Apertures of the BESSY Storage Ring

P. Kuske, BESSY

Introduction – Light Source Layout, Features, Lattice

Apertures

• **physical**

•**longitudinal** – cavity voltage scan

• **vertical** – scraper and (kick excitation experiments)

• **horizontal** – (scraper) and kick excitation experiments

Studies of the horizontal aperture

• **impact of intensity, septum stray field, and slicing setup**

• **tune dependent dynamical limitations** – with 4 sc IDs

Conclusions

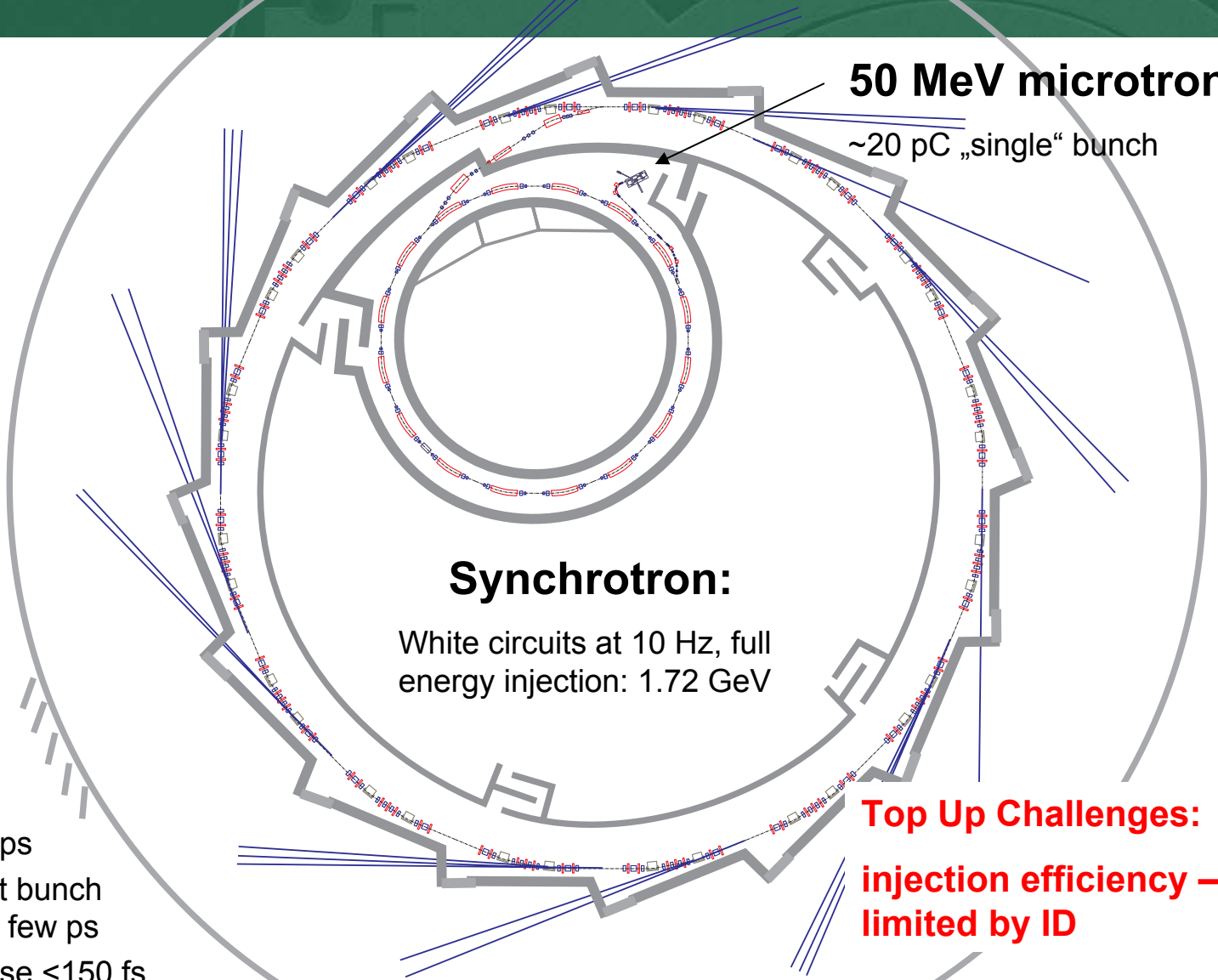
Features of the BESSY Light Source

Storage Ring:
14 straight sections:
12 wiggler/undulators
– 6 APPLE II-type
VUV-range, polarisation

up to 50 keV
with 4 sc WLS

IR to coherent THz-radiation
bending magnets

time resolution:
4 weeks single bunch,
pulse duration 40 – 100 ps
~2 weeks low alpha/short bunch operation, pulse duration few ps
fs-slicing operational, pulse <150 fs

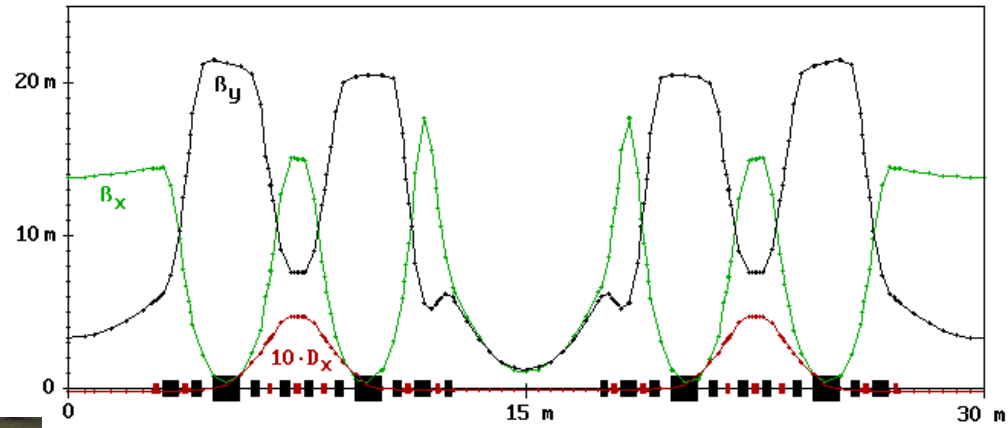


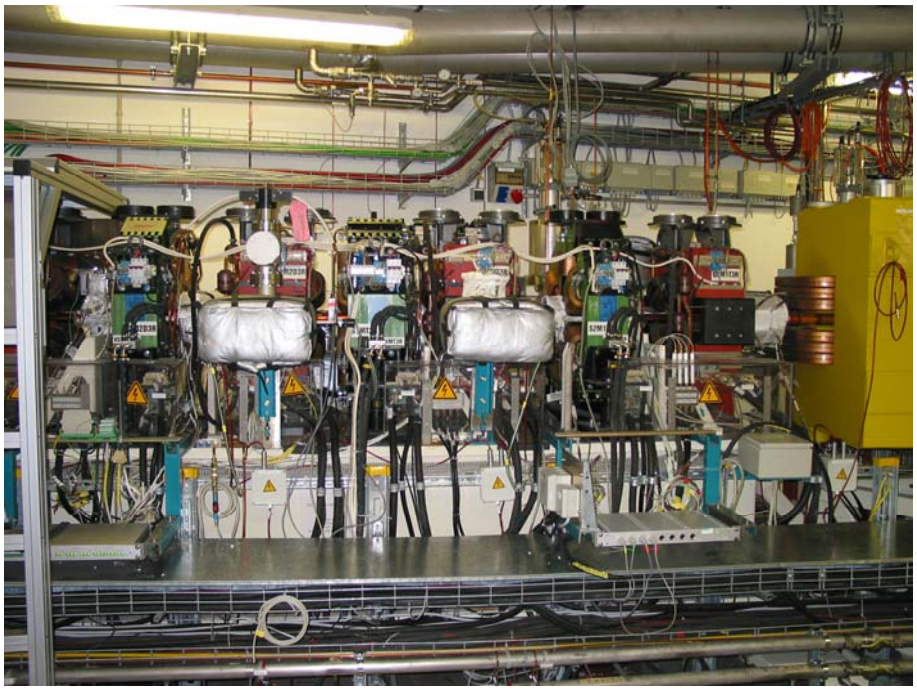
Lattice – Linear Optics

Double Bend Achromat with 7 sextupole families

high and low beta straights with doublet or triplet focusing

8 fold symmetry – broken by 7 T wiggler





closely spaced magnets

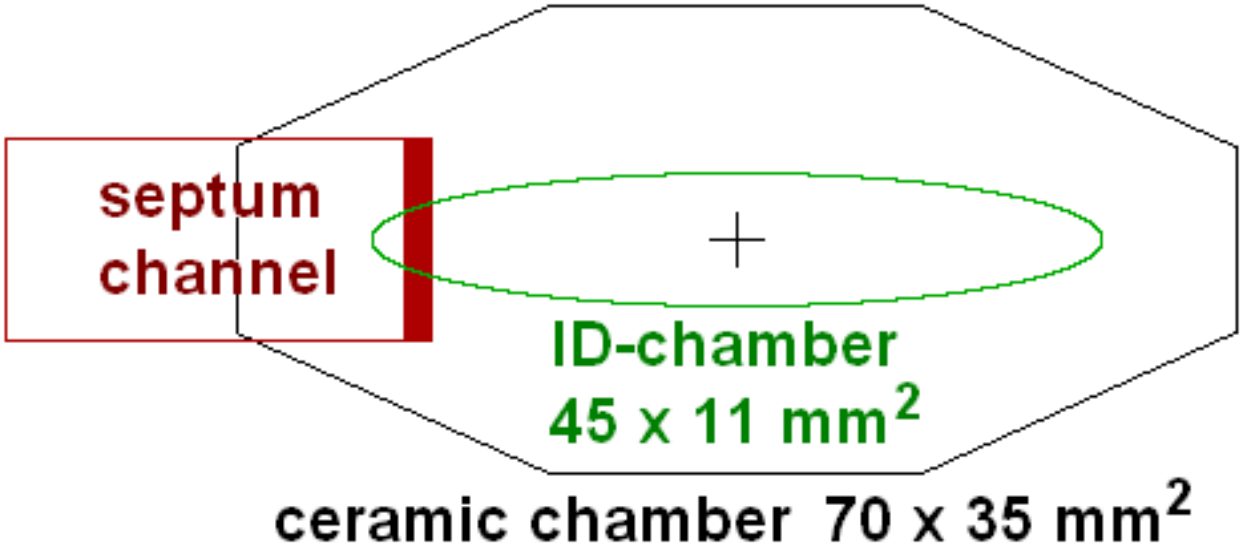
sextupole magnets serve as dipole- and skew quadrupole correctors - with impact on horizontal dynamic aperture

$\varepsilon_0 = 6 \cdot 10^{-9}$ π m rad, $\varepsilon_y/\varepsilon_x \sim 3\%$

injection every 8 hours: 290 mA + 10 mA single bunch in 100 ns dark gap

lifetime: 10 h @ 300 mA, single bunch 3 h

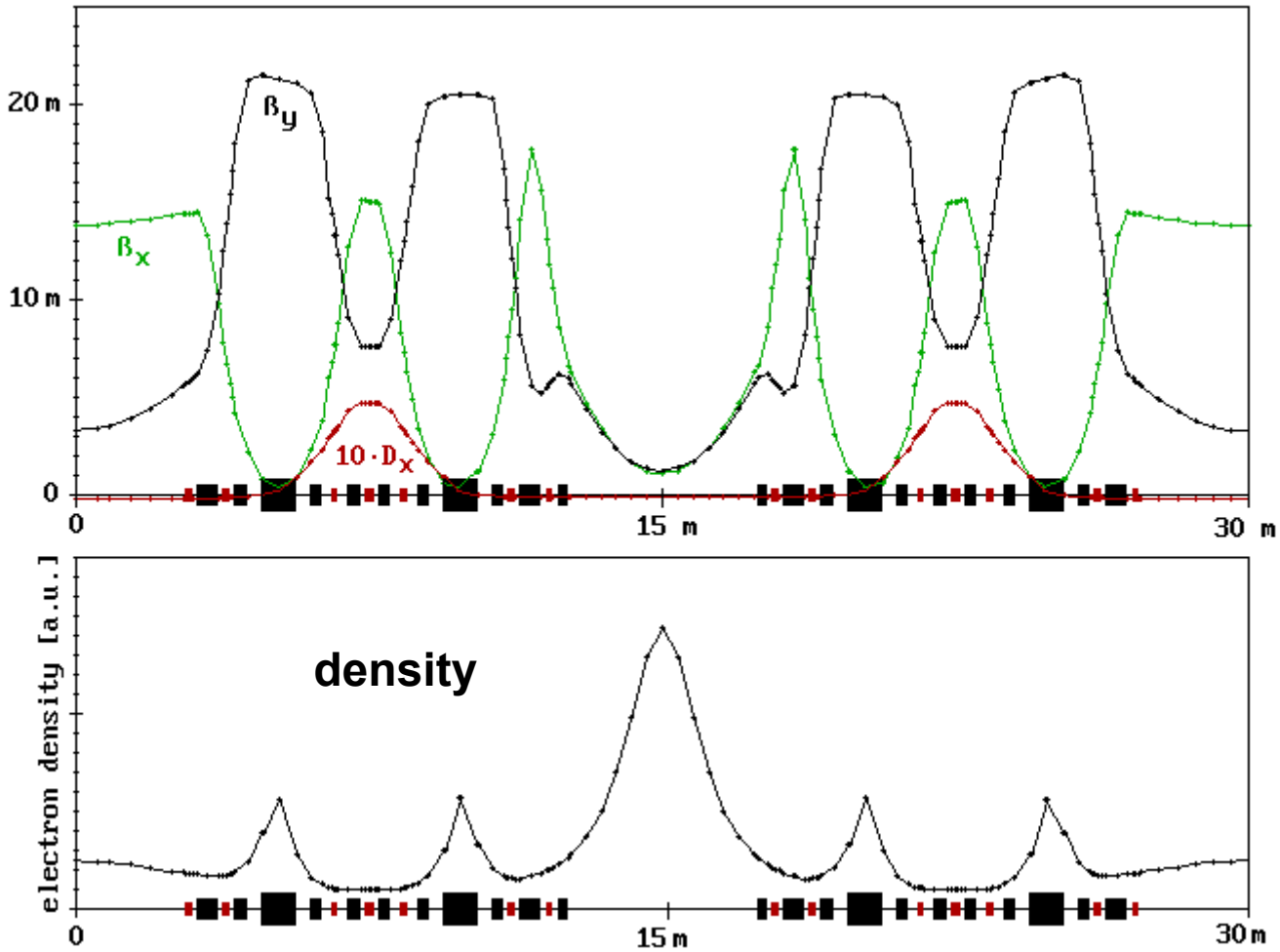
Physical Apertures



smaller due to

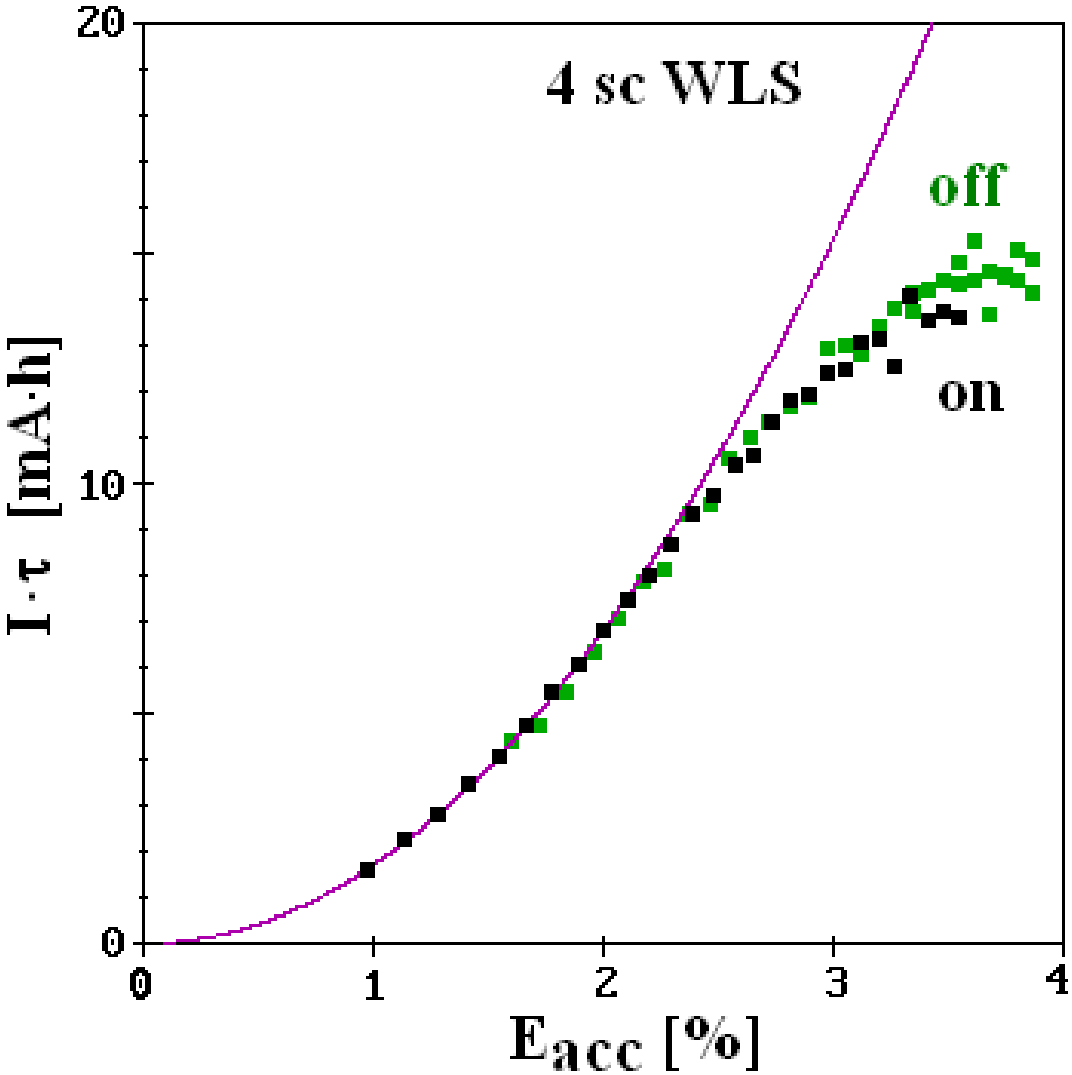
- **slicing set up**
- **manufacturing tolerances of the chambers**
- **alignment errors of girders**

Touschek Scattering and Longitudinal Acceptance



highest particle density where dispersion is zero → Touschek scattered particles move on dispersive orbits

Longitudinal Acceptance



soft limit ~2.5% energy acceptance

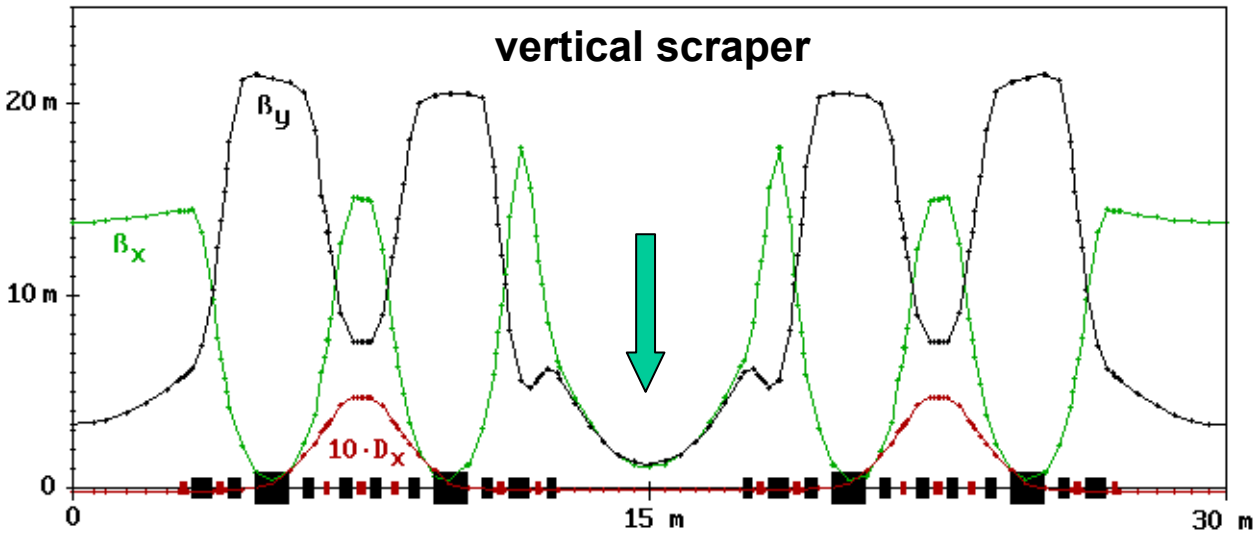
no impact of two 7T-WLS, one 4T-WLS and one 7T-Wiggler

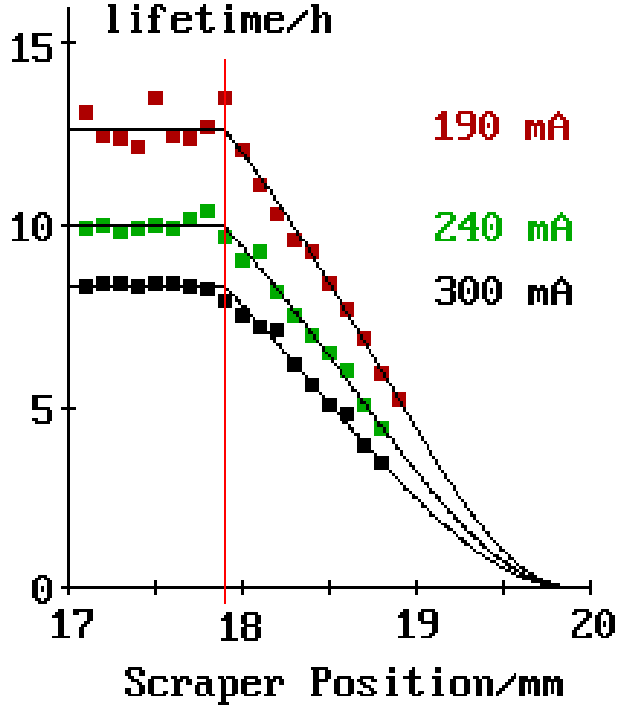
Lifetime and Vertical Aperture

elastic Coulomb scattering @ 1.7 GeV is one of the dominant loss mechanisms

in the vertical plane:
loss rate depends on pressure especially in the dipole chambers where β_y is largest

lattice functions

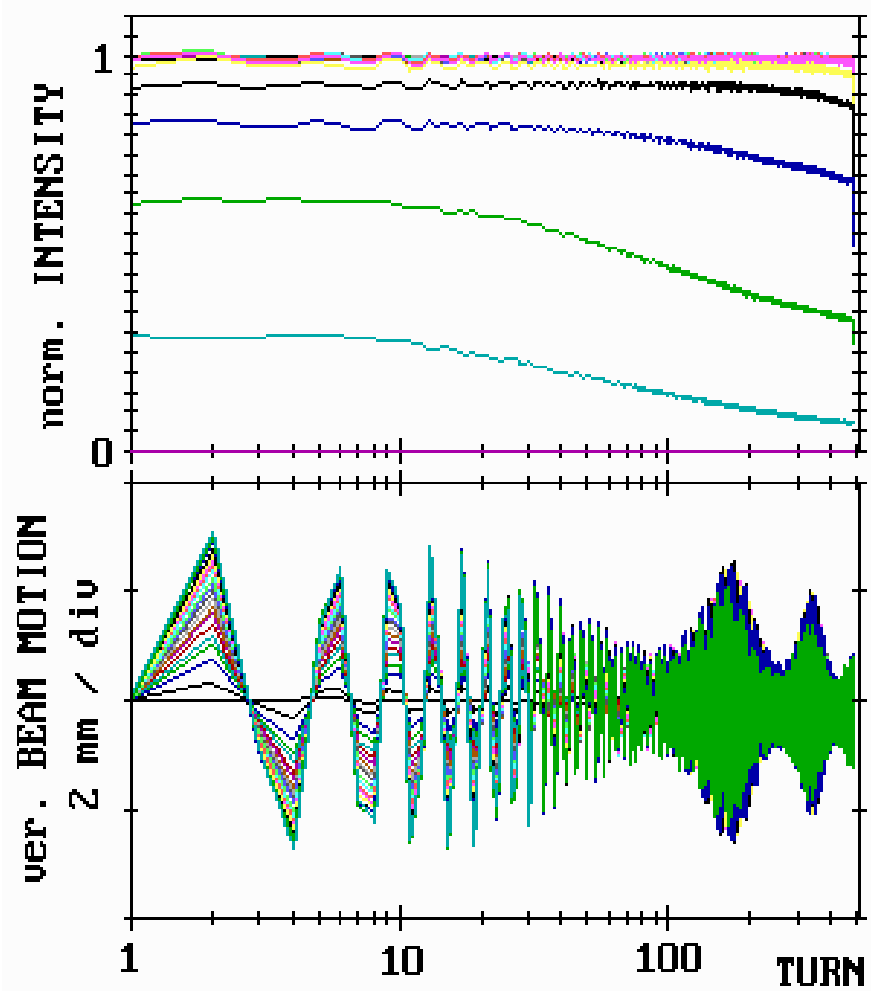


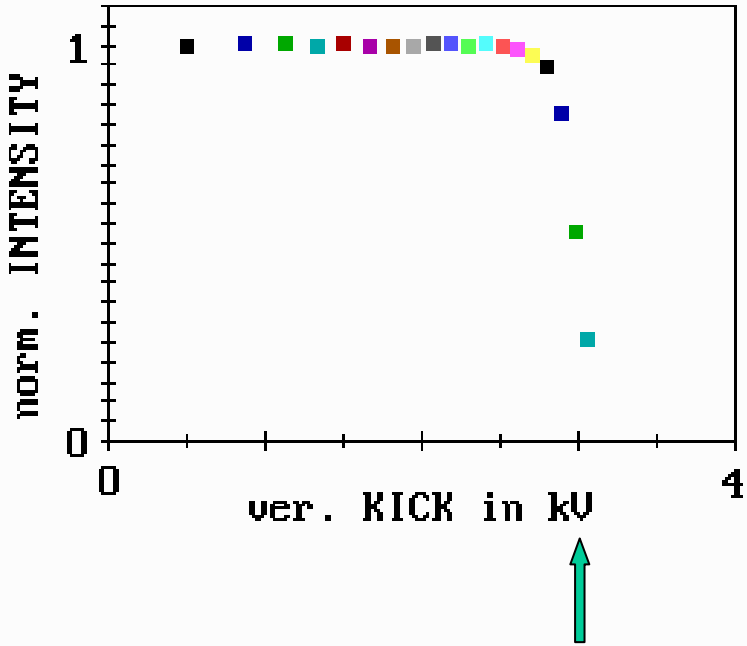


aperture of 2.1 mm is expected from the small vertical gap of ID chambers

Vertical Aperture Determination

kick excitation until particles get lost

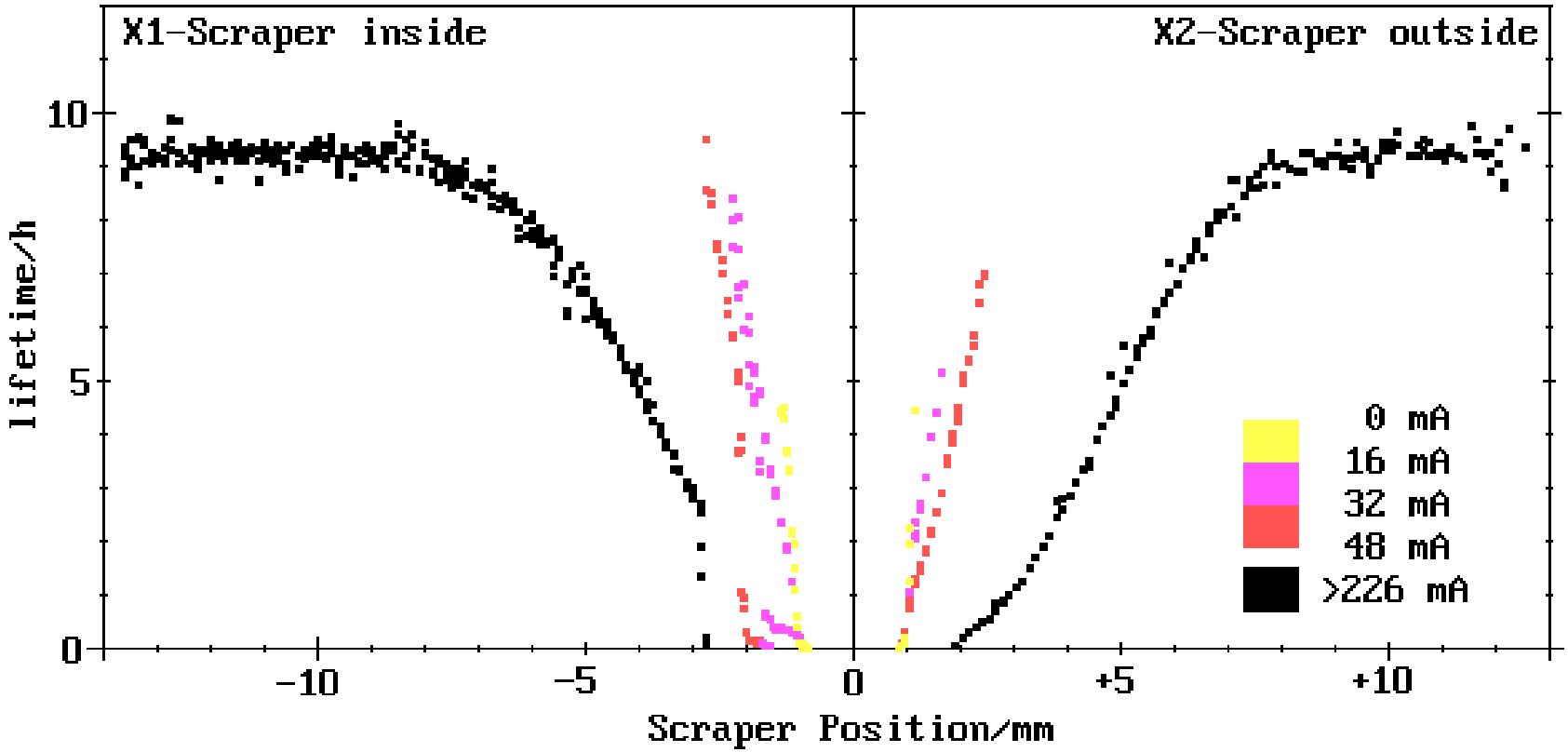




“verticall aperture“ – kick strenght where half of the beam is lost

Horizontal Aperture

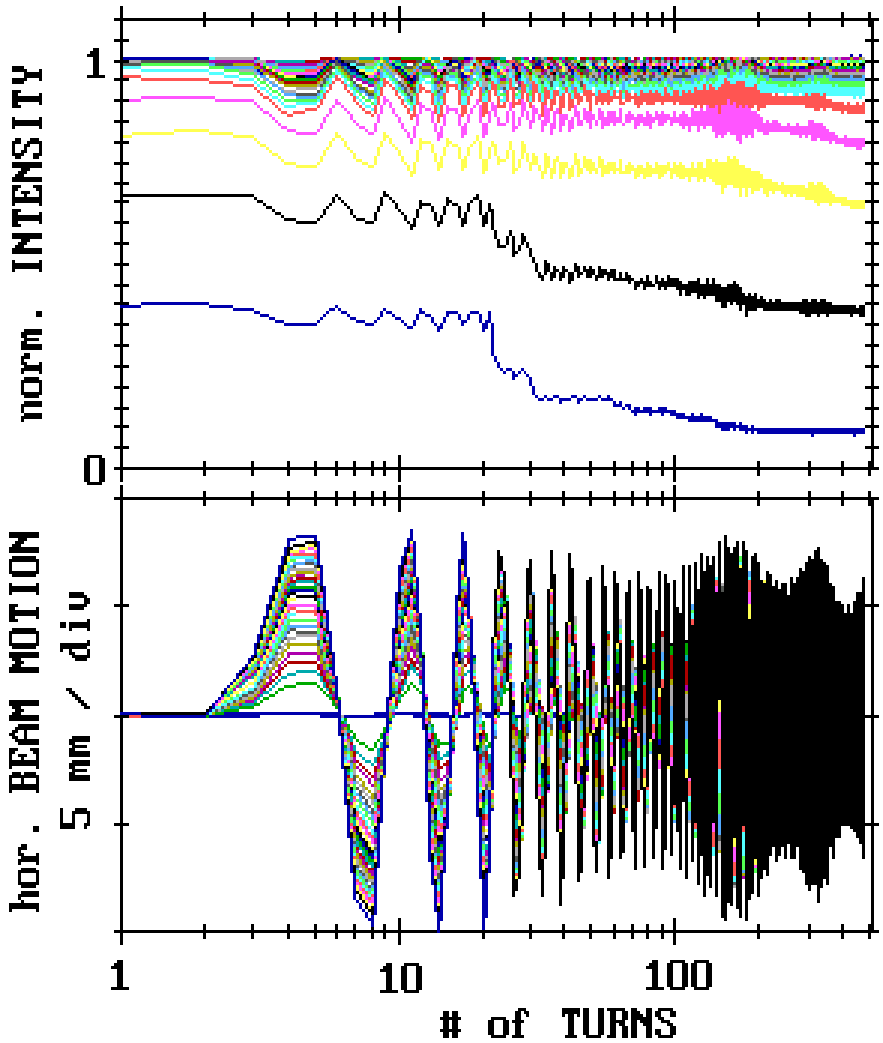
two horizontal scraper in the low β_x-straight section

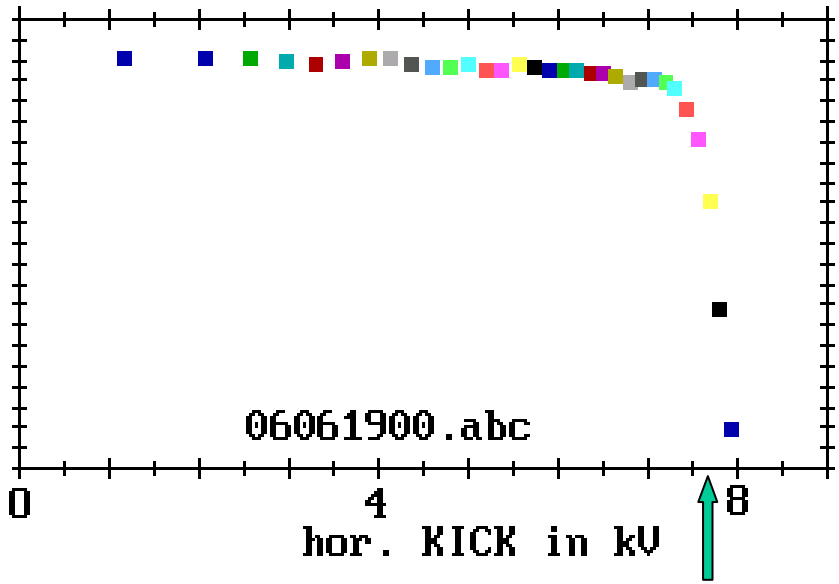


shadow of septum at -12.1 m –
no clear limitation visible

Horizontal Dynamic Aperture

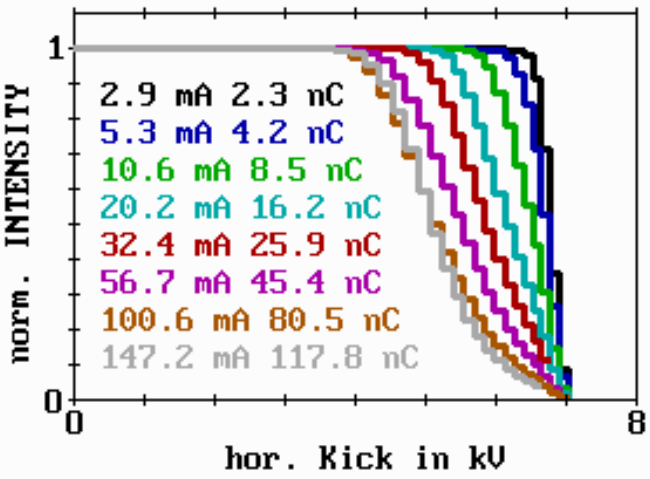
kick excitation until particles get lost





"horizontal aperture" – kick strenght where half of the beam is lost

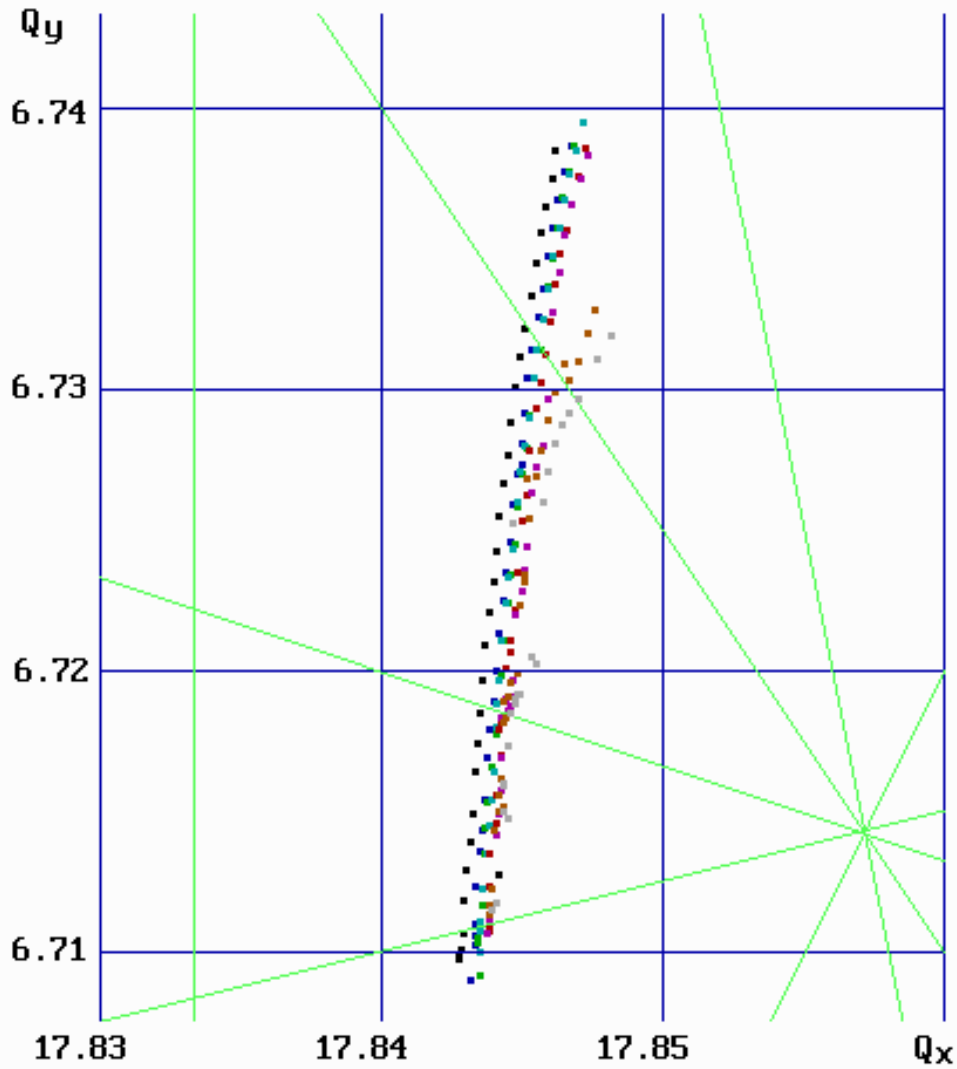
Horizontal Aperture vs. Intensity



100 ns-long bunch train

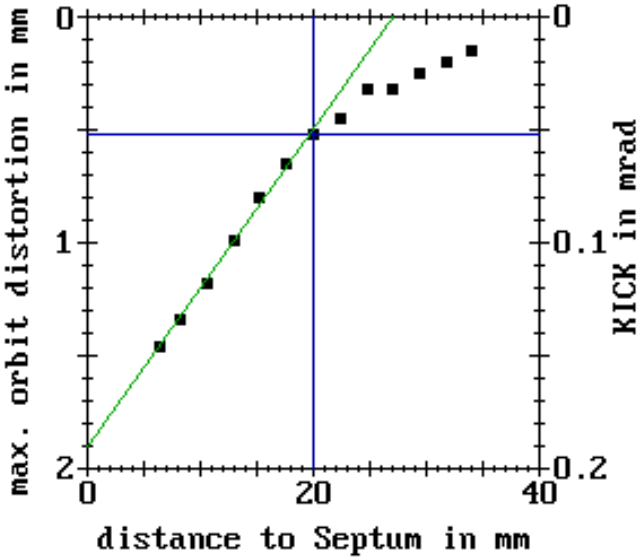
high intensity: vertical defocusing and horizontal focusing

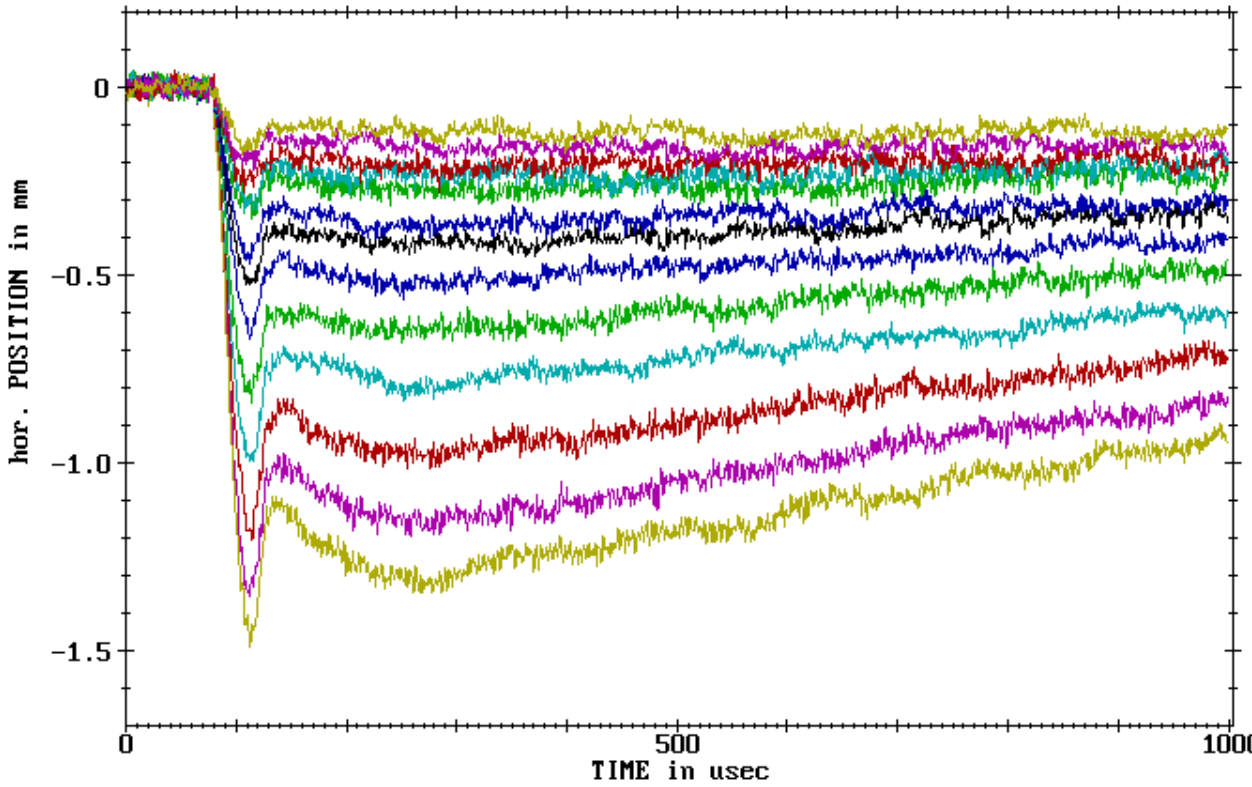
injected beam sees transverse wakes of much larger stored beam



Horizontal Aperture at Injection

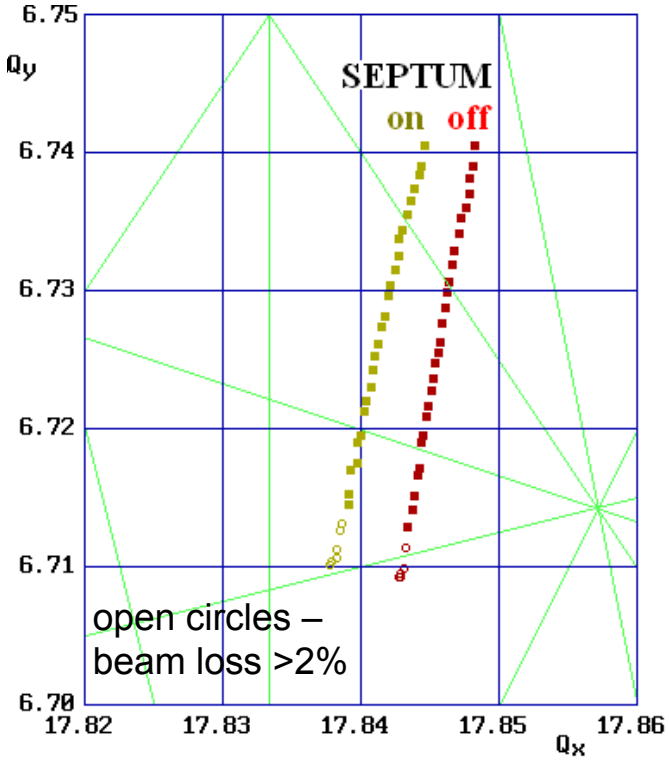
long lasting septum stray field significantly perturbs the orbit of the stored beam

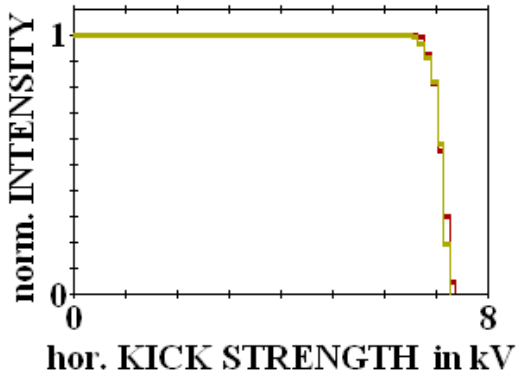


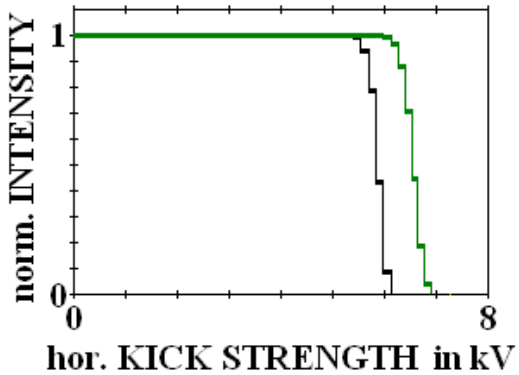


injected beam oscillates in the non-linear stray field

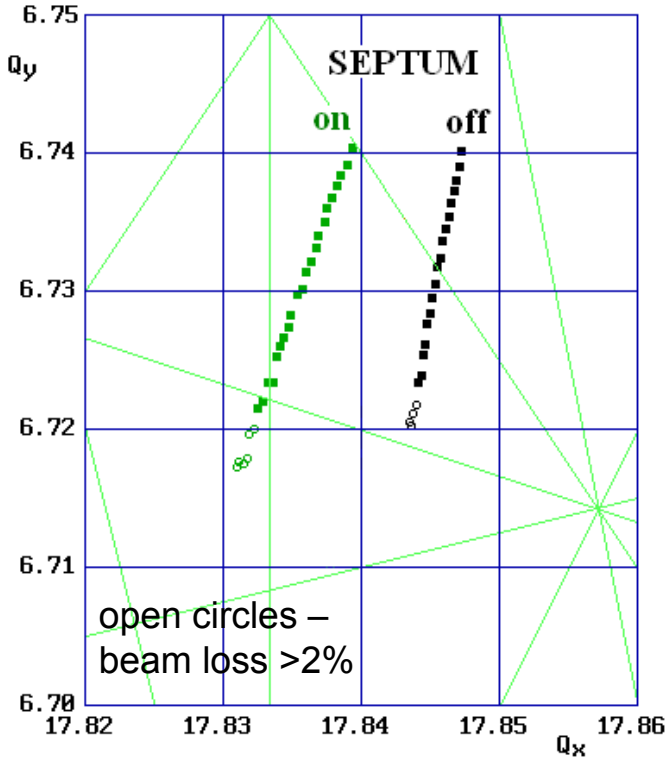
Horizontal Beam Dynamics of Injected Beam





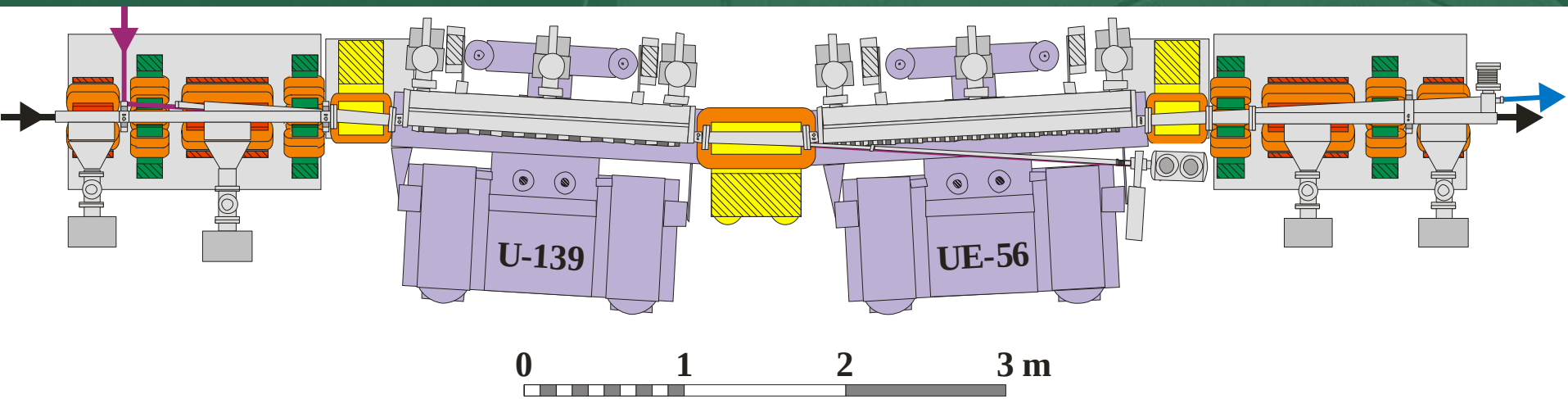


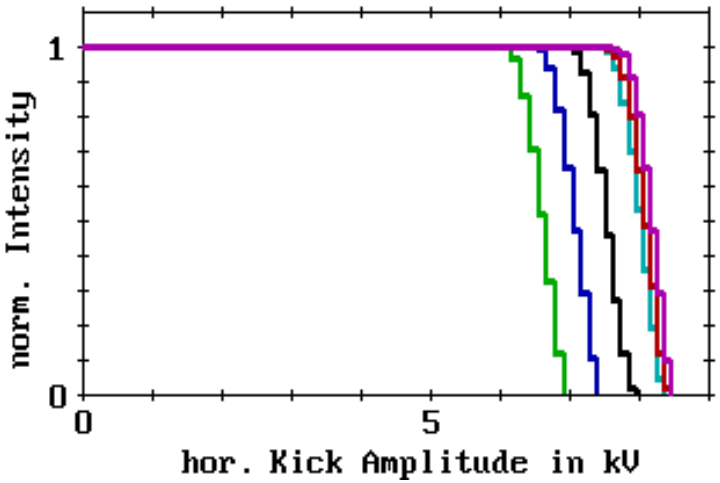
beam closer to septum

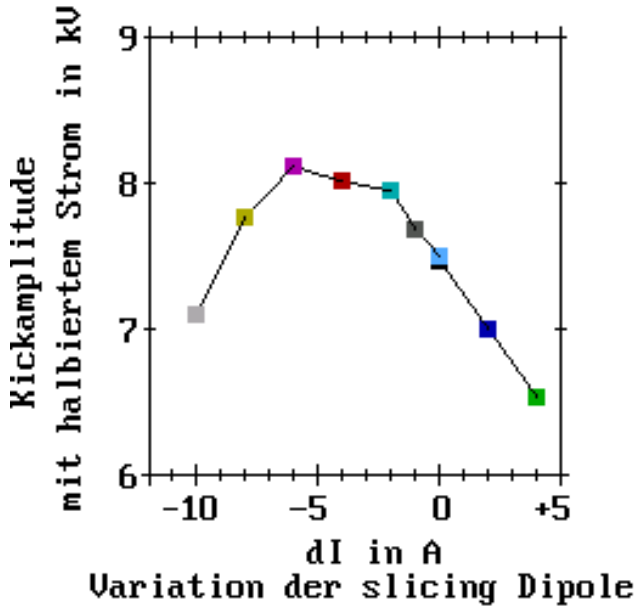


injected beam perturbed by non-linear strayfield of the septum: shifts the horizontal tune and modifies amplitudedependent tune shift, inj. beam pushed away from the septum

Horizontal Dynamic Aperture

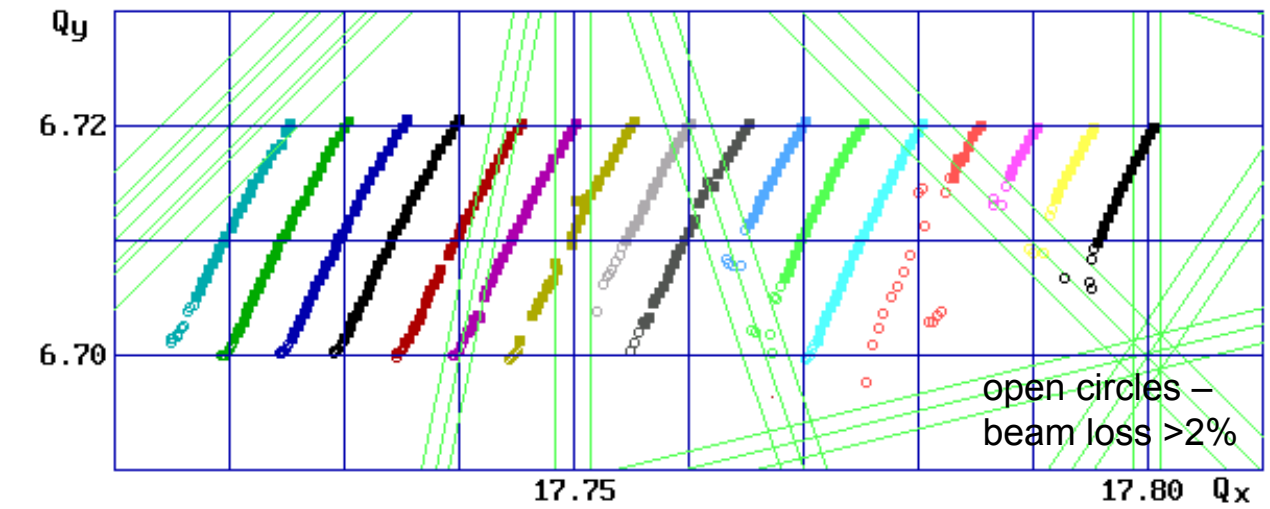


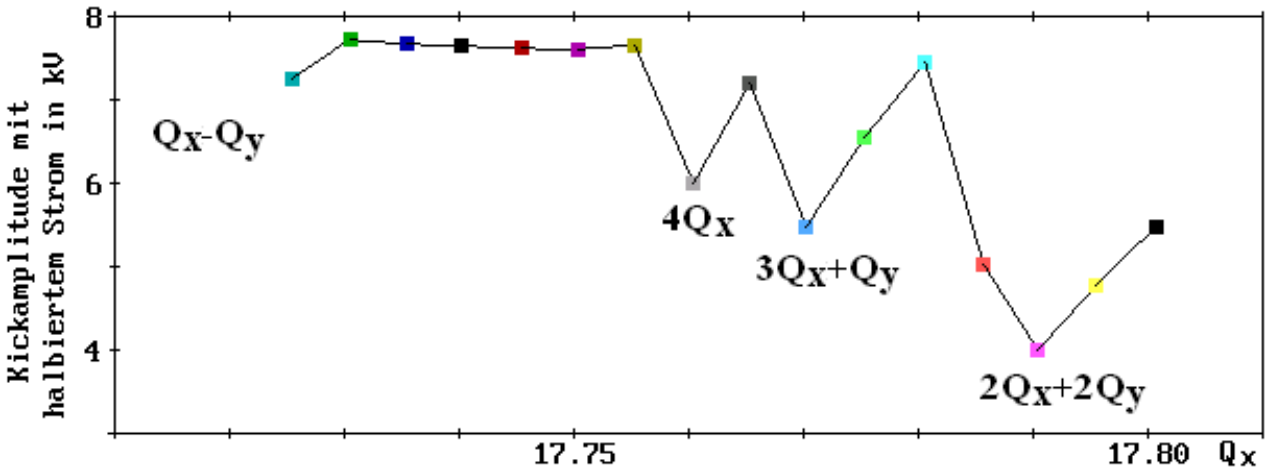




physical aperture increased if bump-amplitude is slightly reduced - black: nom. hor. position

Horizontal Dynamic Aperture vs. Tune

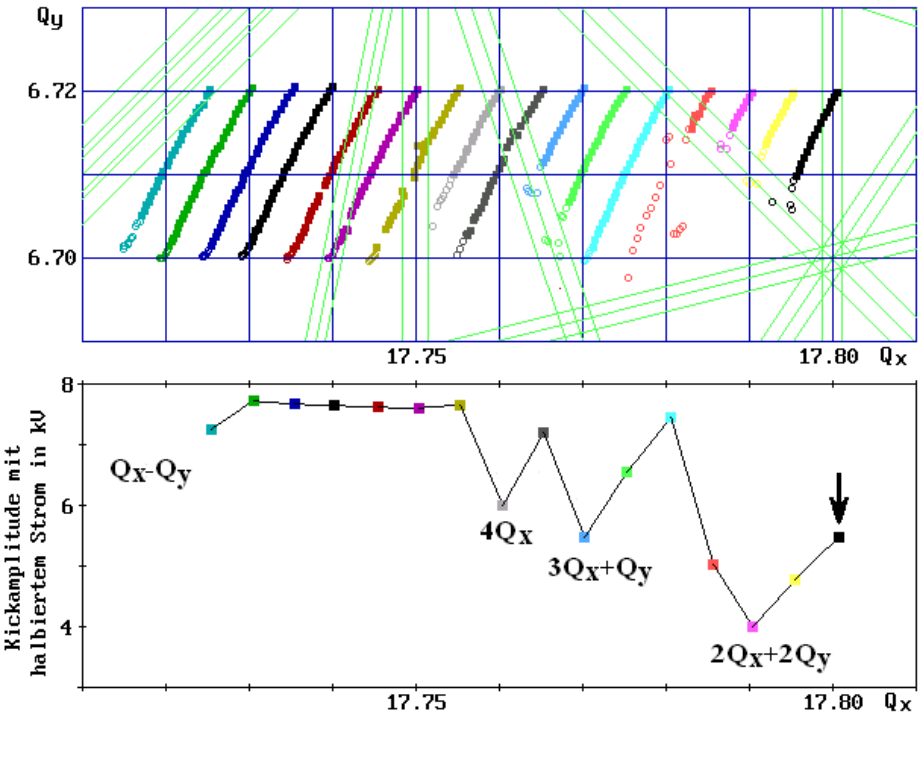


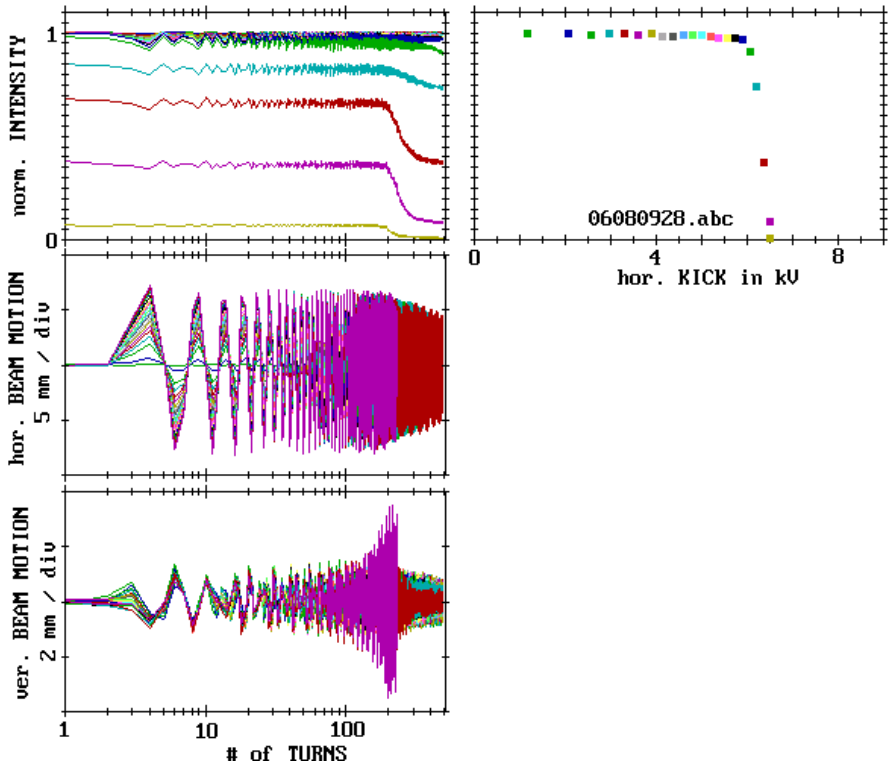


$\xi_{x,y} \sim 0$

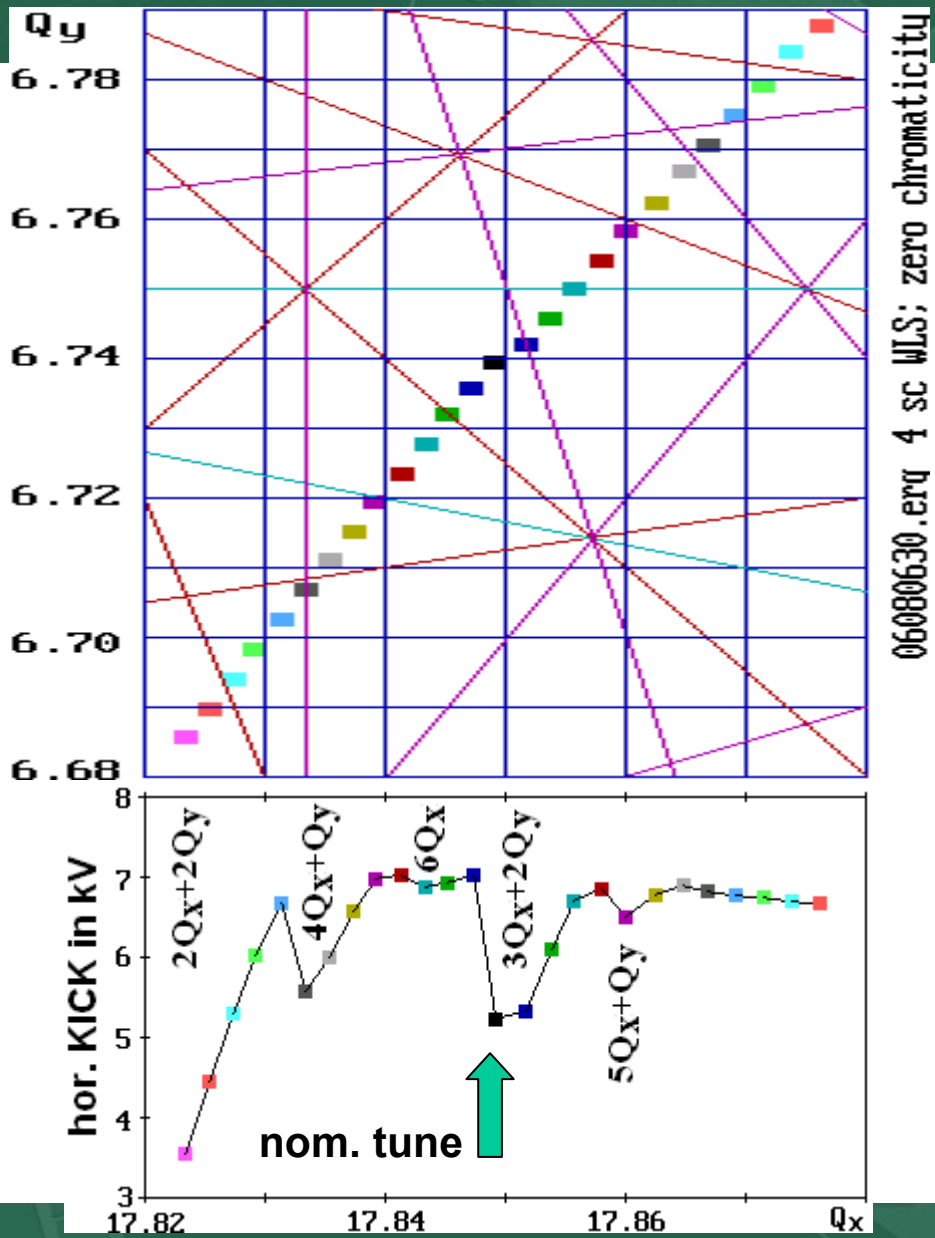
with 4 sc WLS

Horizontal Dynamic Aperture - Tune Dependence





Horizontal Dynamic Aperture vs. Tune



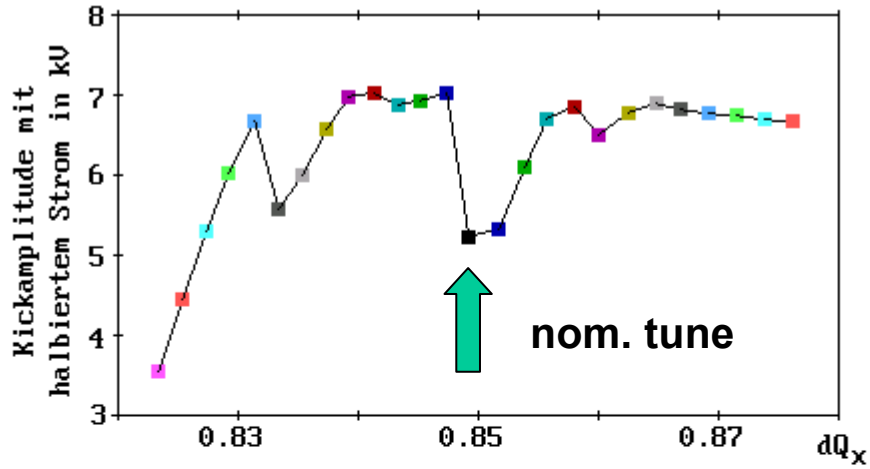
initial tune varied like the amplitude dependent tune shift

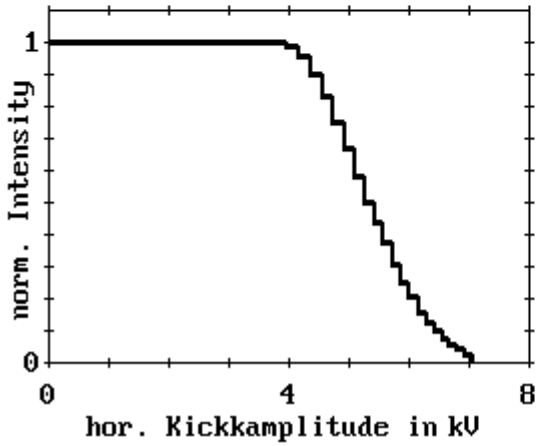
$\xi_{x,y} \sim 0$

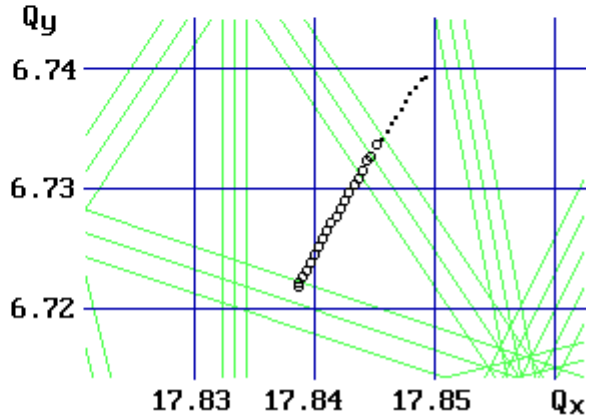
with 4 sc WLS

proposed by F. Schmidt

Horizontal Dynamic Aperture - Tune Dependence



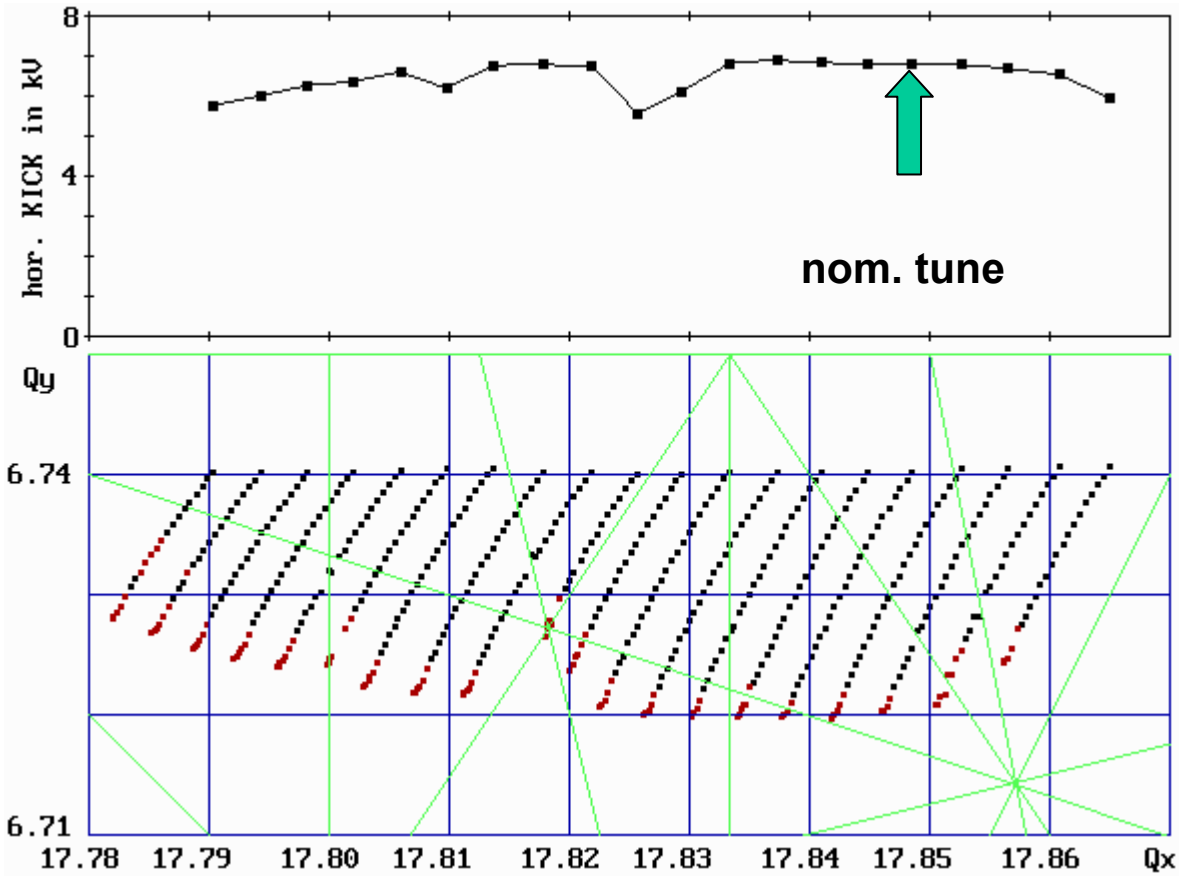




$\xi_{x,y} \sim 0$

with 4 sc WLS

Horizontal Dynamic Aperture vs. Tune

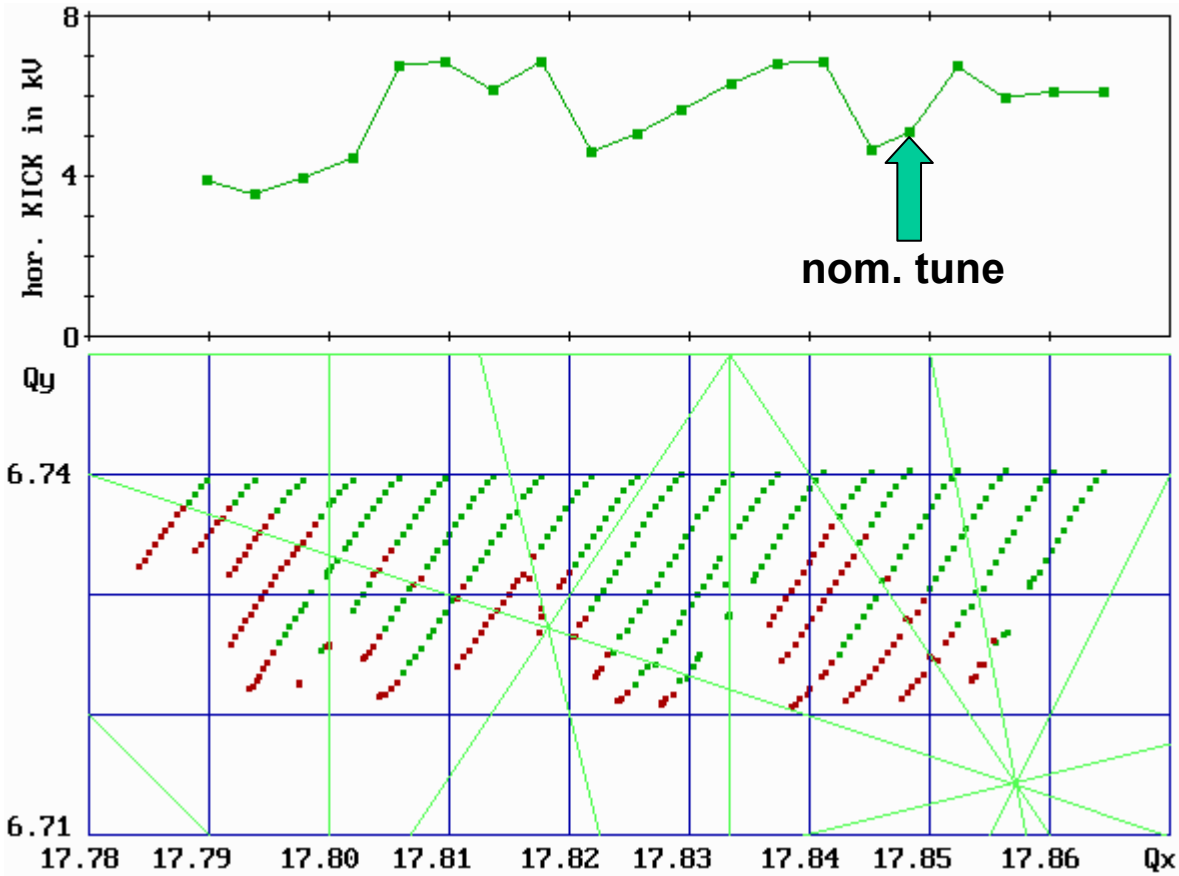


red dots –
beam loss >2%

$\xi_{x,y} \sim 0$

with 4 sc WLS

U125ID2R – gap=15.7 mm

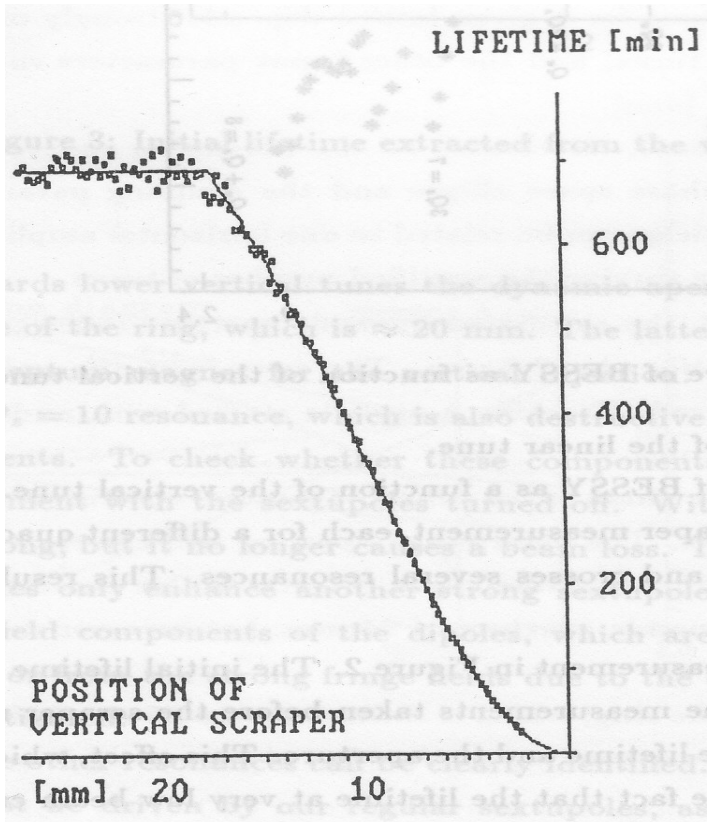


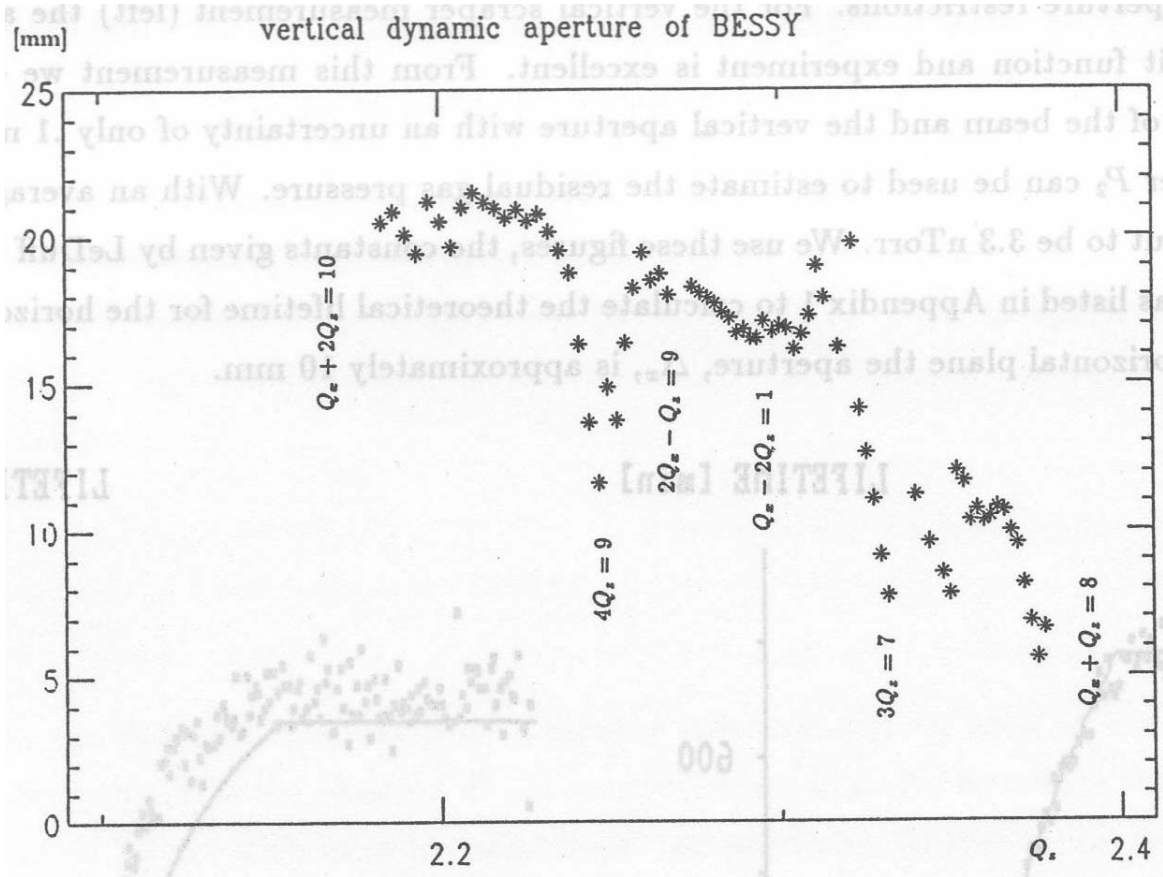
red dots –
beam loss >2%

$\xi_{x,y} \sim 0$

with 4 sc WLS

BESSY I - 20 Years ago: Vertical Dynamic Aperture vs. Tune





Bettina Simon, Peter Kuske in „The Dynamic Aperture of BESSY“

2nd advanced ICFA Beam Dynamics Workshop in Lugano, 1988, CERN 88-04

Conclusions

Apertures of the BESSY II Storage Ring:

- longitudinal acceptance of ~2.5% determined with a cavity voltage scan – not as large as desired
- vertical aperture determined with scraper in agreement with expectations – physically limited
- horizontal acceptance determined by kicking the beam – physically limited
- dynamic horizontal aperture often smaller – due to non-linear field components (lattice and ID)
- as a consequence – septum will be moved closer to the stored beam – will relax injection kicker requirements