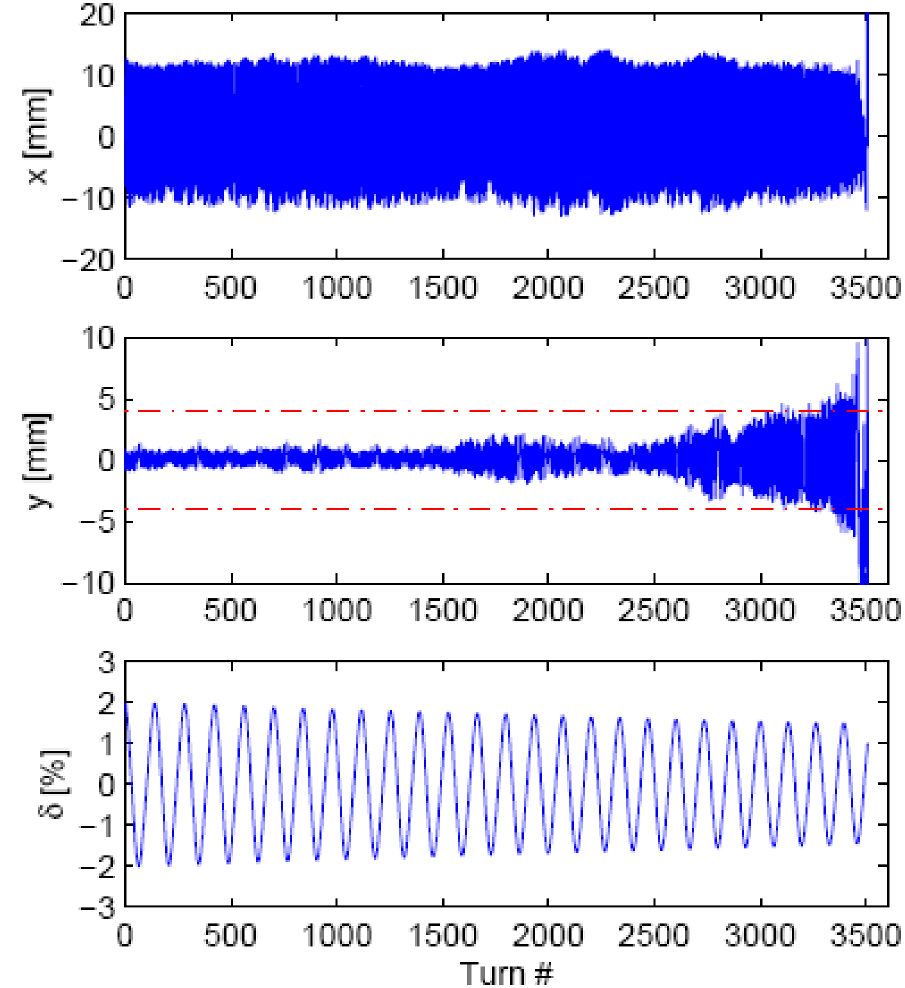


Figure 2: Simulation of the horizontal (top), vertical (middle), and longitudinal (bottom), position versus turn number of a particle which was launched with initial coordinate of x = 12mm, y = 1mm, and $\delta = 2\%$.

Experiments and simulations at ALS →

Ref. D.Robin et al., PAC-2003

Scraper measurements for 0.4% coupling and high/low chromaticity

Ref: Å.Andersson & A.Streun, EPAC-06

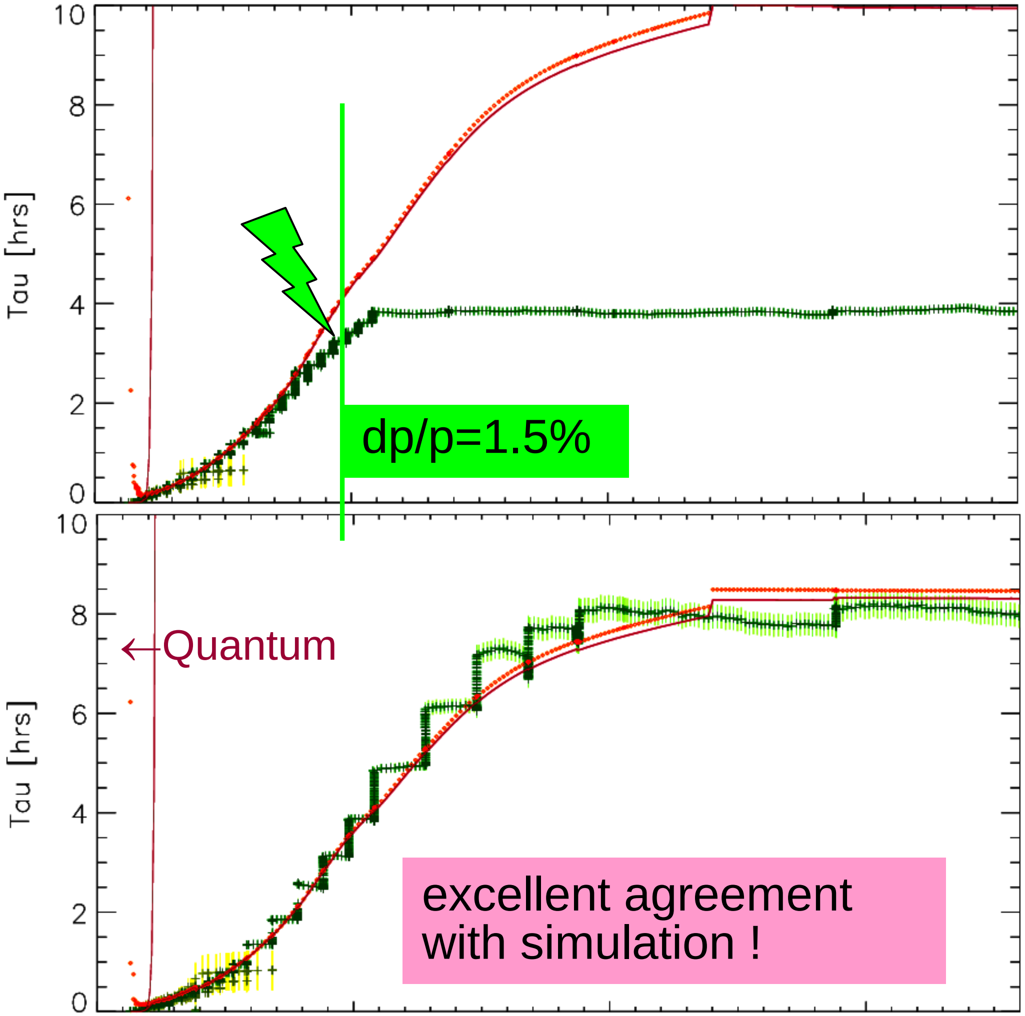
Dispersive horizontal scraper:

+++ measurements

------ TRACY 6D tracking (ideal lattice)

Cx = +3.8

Cx = +0.4



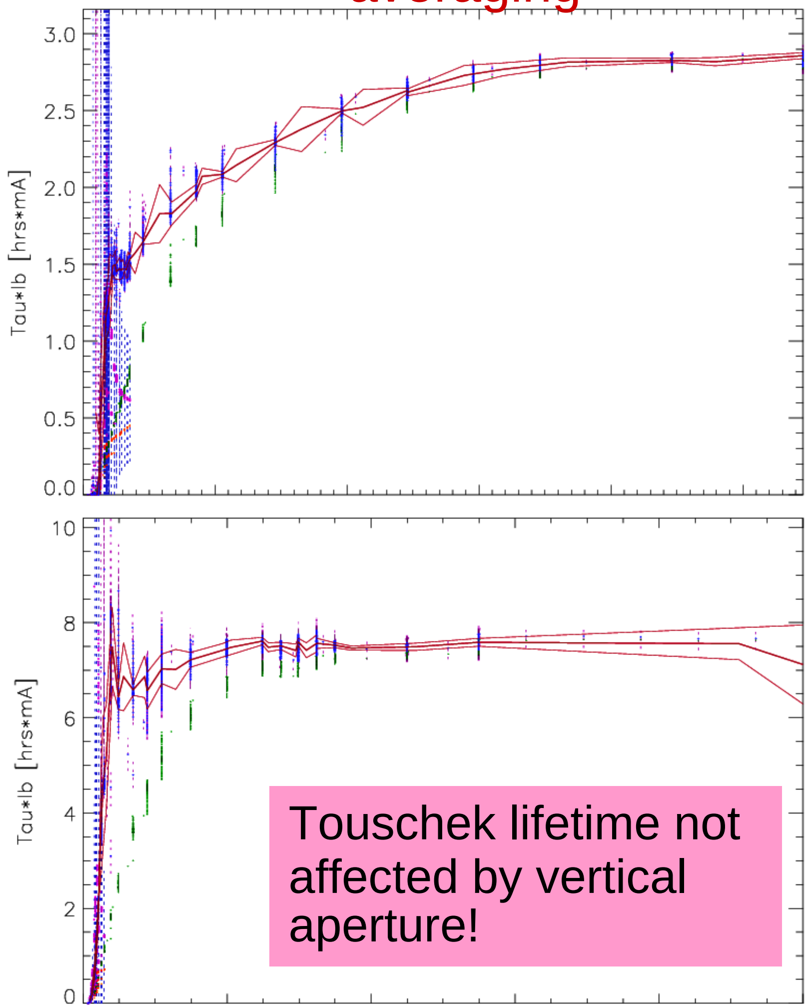
Horizontal scraper position

Vertical scraper:

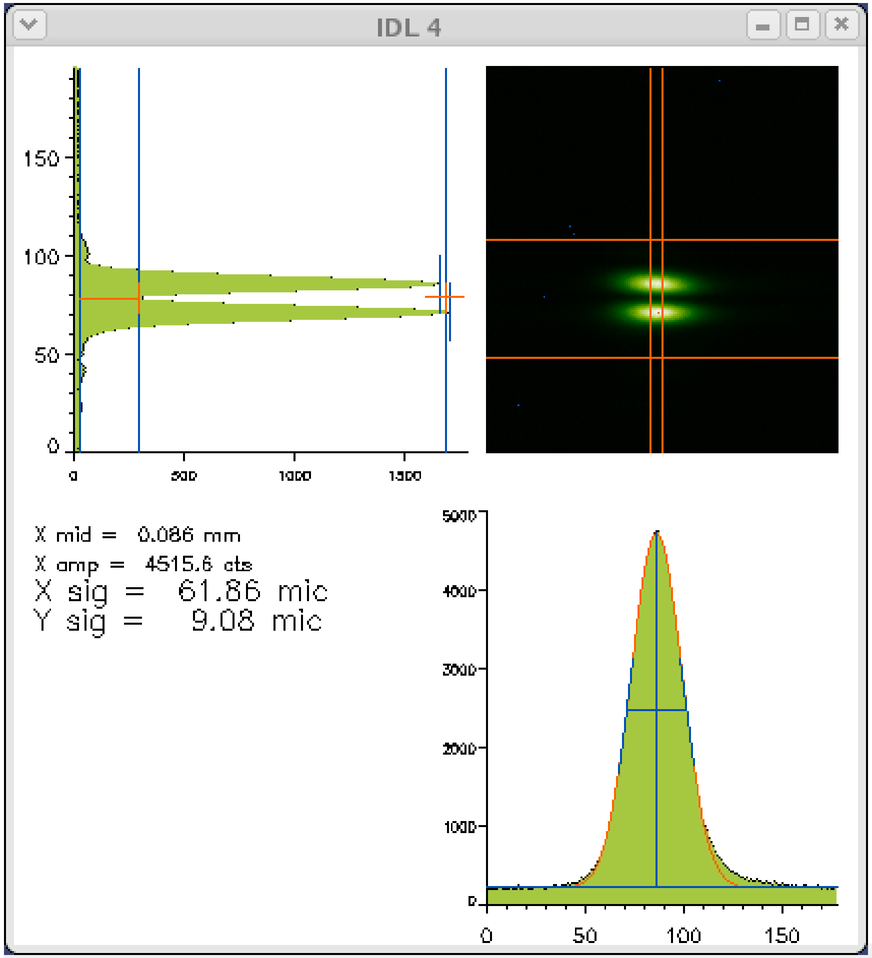
+++ measurements

+++ Touschek only (res. gas subtracted)

------ averaging



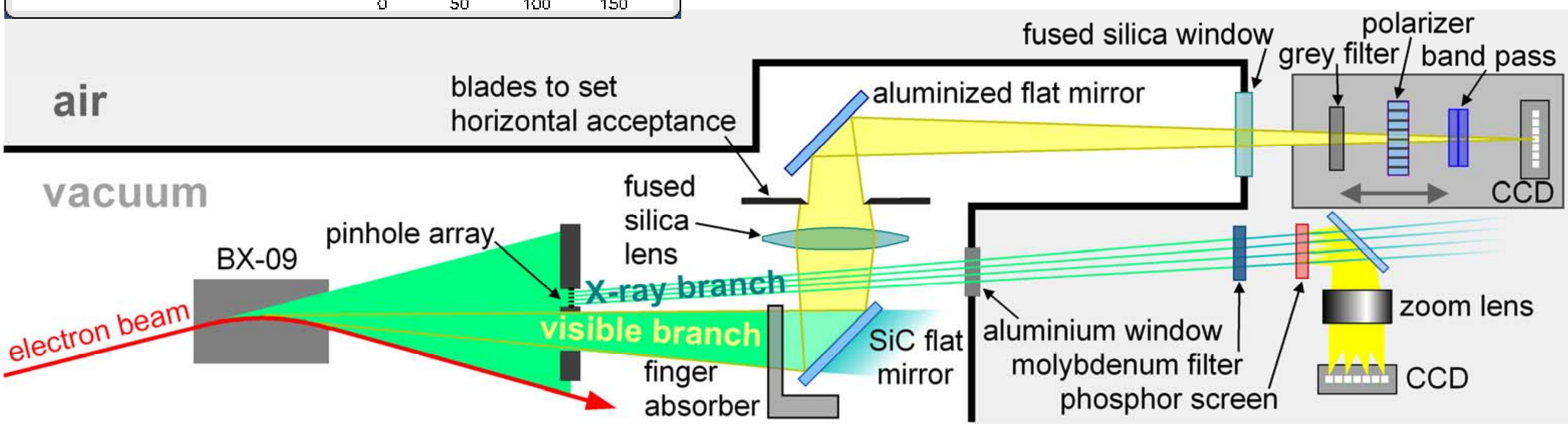
Vertical scraper position



Beam size monitor

vertically polarized, near-UV (384 nm) synchrotron light

Ref.:
Å. Andersson et al, NIM A, in press

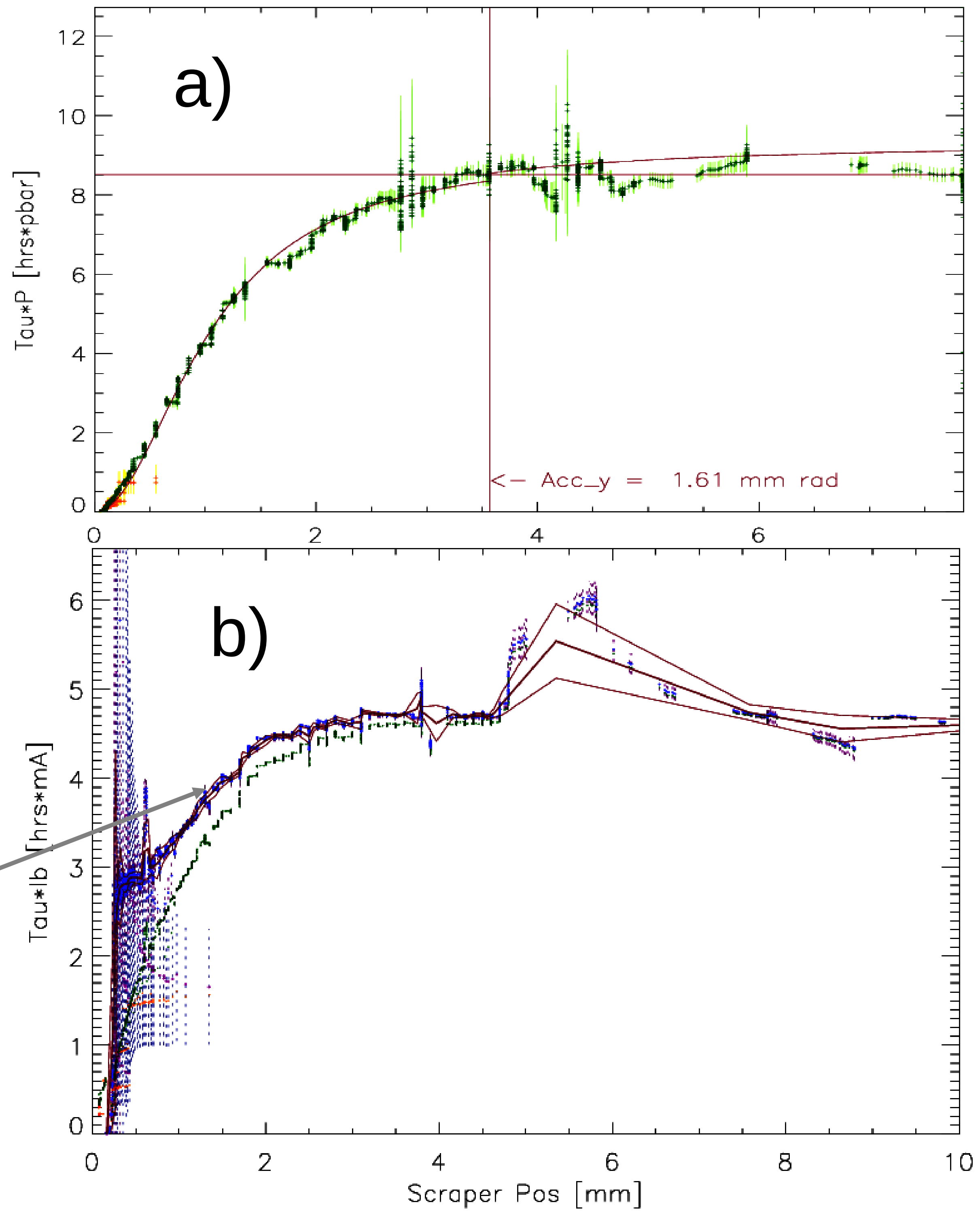


Coupling → 0.15 %

a) 50 mA in 390 bunches: elastic scattering
+++ measurements
------ lifetime fit

b) 50 mA in 50 bunches: Touschek scattering
+++ measurements
+++ Touschek only
------ averaging

Touschek lifetime still affected by vertical aperture.



Momentum acceptance and Touschek lifetime: Conclusions

- Low chromaticity 0...+1
  $(dp/p)_{acc}$ ~3% (like RF), $T \approx 14$ hrs $(k[\%])^{1/2} / I_b[mA]$
- High chromaticity +5
  $(dp/p)_{acc} \rightarrow$ ~1.5% (loc.), $T \approx 6$ hrs $(k[\%])^{1/2} / I_b[mA]$
  Problem: crossing of main coupling and 3Qx

$\Rightarrow$ move working point away from main coupling

$\Rightarrow$ auxiliar sextupoles for ***h***-phase rotation (3Qx et al.)

$\Rightarrow$ improve multi bunch feedback to reduce chroma.

➢ status: 3rd harmonic cavity: $T \rightarrow 3 \cdot T$
  $\Rightarrow$ T = 7...8 hrs at 400 mA (390 bunches), $k \approx 0.15$ %
  $\Rightarrow$ 60..80 sec top-up interval for $\Delta I = 1$mA

Summary

- Vertical acceptance is well understood.
  - Margin for even lower gaps and round beams.
- Horizontal acceptance < theory.
  - but sufficient for 100% injection efficiency.
  - further investigation required.
- Energy acceptance and Touschek lifetime:
  - good for low chromaticity, bad for high.
  - wide tune spread for high chromaticity leads to crossing of coupling and nonlinear resonances.
  - another working point and auxiliary sextupoles may help.
- Beam lifetime 8 hrs in user operation is acceptable.