Injection Efficiency – Impact of IDs on the Horizontal Beam Dynamics

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Introduction – Top Up, static and dynamic field components

Planar Undulator U125

• before re-shimming

• afterwards

•remaining problems

APPLE II-type Undulator UE112

compensation of dynamic field components:

• passive – with L-shims in the elliptical mode

• active – with current carrying wires in the inclined mode

•non-linear lens

Summary

Top Up operation - radiation safety requirement:

Injection efficiency > 90 %, assured by interlock

currently impossible with the IDs installed at BESSY – especially if located in high $ß_x$ straight sections (like the U125 and the UE112)

Mechanism of the beam interaction with IDs

problems can arise from poor field quality of ID – *static field components:*
prop. 1/E - example U125, before re-shimming

oscillatory beam motion - even in the ideal 3D-undulator fields - leads to noticeable modifications of the dynamics – *dynamic field components, prop.* $1/E^2$*:*

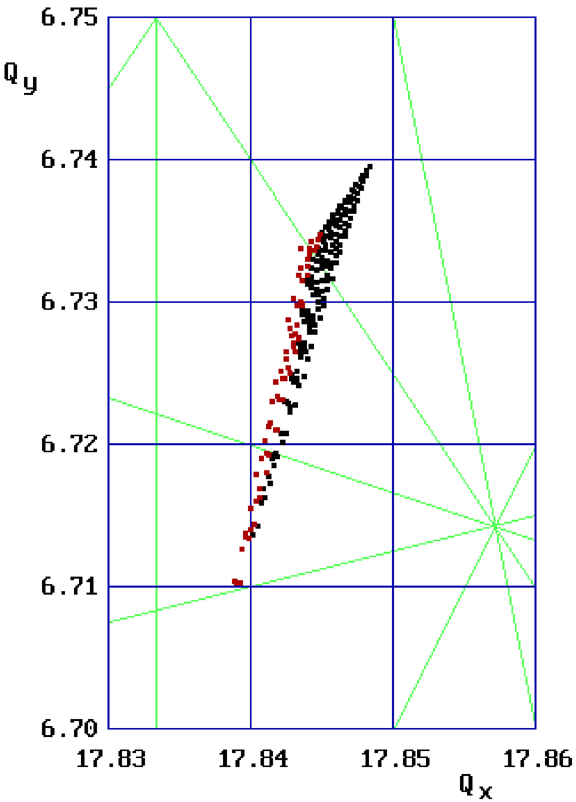
- **horizontal plane – field roll-off due to finite width of poles, non-linearity important for large beam excursions**
- **vertical focusing – like in ordinary dipoles, non-linearity usually not important**

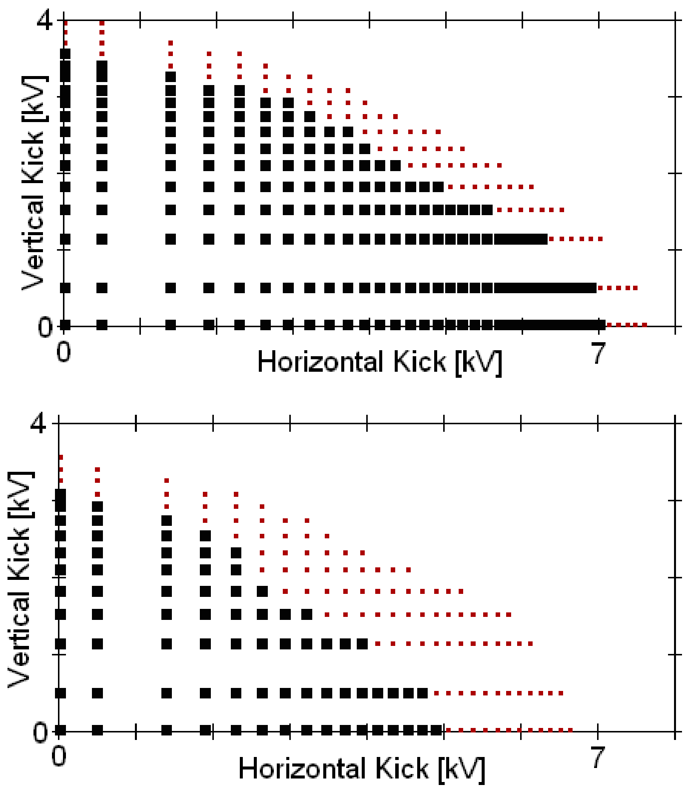
APPLE-type undulators show a mixture of both effects

general observation: injection efficiency scales with the available dynamic aperture

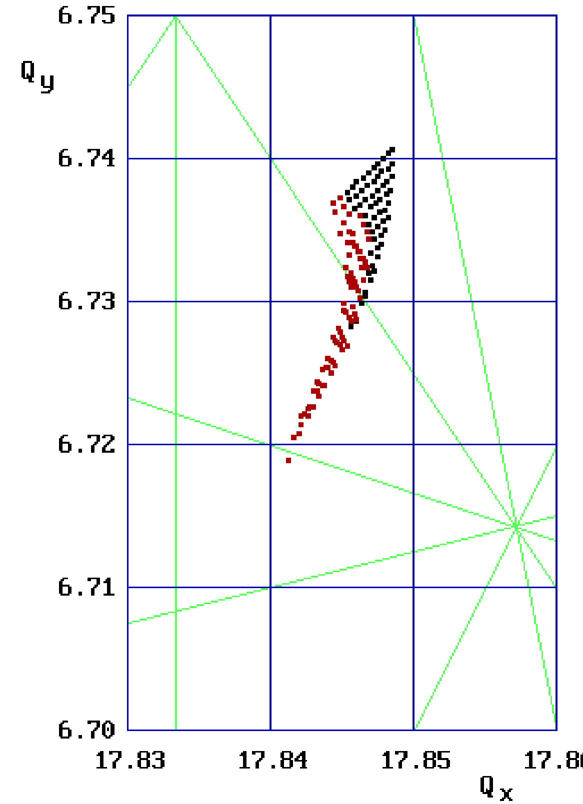
Static Field Errors: U125ID5R

ID-gap open





U125ID2R = 15.7 mm



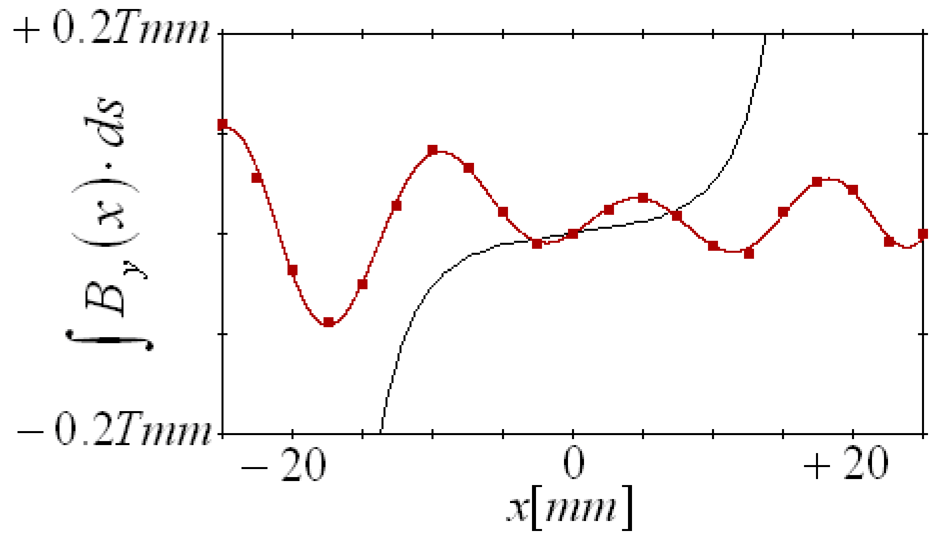
U125ID2R planar undulator with 1 T peak field:

- Expected modification of vertical beam dynamics – aperture reduction linear effect
- Unexpected horizontal dynamics – 30% reduction of dynamic aperture

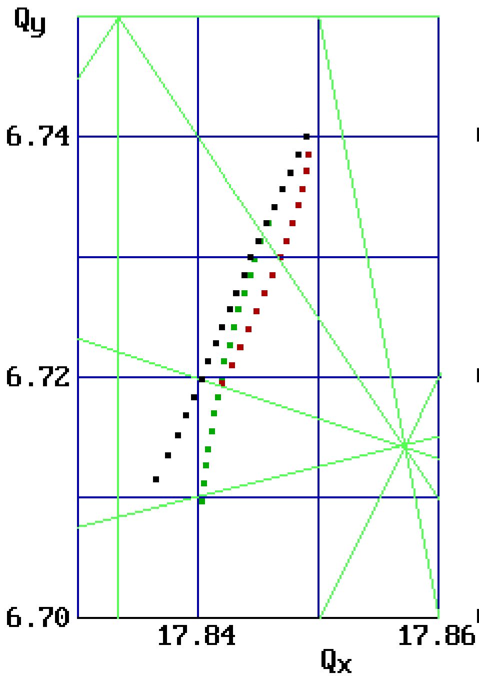
Static Field Errors: U125ID2R, gap = 15.7 mm

horizontal beam dynamics:
•dynamic field integrals due to field roll off
(estimated by J. Bahrdt)

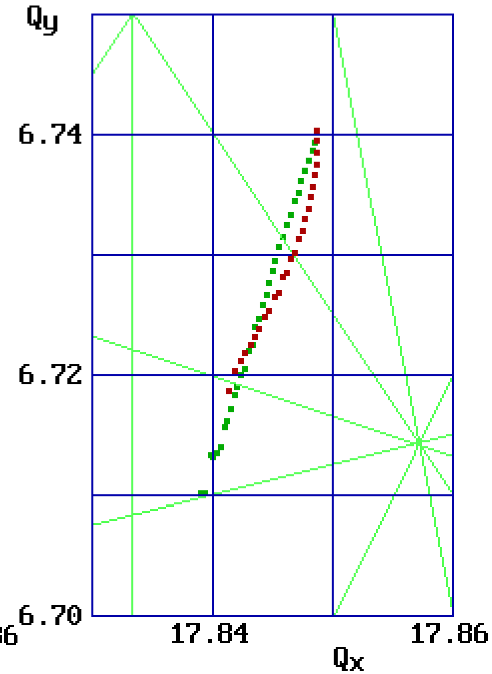
•static field integrals
stretched wire measurement (BESSY ID-group)



theory



measurement



•gap open

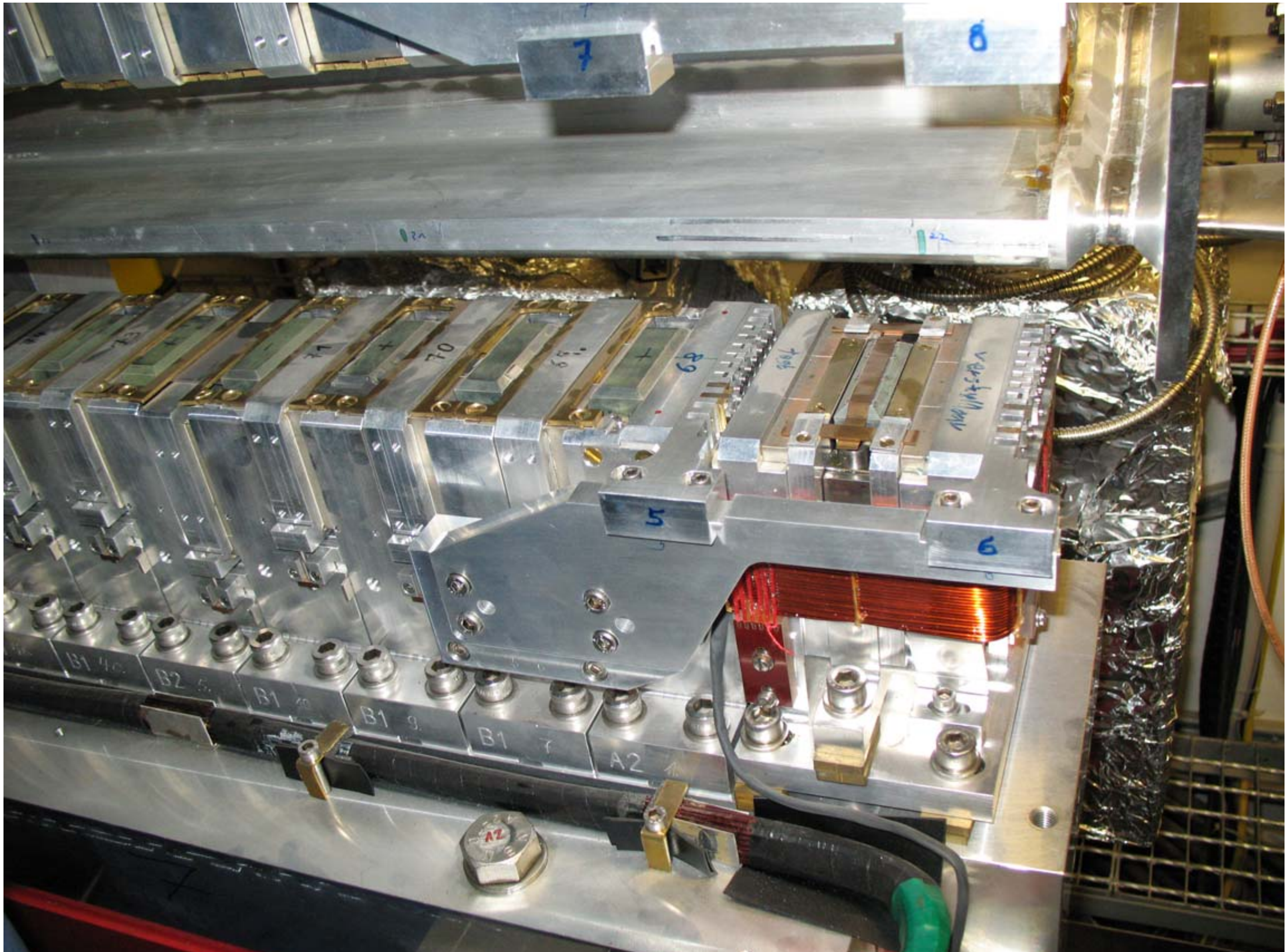
•gap closed - dynamic effects only

•gap closed - dynamic and static effects

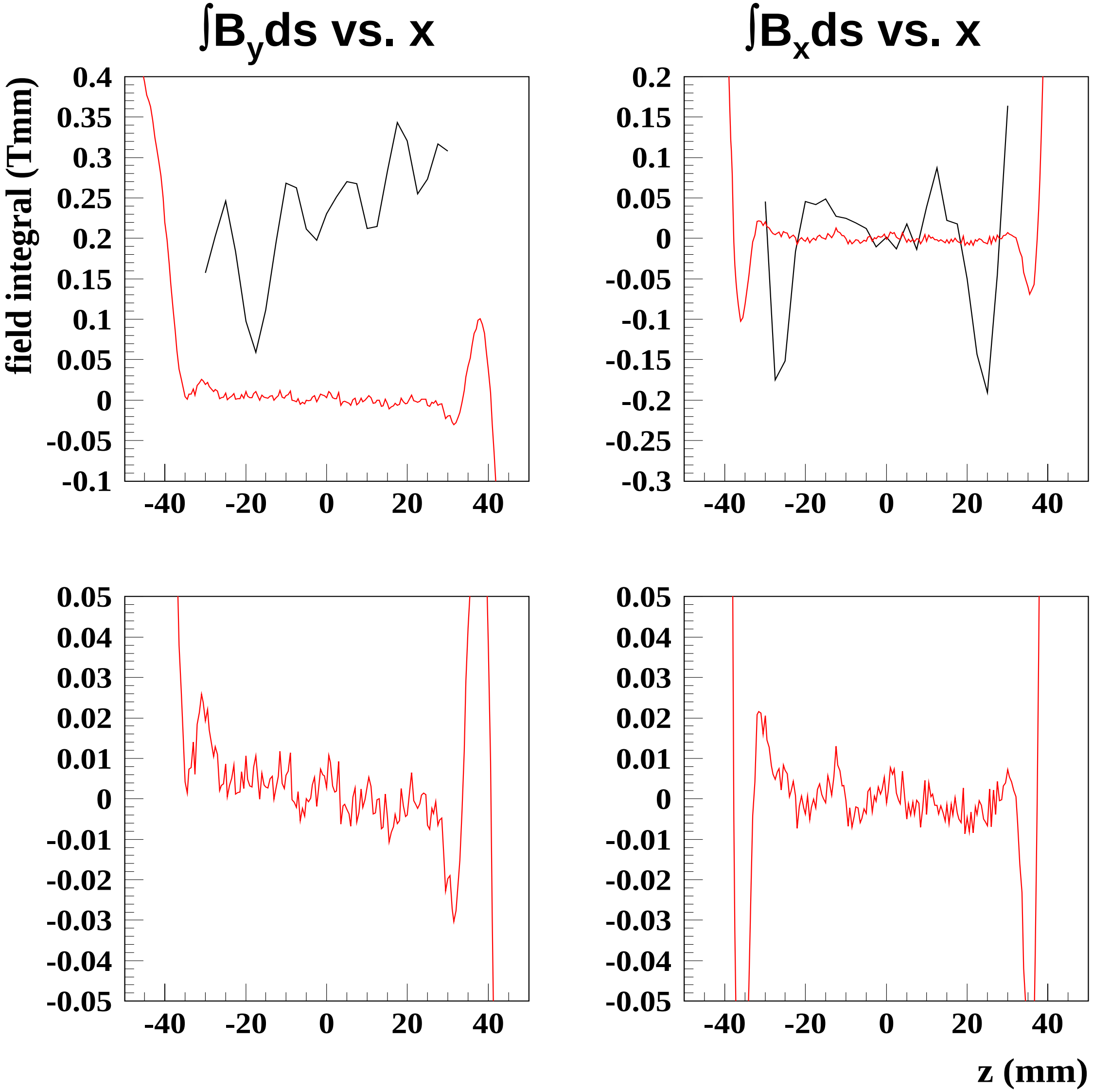
ID re-shimming required

BESSY

Magic Fingers for the U125ID2R



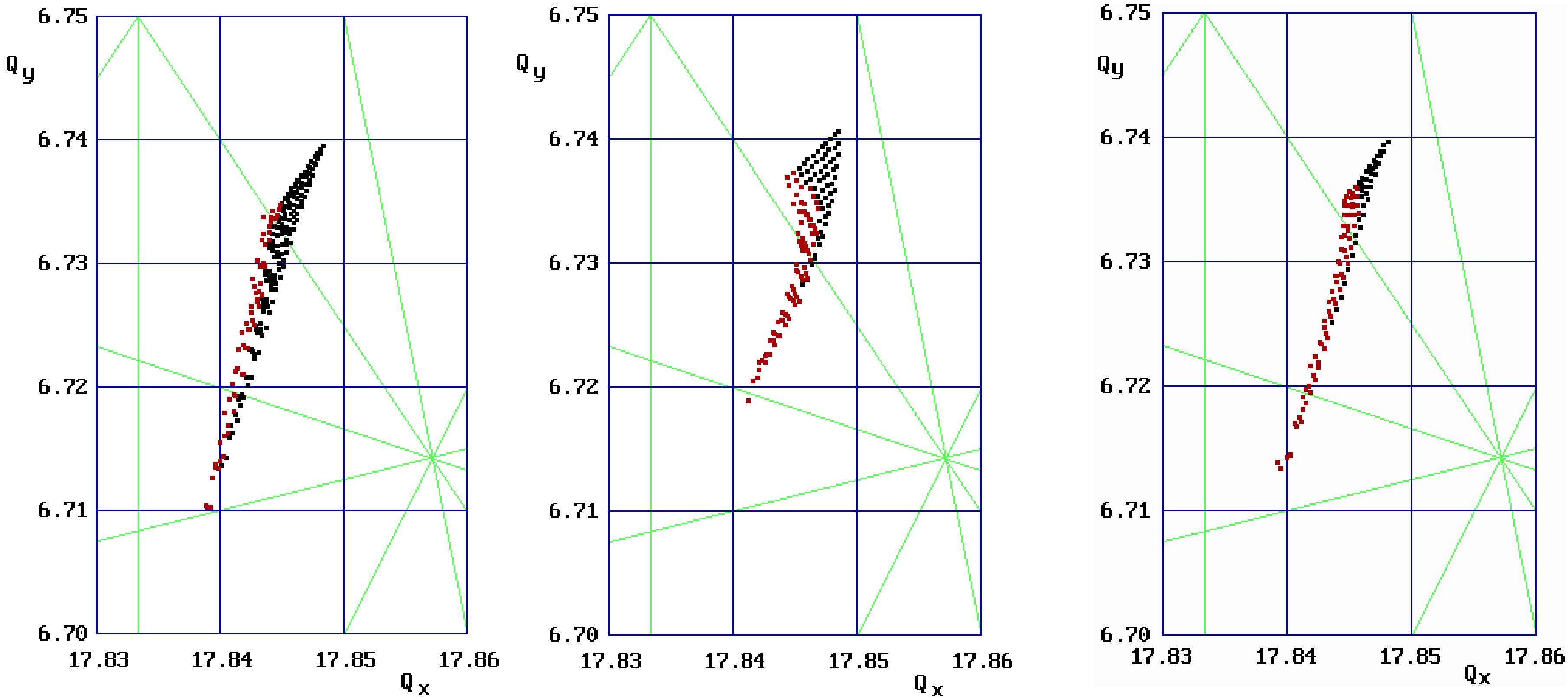
Improvement of the Fields



before installation of magic fingers

after installation

Before and After Re-Shimming of the U125ID5R



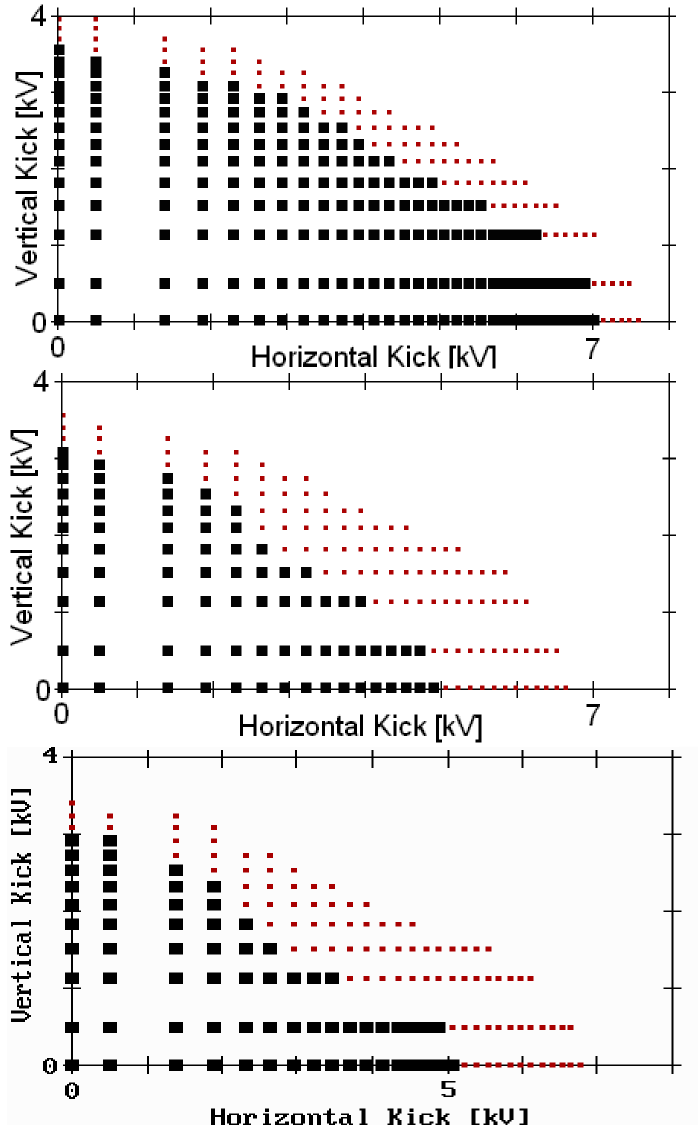
ID-gap open

ID-gap = 15.7 mm

before

after re-shimming

Before and After Re-Shimming of the U125ID5R



ID-gap open

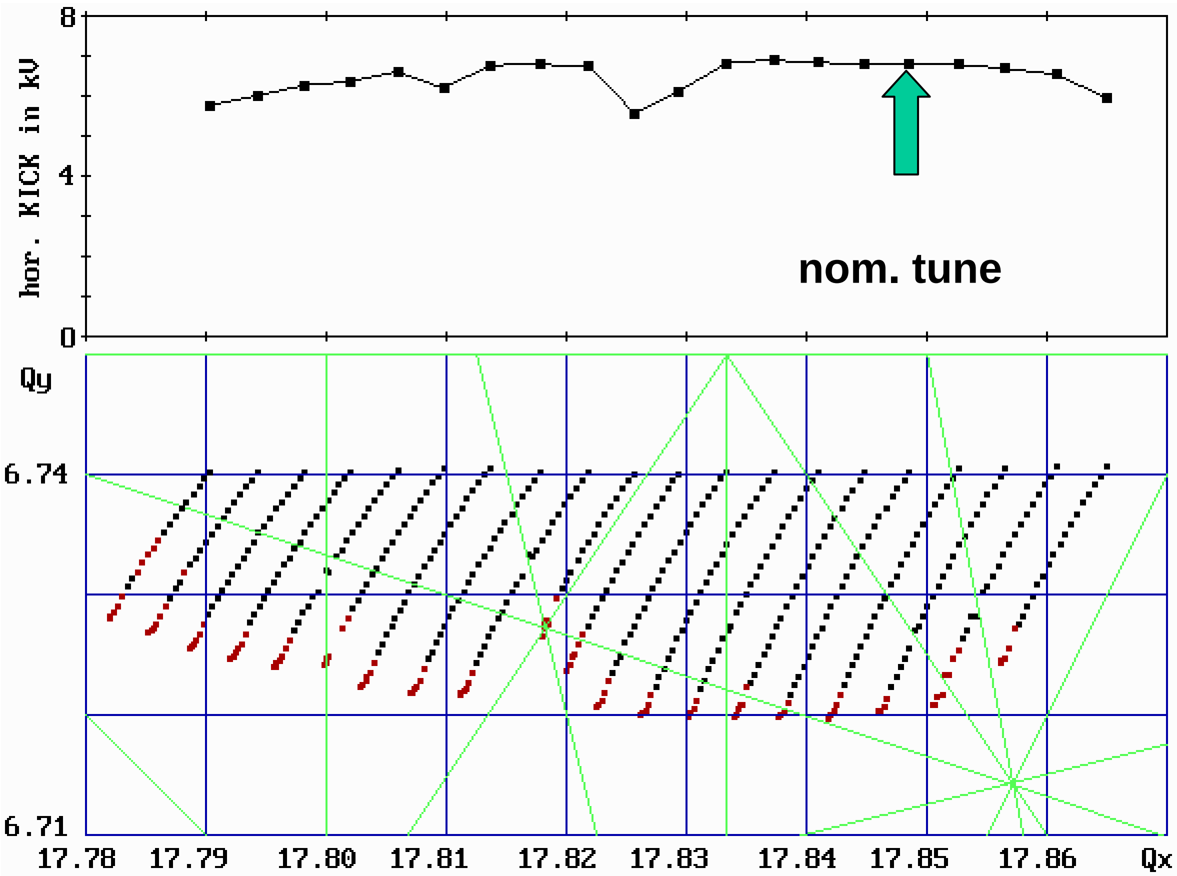
U125ID2R = 15.7 mm

before

after re-shimming

next step – compensation of dynamic field components

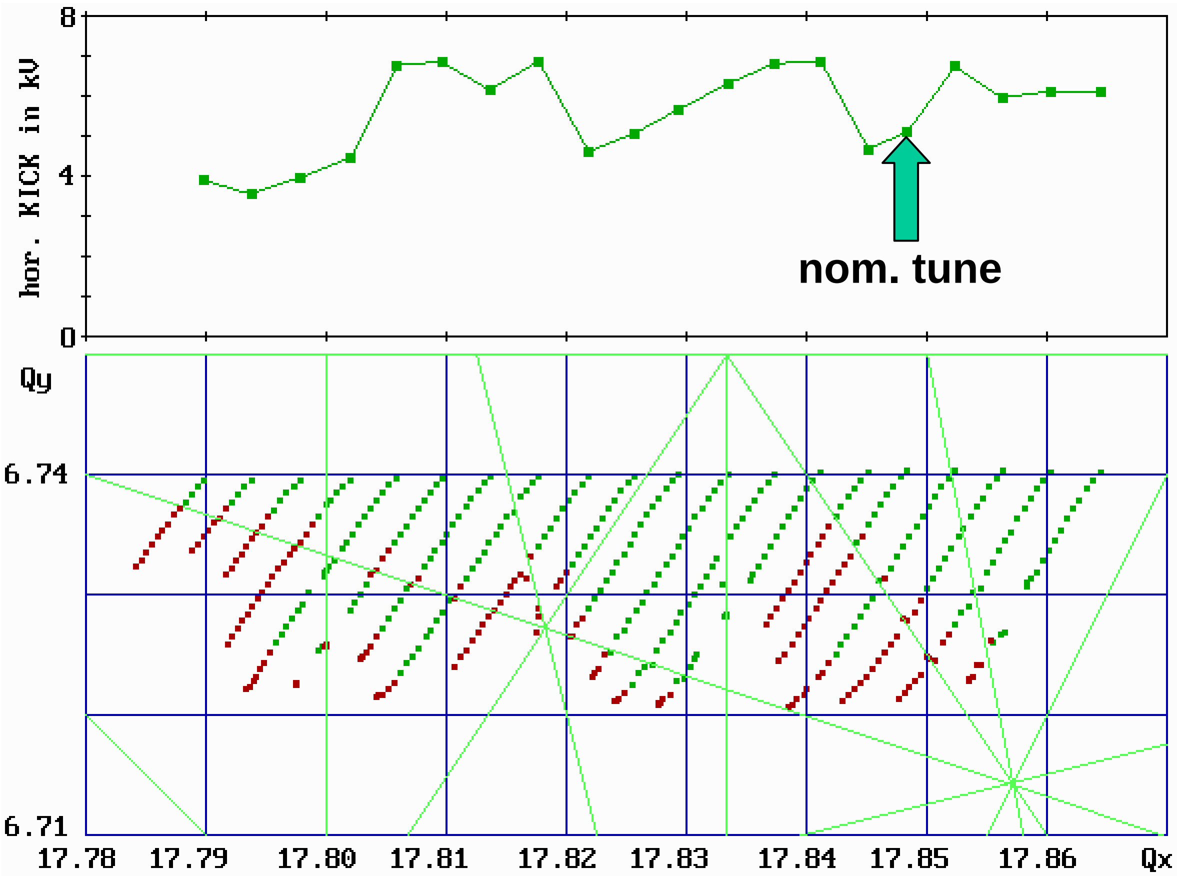
ESLS @ DIAMOND



red dots – beam loss >2%

Horizontal Dynamic Aperture vs. Tune

U125ID2R – gap=15.7 mm



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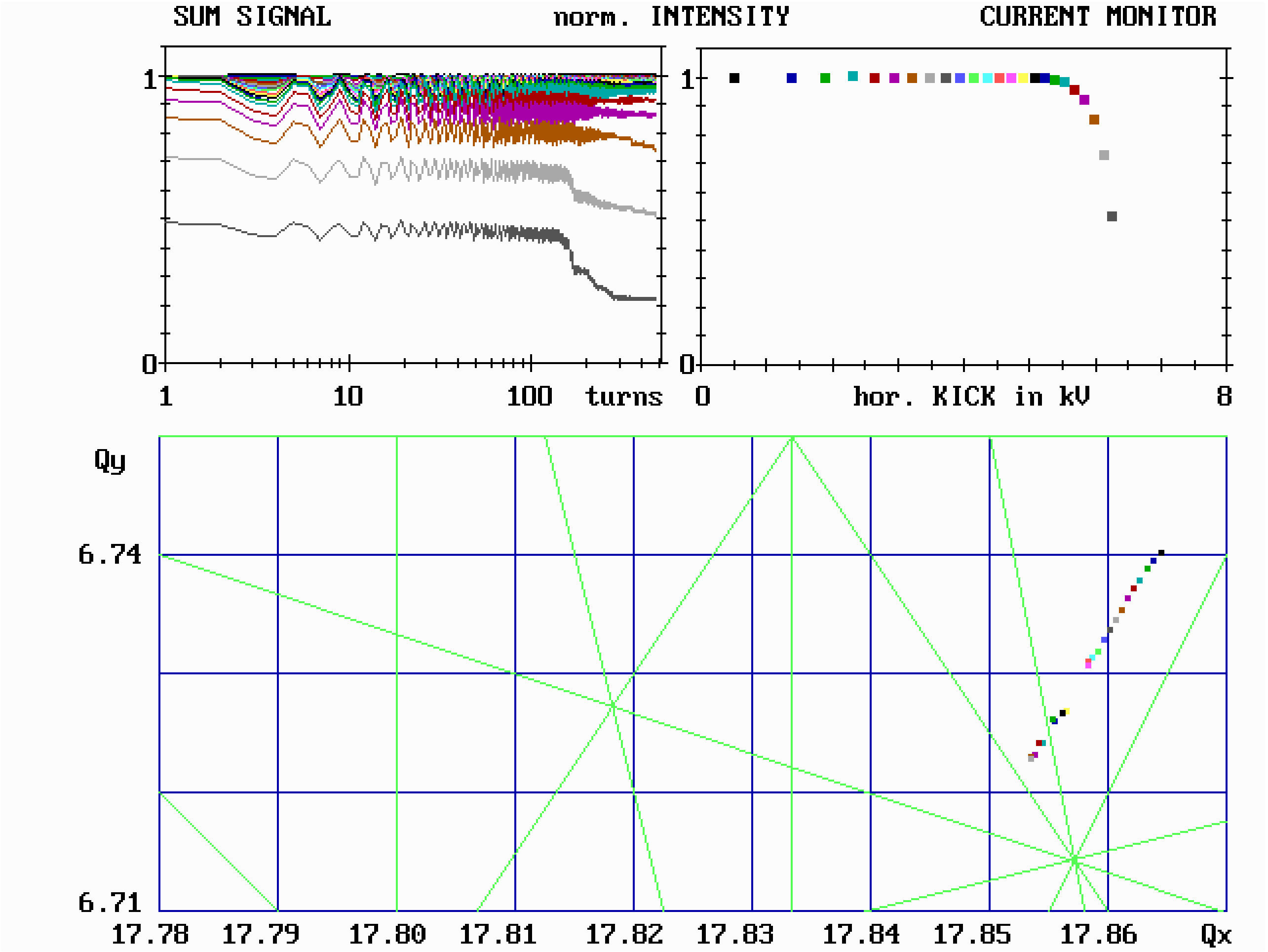
$3Q_x + 2\ Q_y$ – resonance critical at the nom. working point

Horizontal Dynamic Aperture vs. Tune: U125ID2R – gap=15.7 mm



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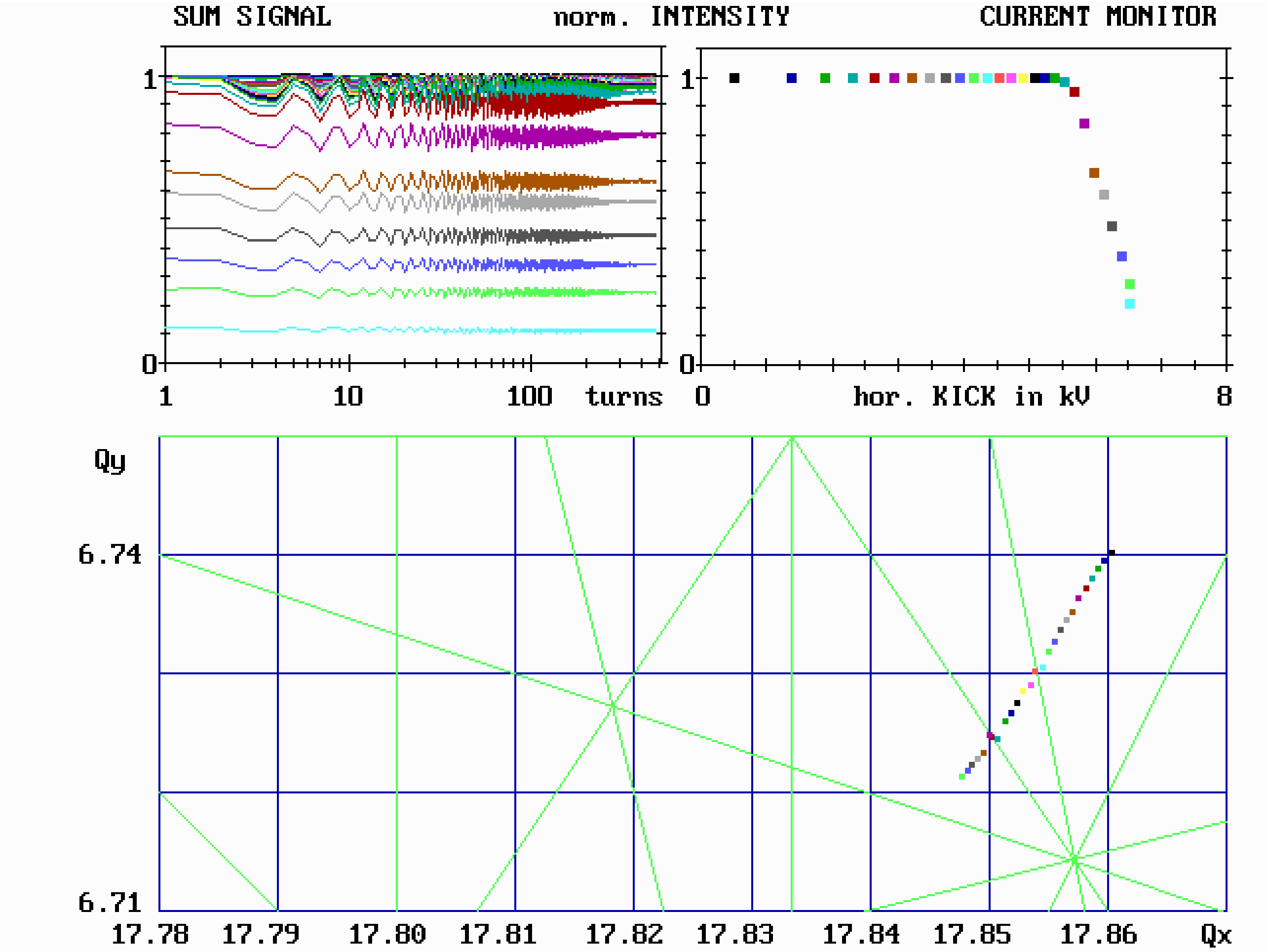

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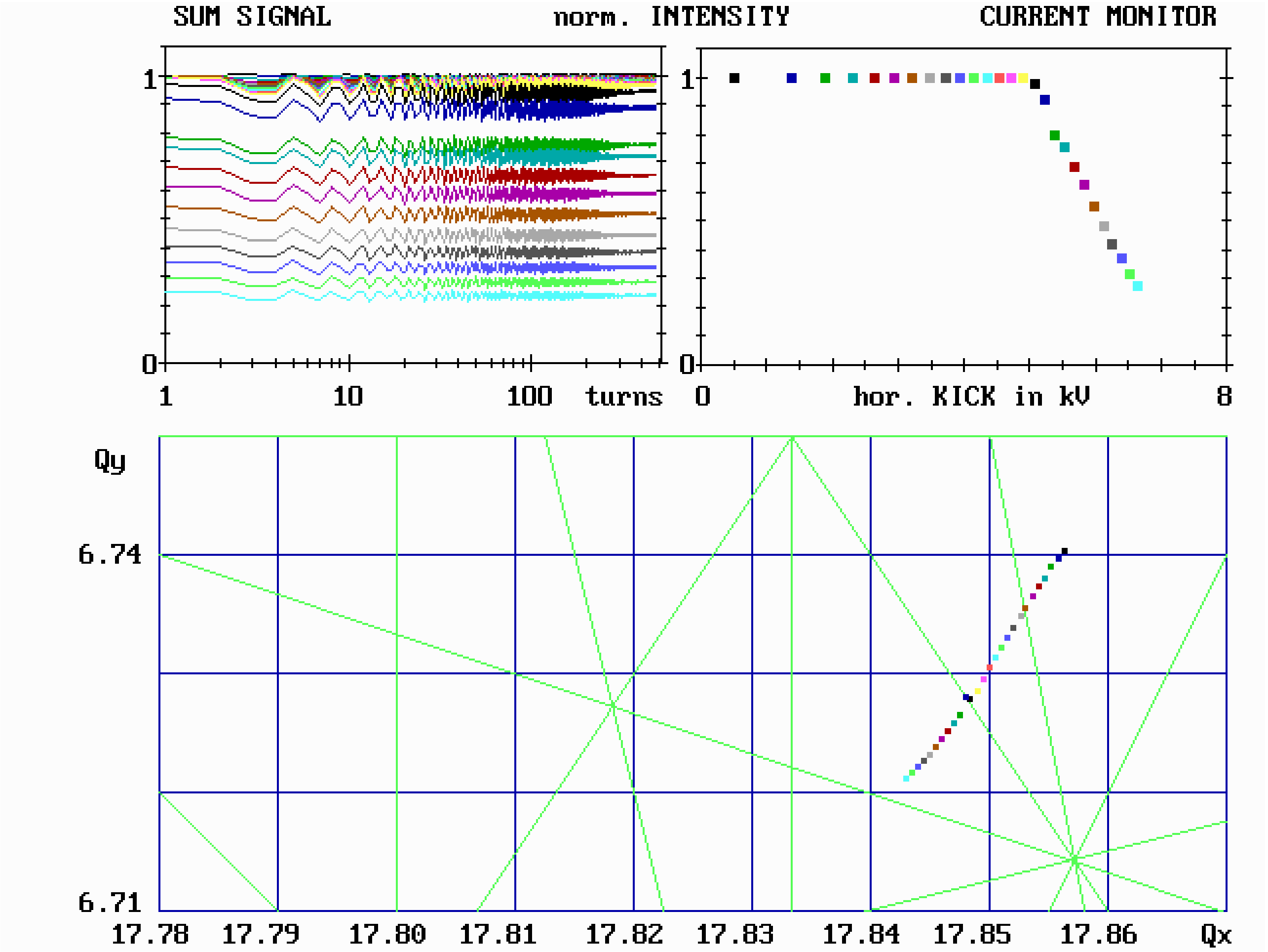

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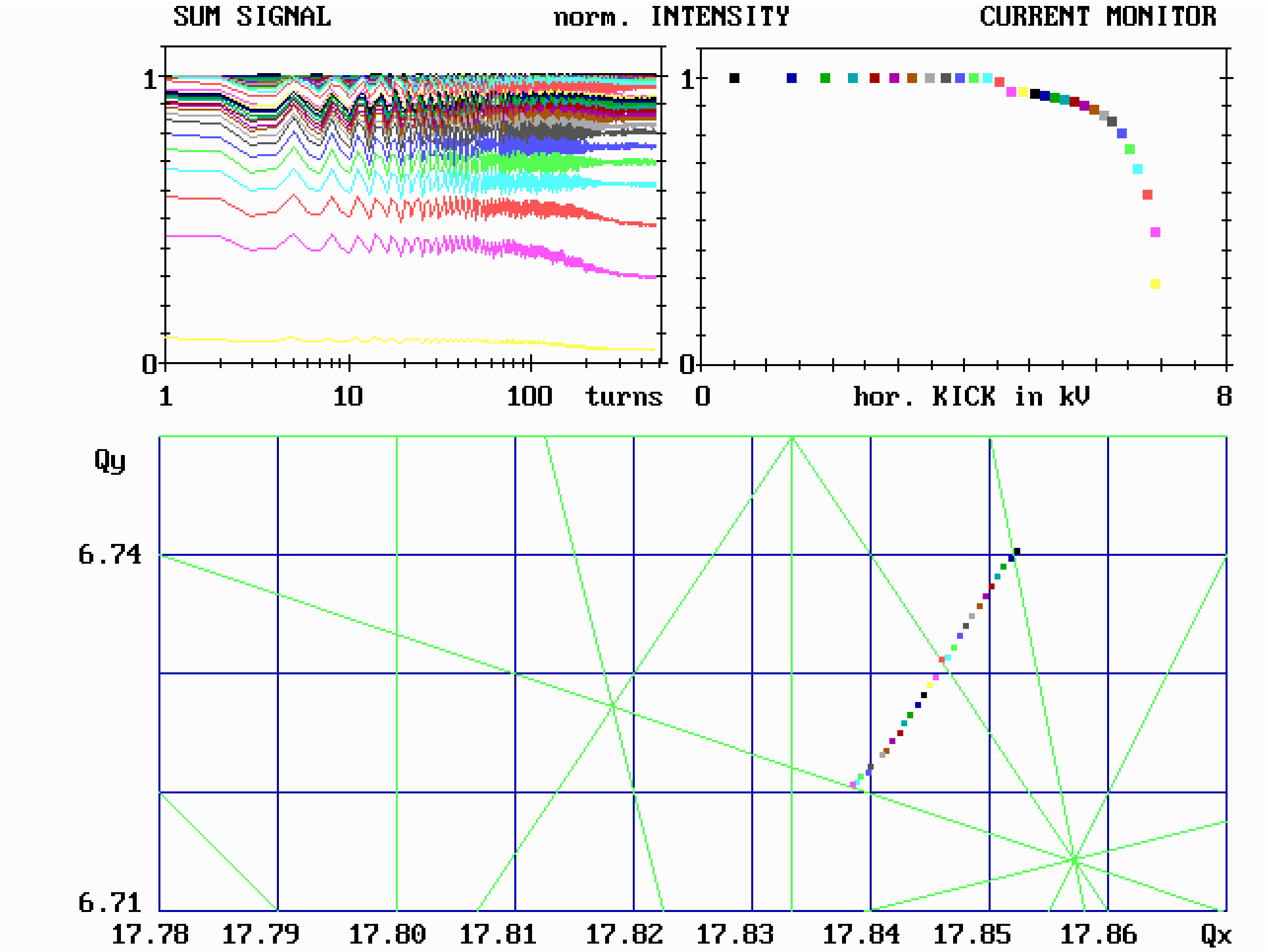

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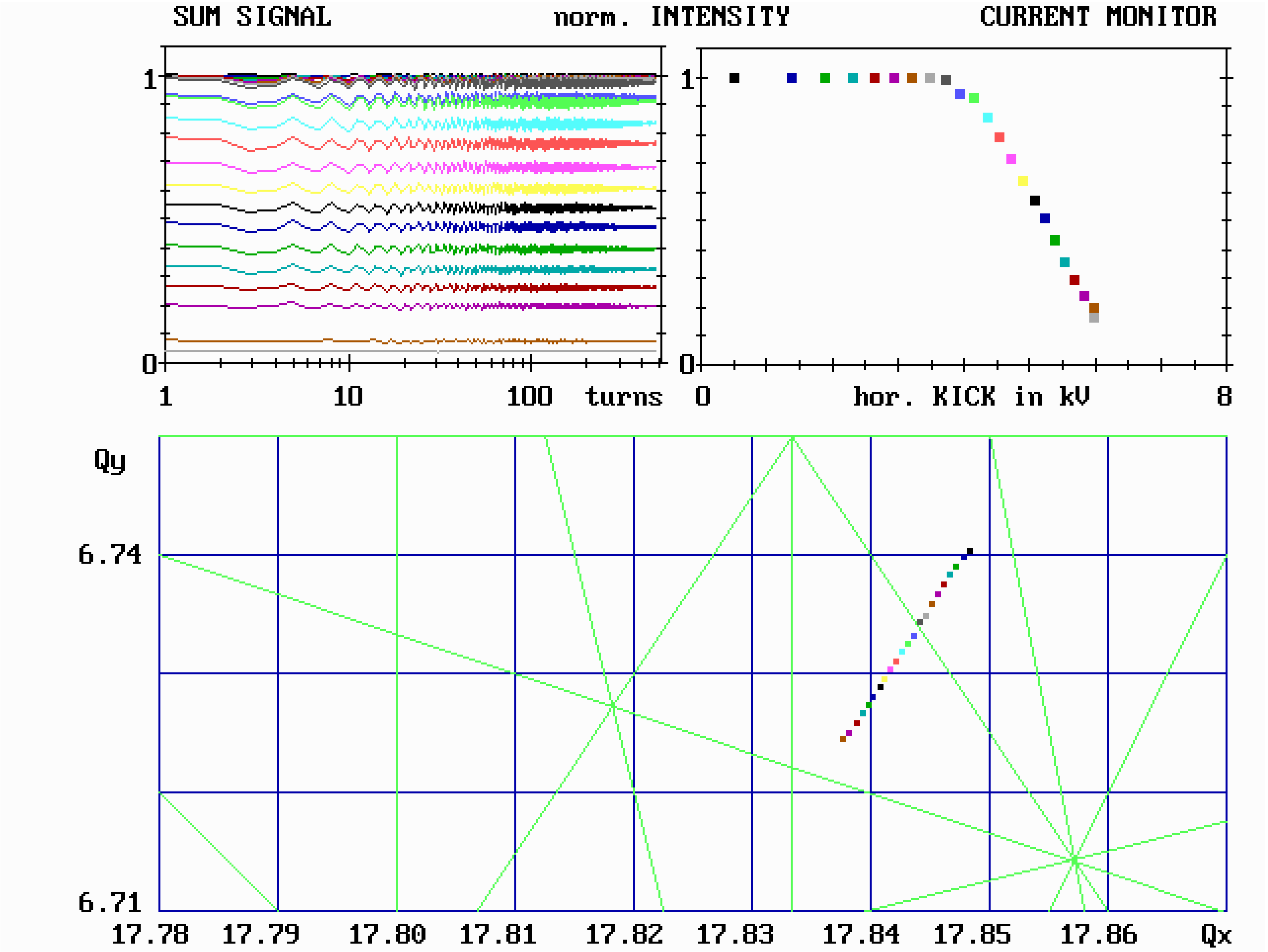

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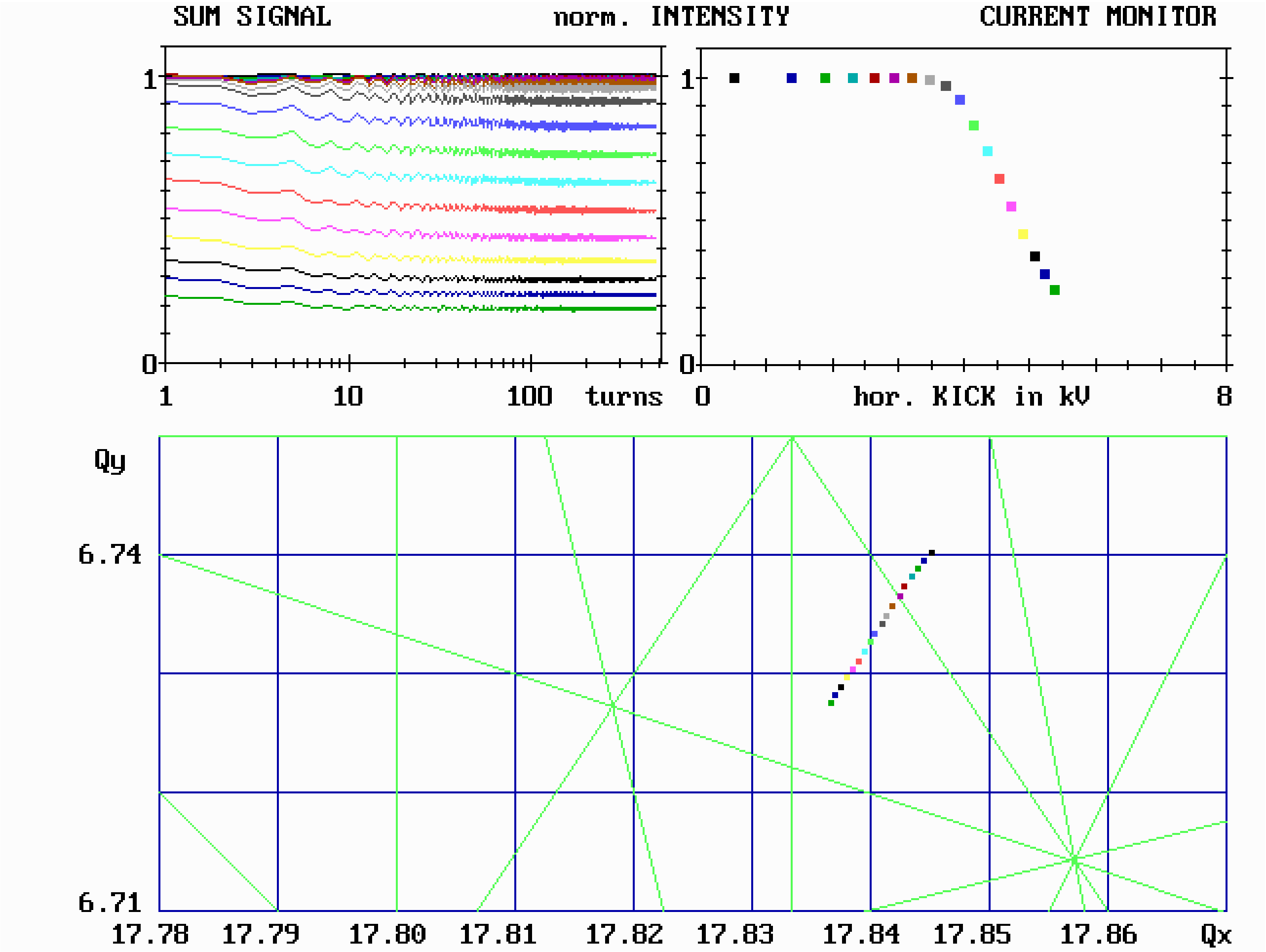

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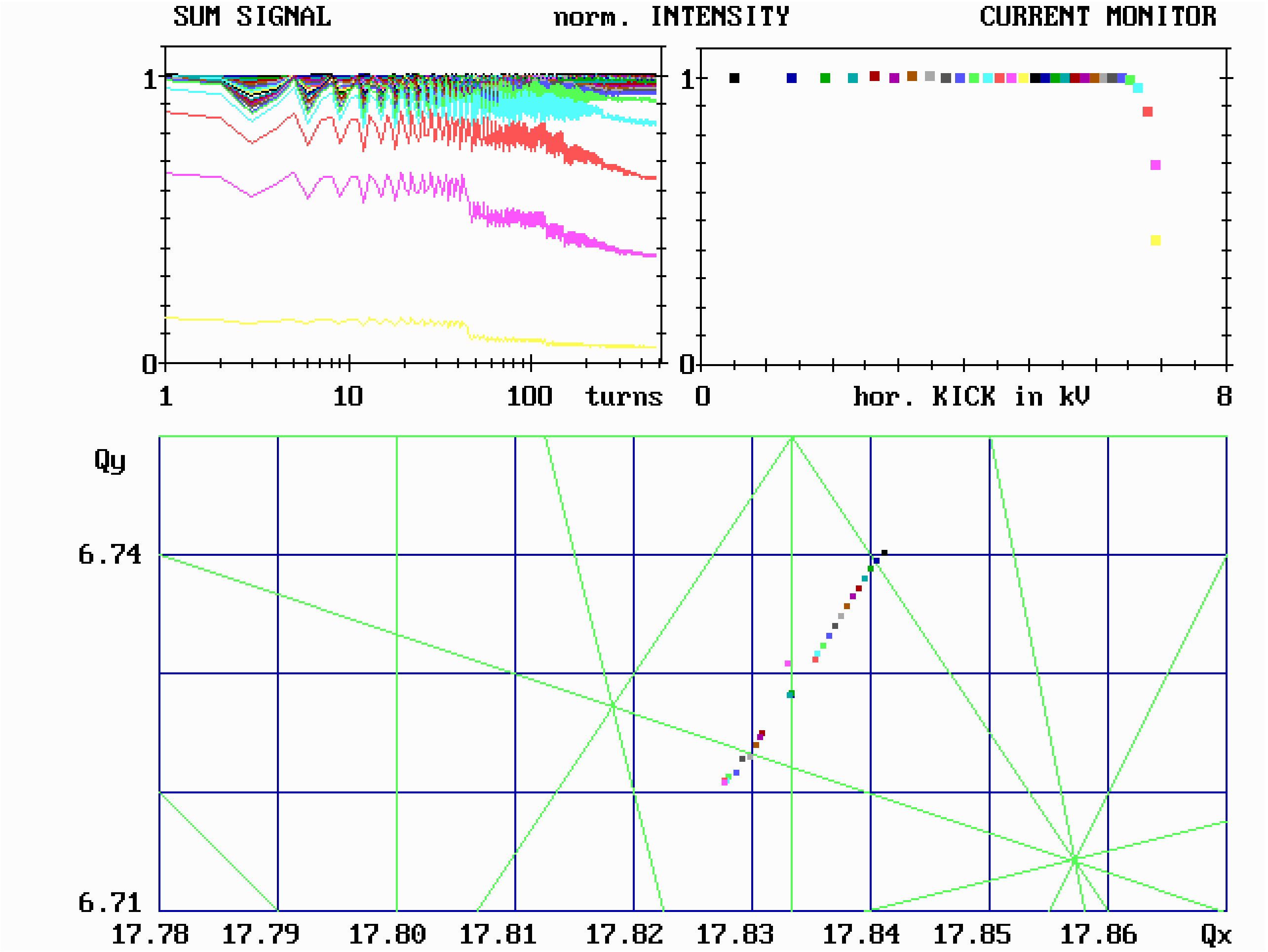

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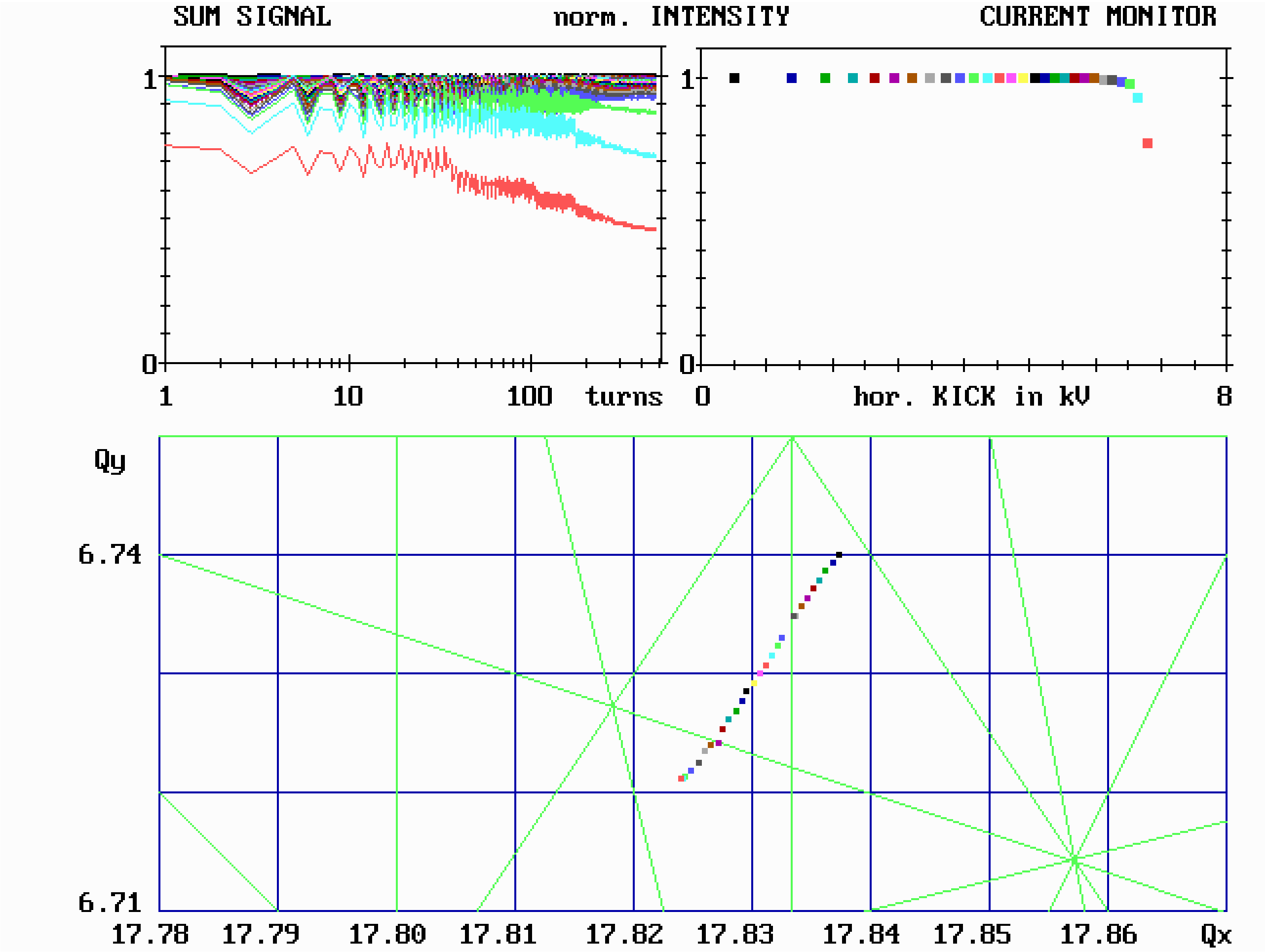

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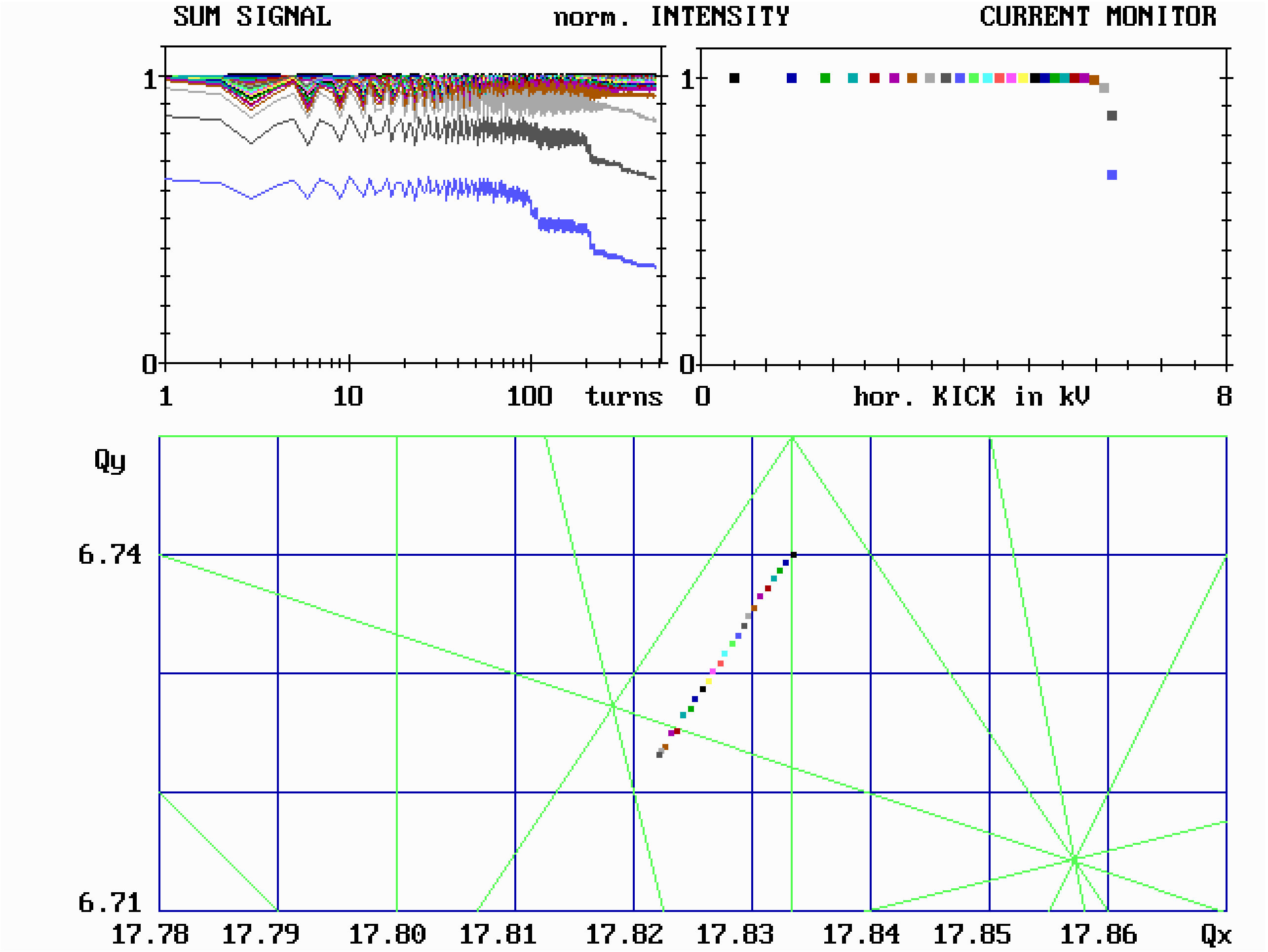

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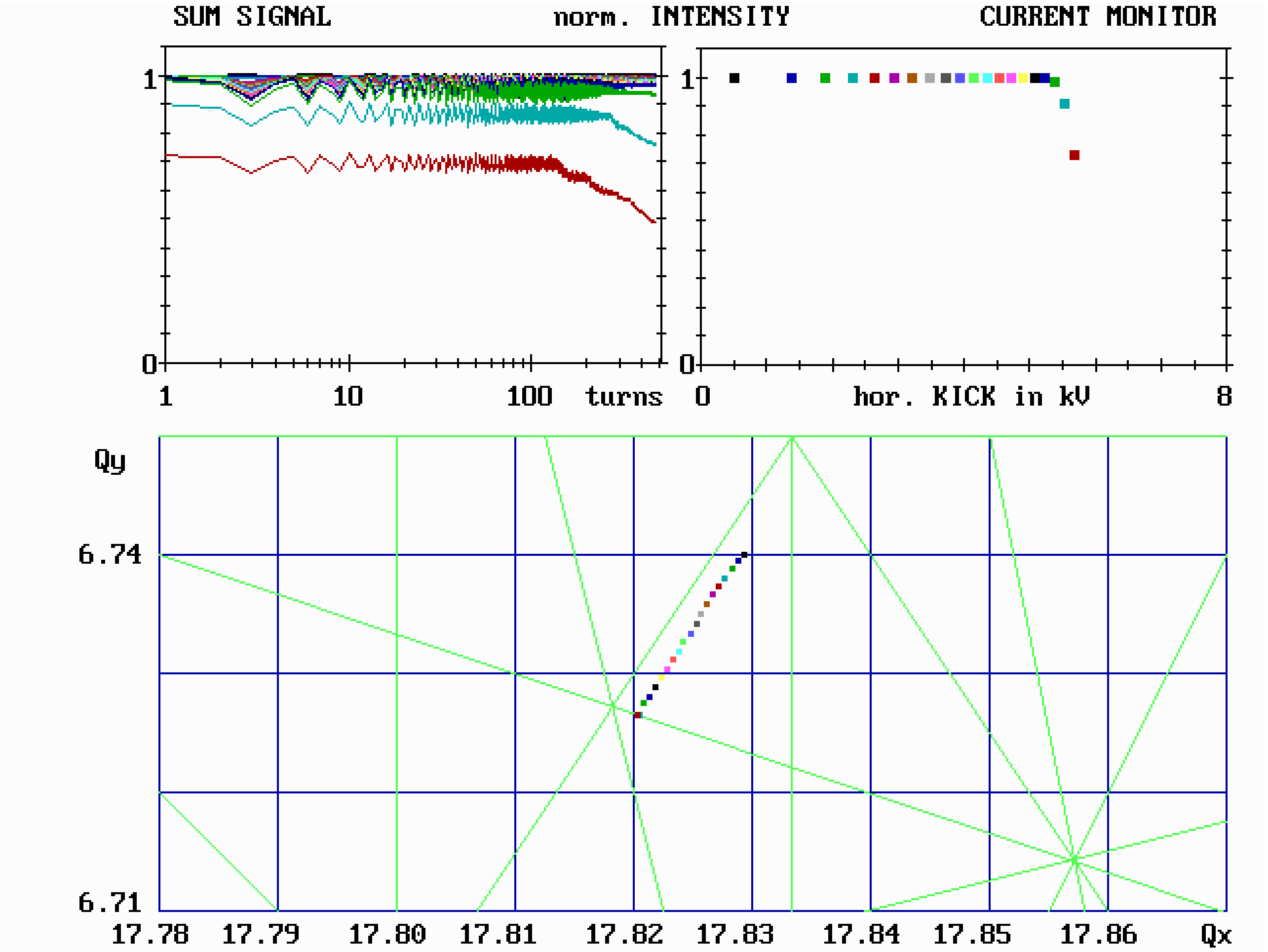

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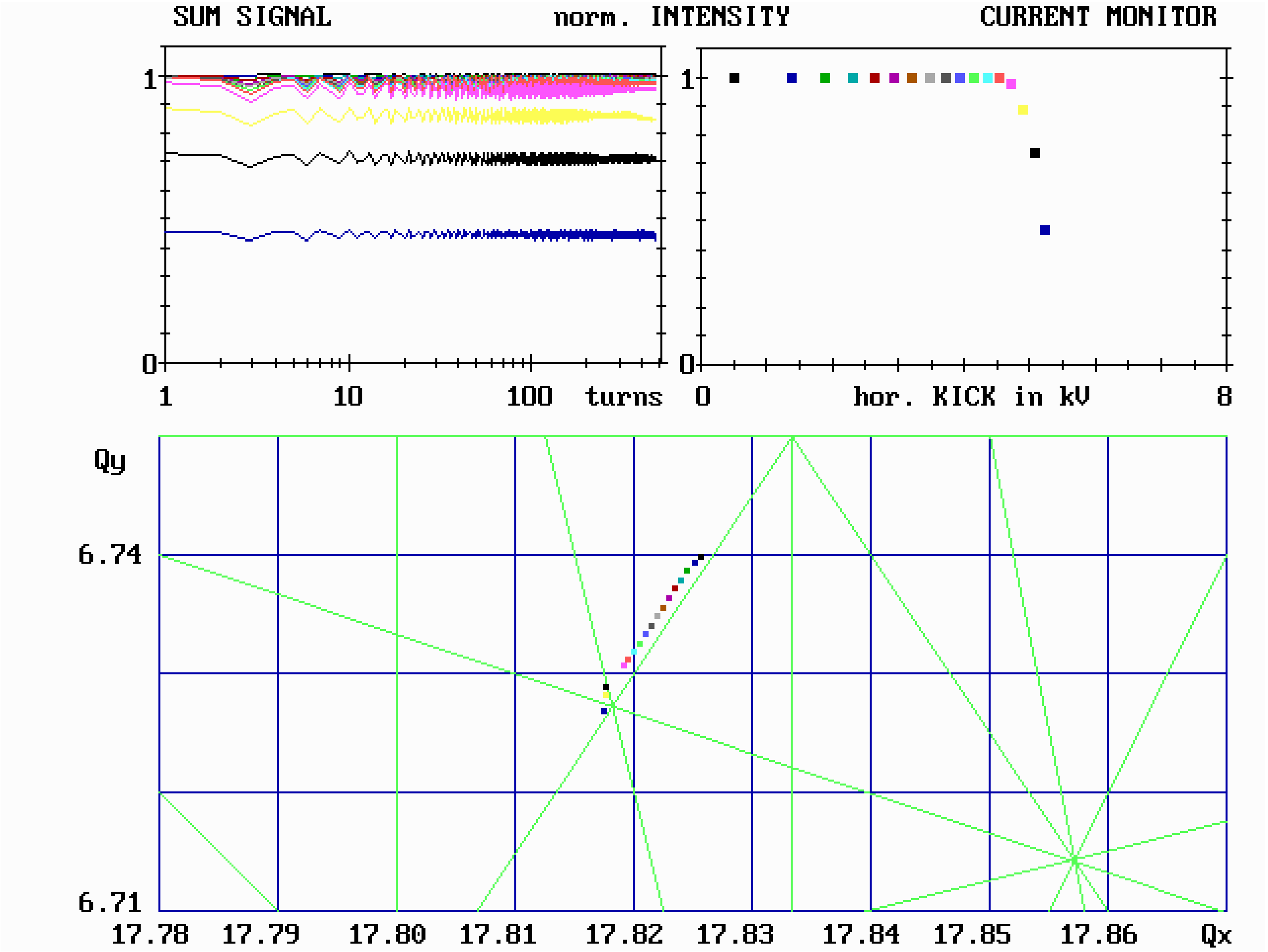

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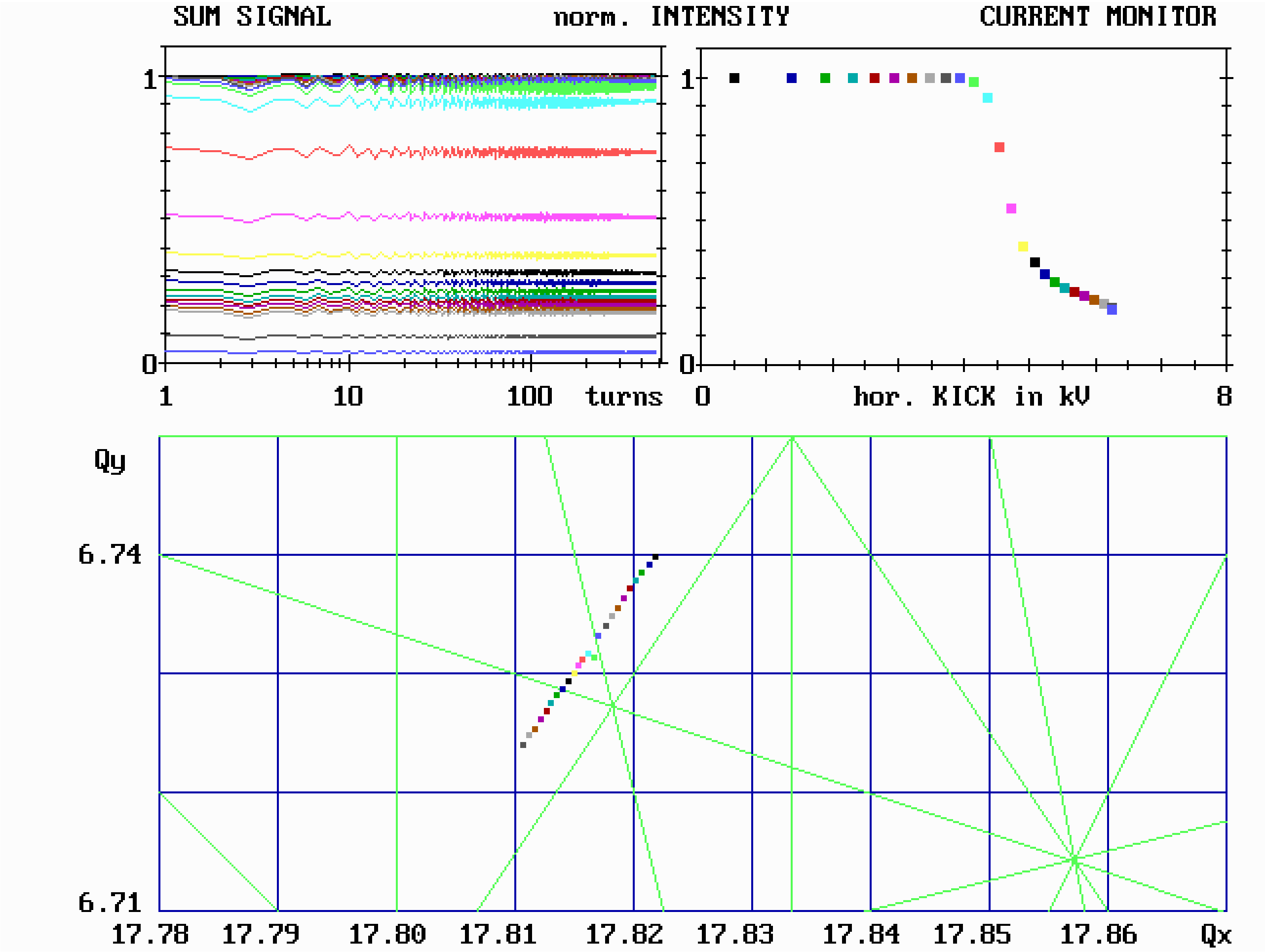

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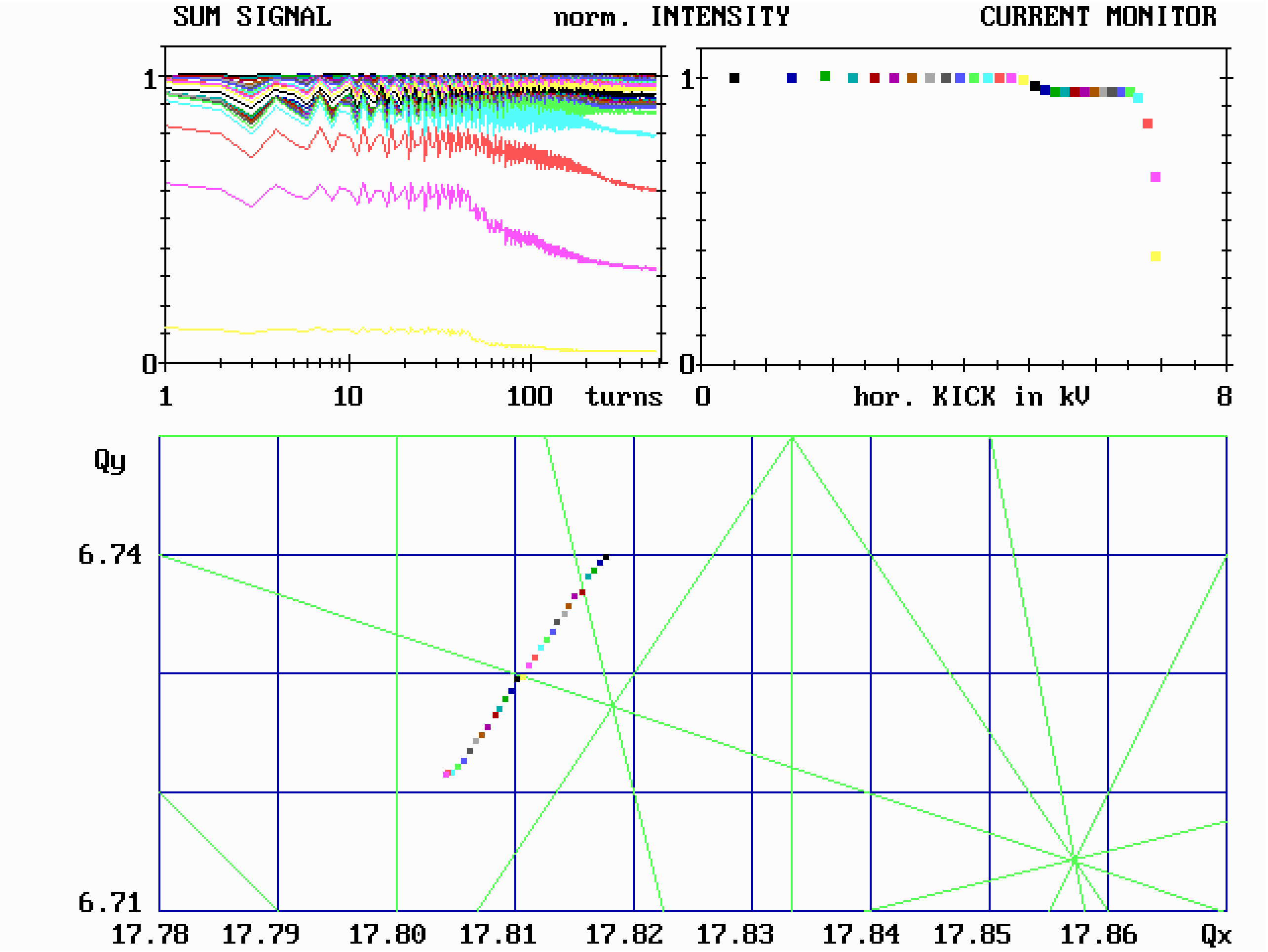

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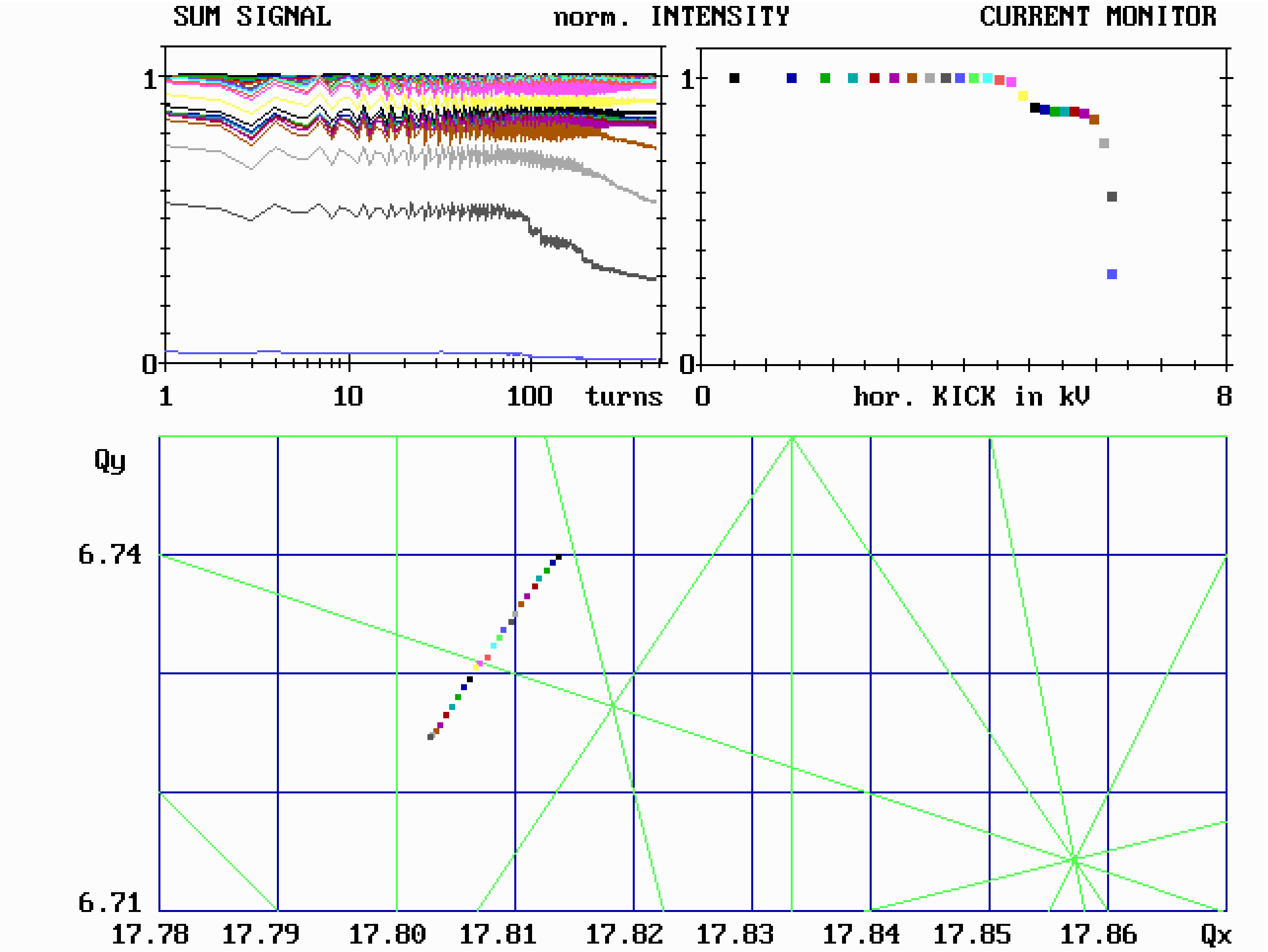

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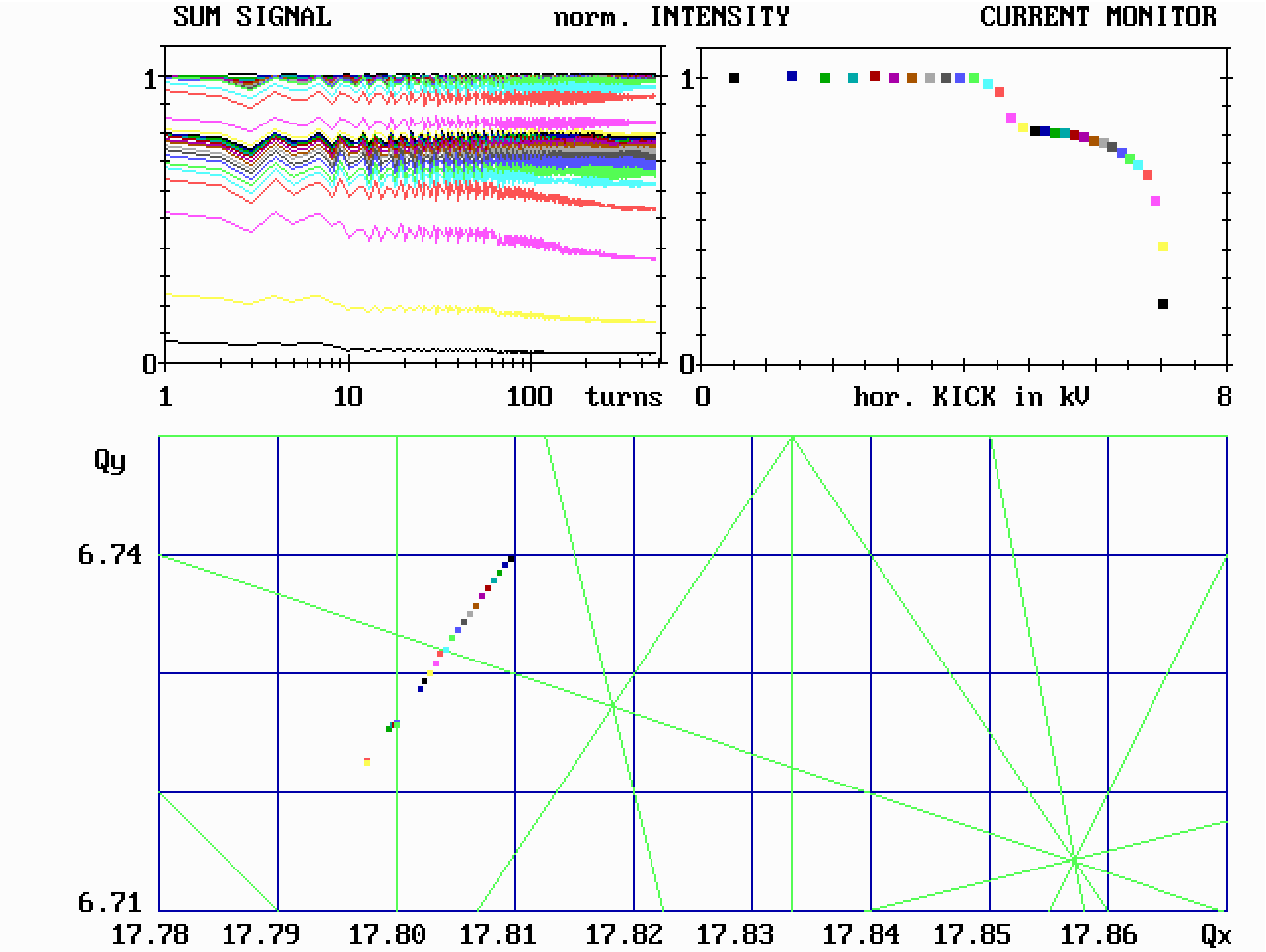

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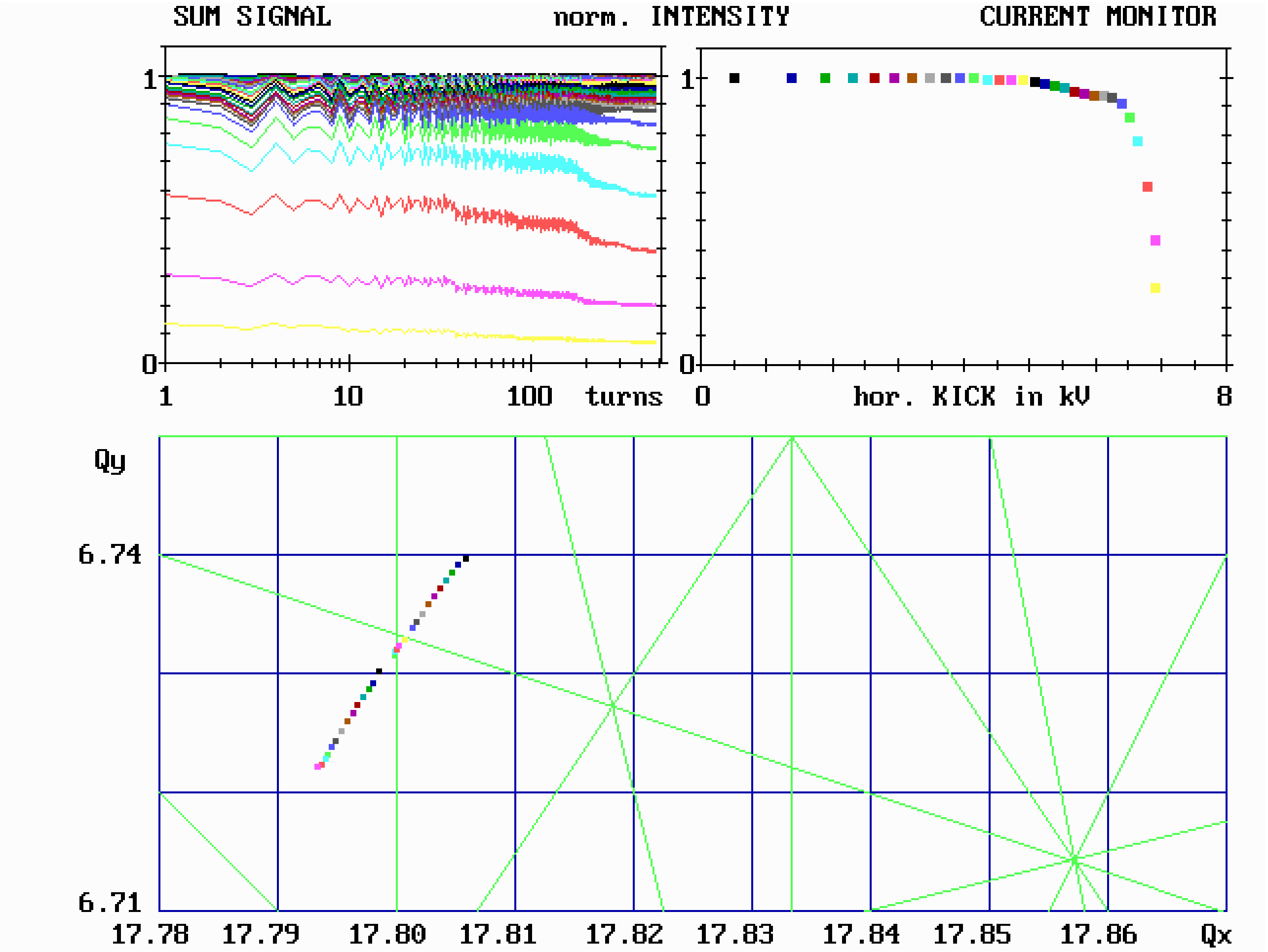

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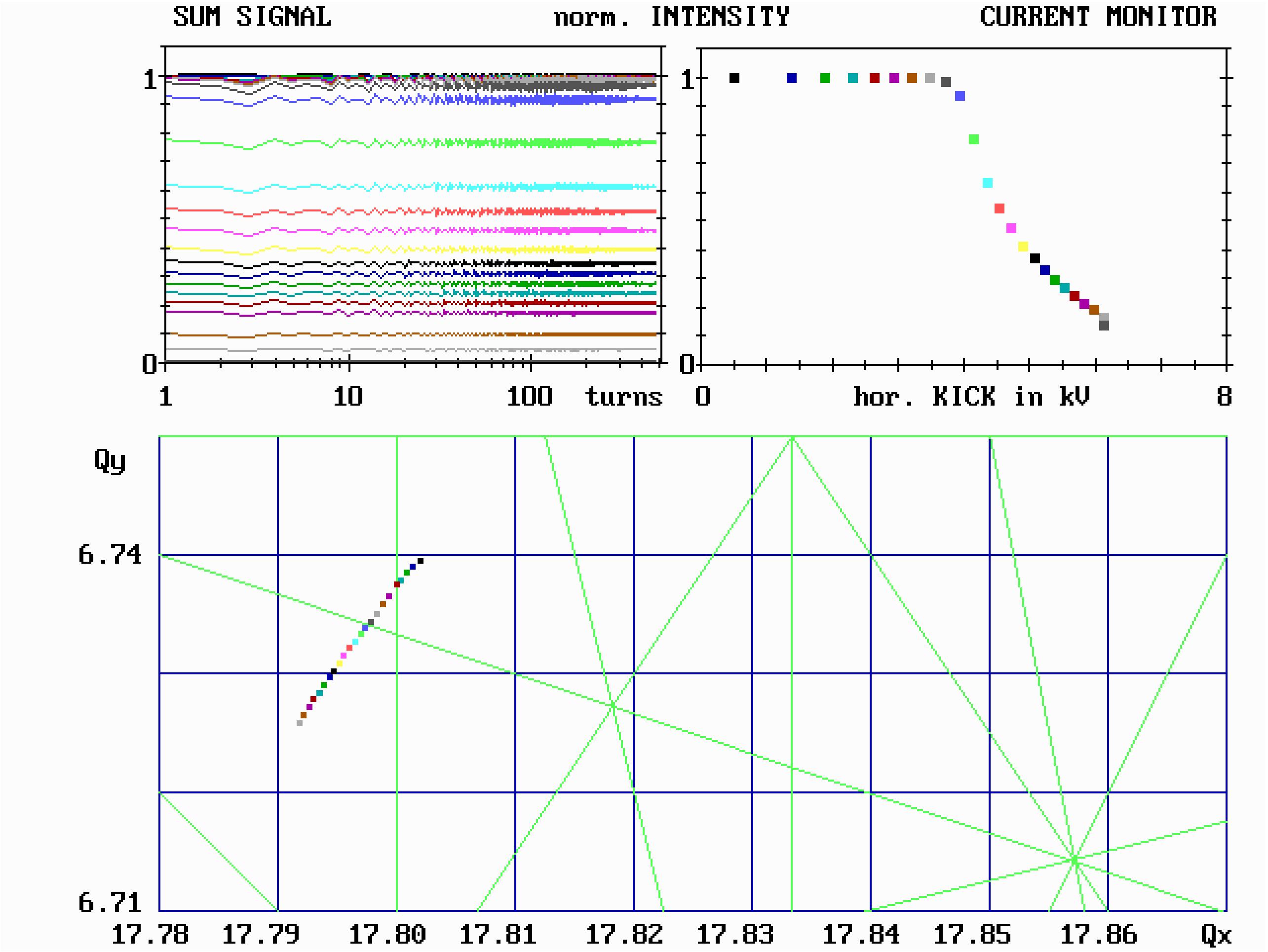

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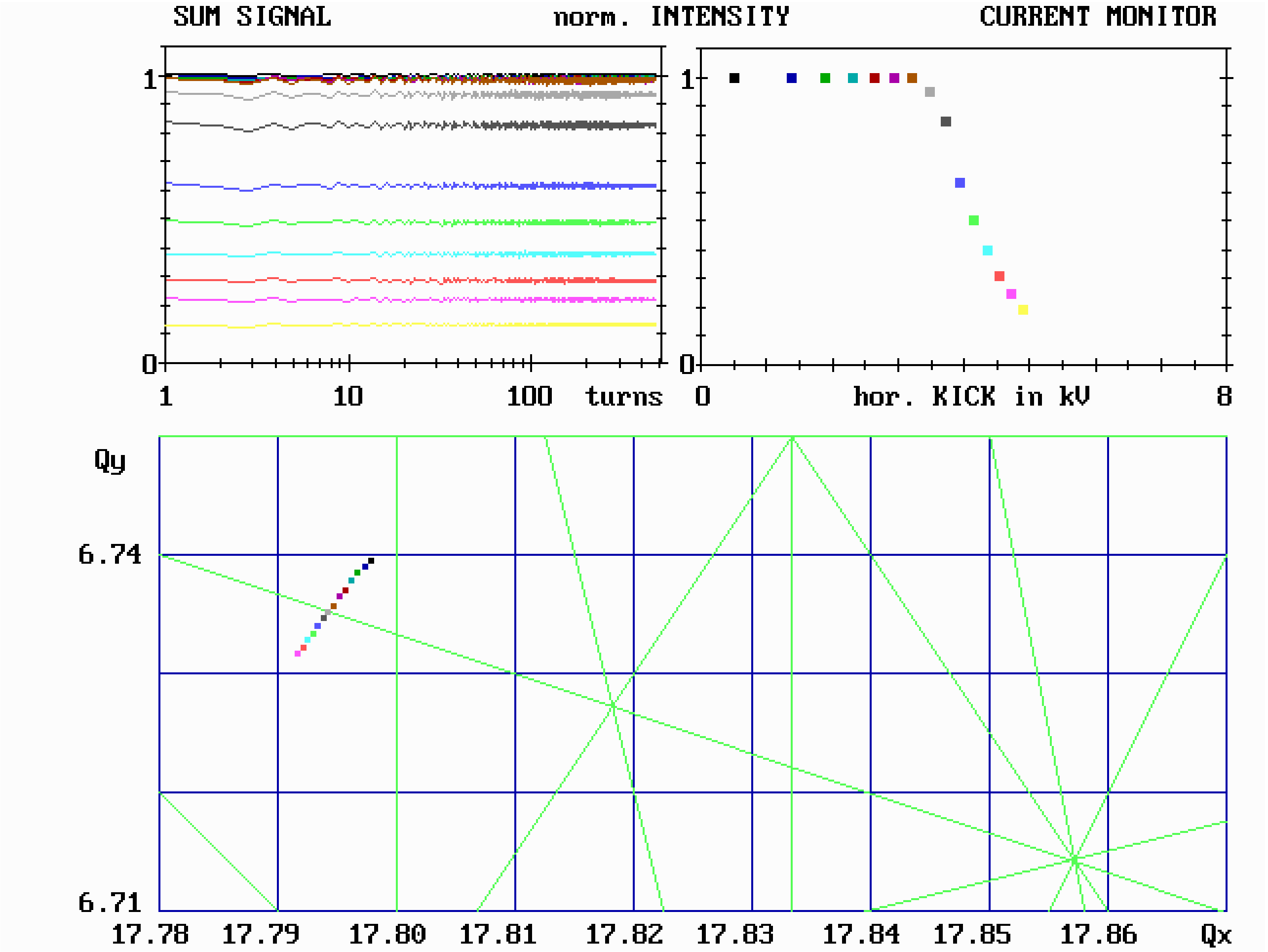

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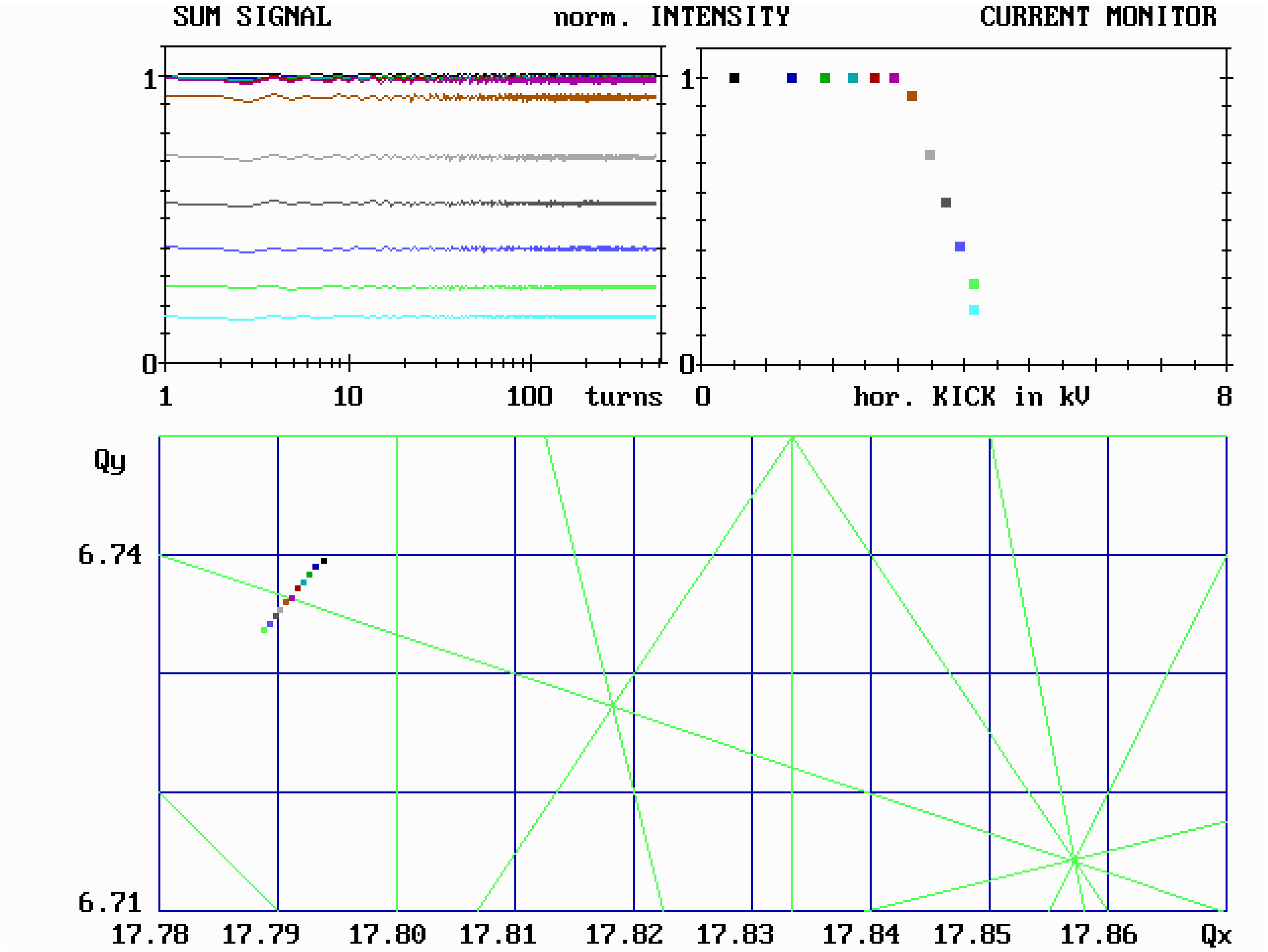

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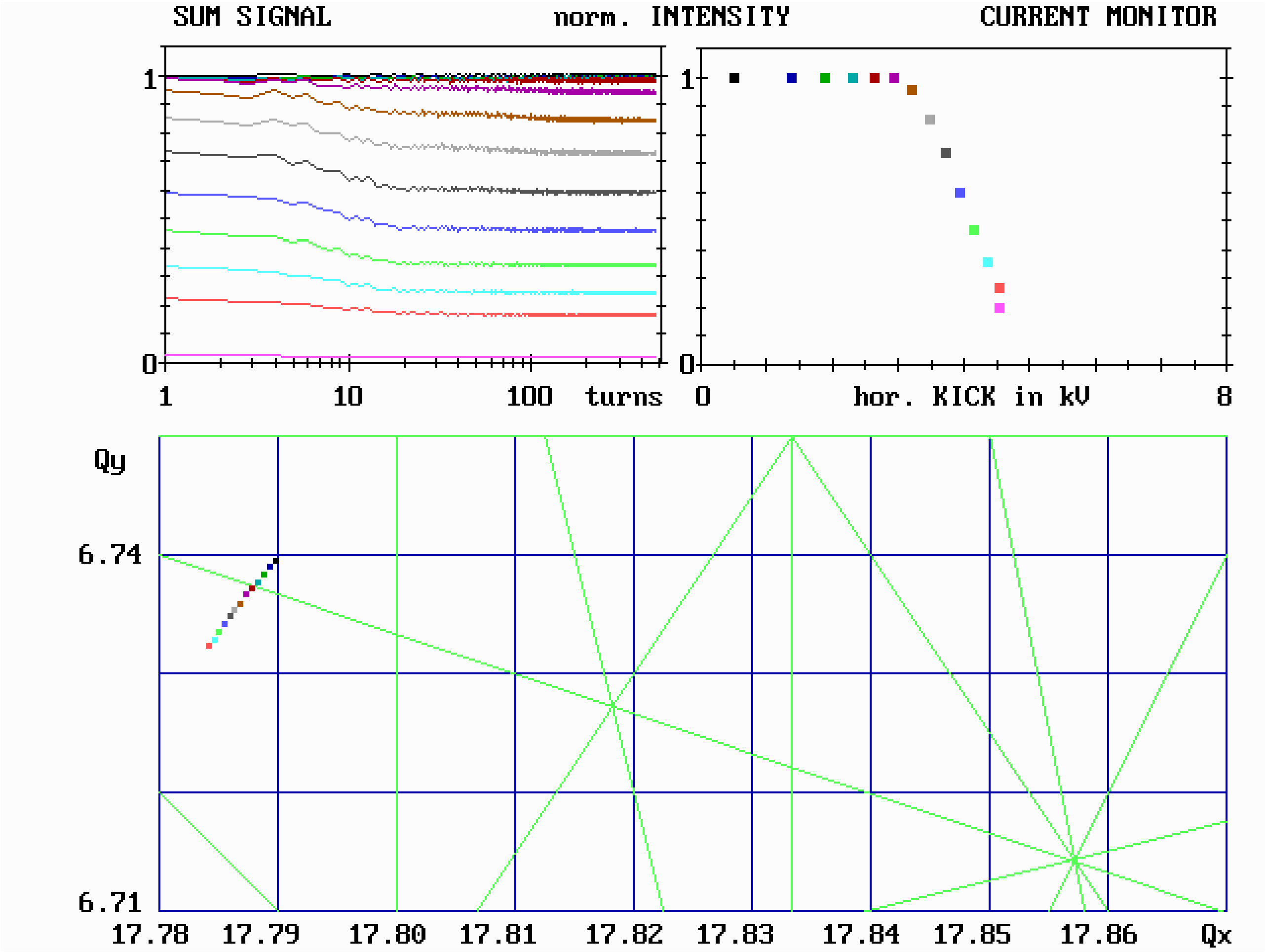

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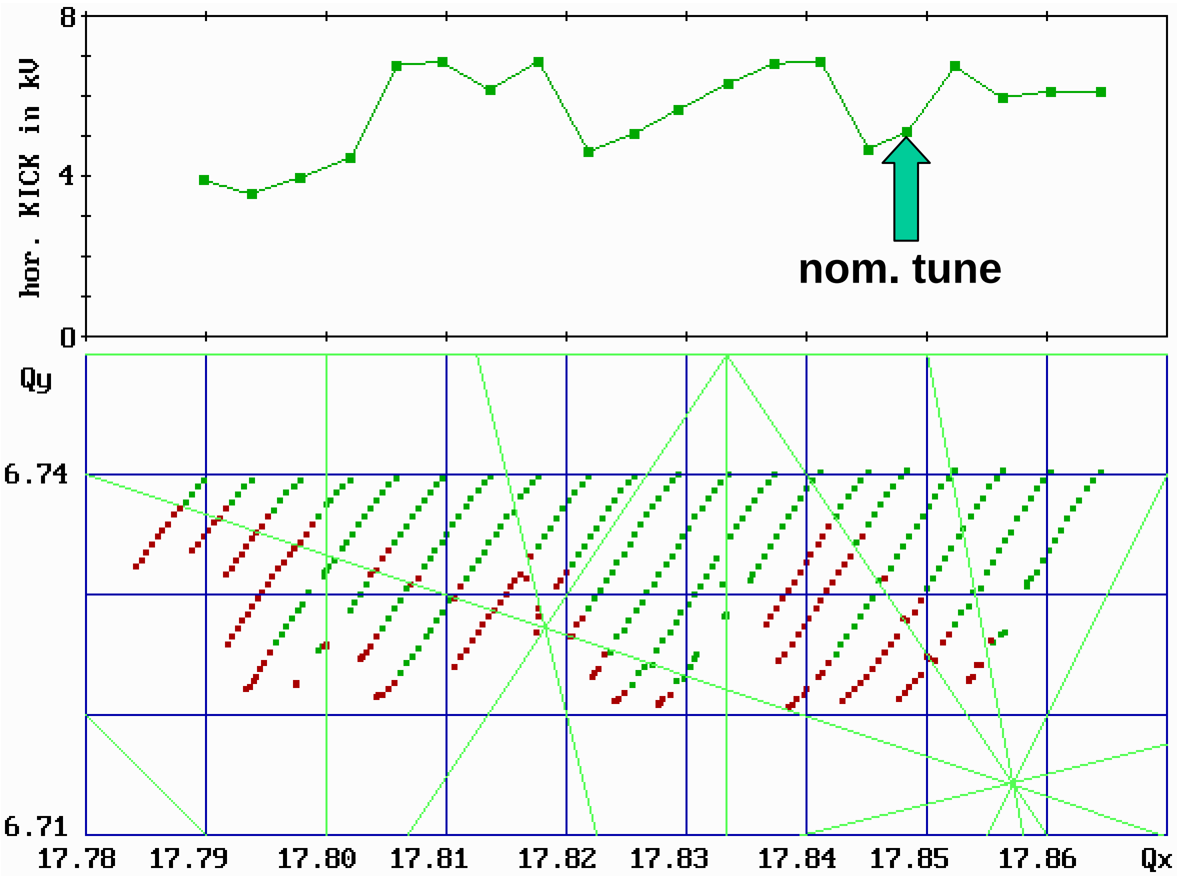

red dots – beam loss >2%

$3Q_x + 2\ Q_y$ – resonance critical at the nom. working point

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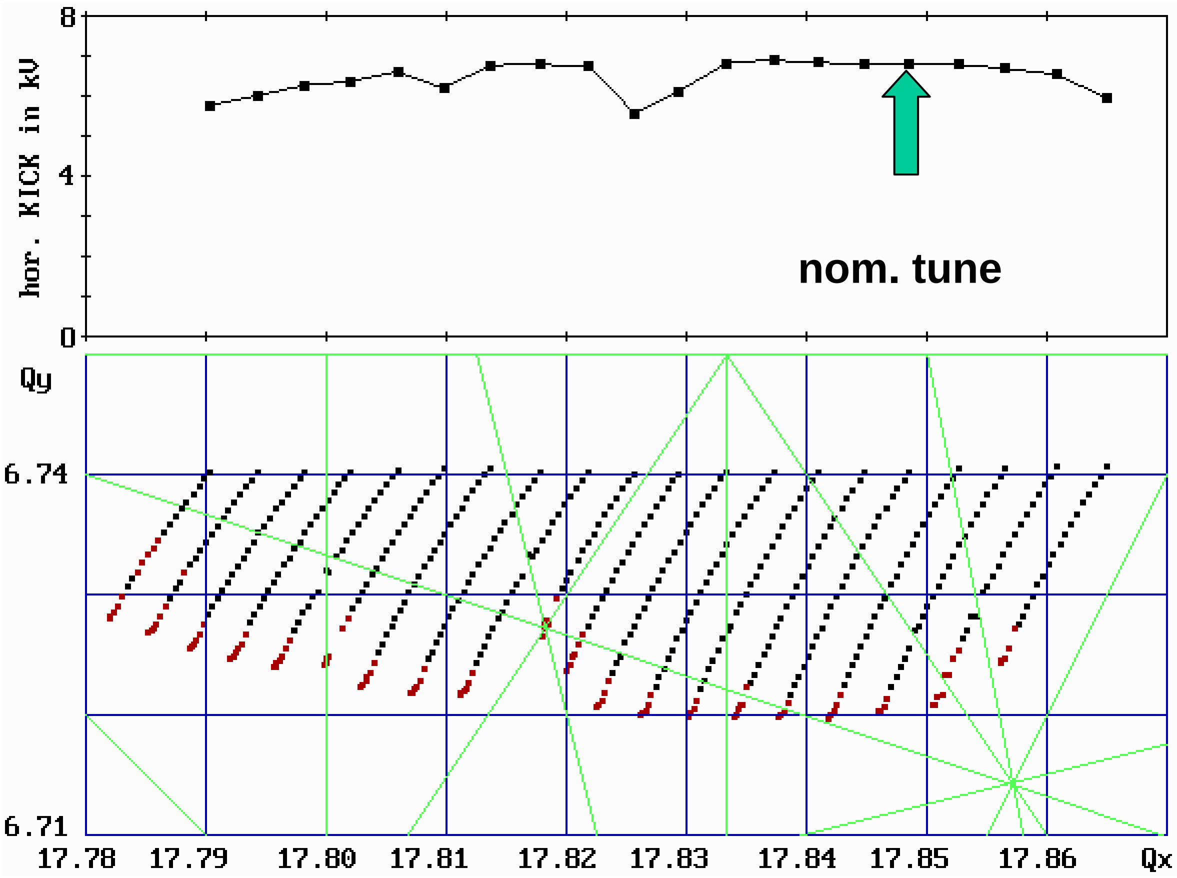

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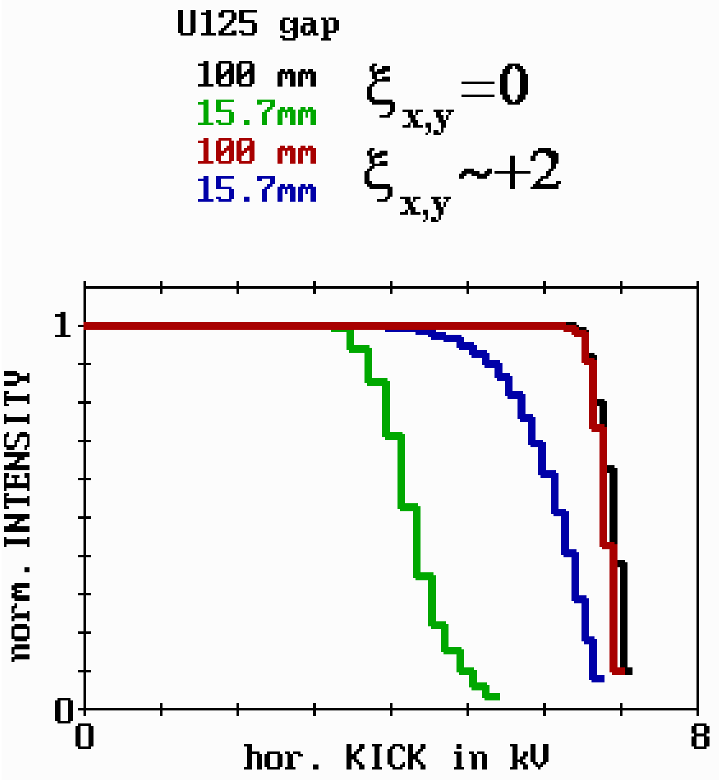
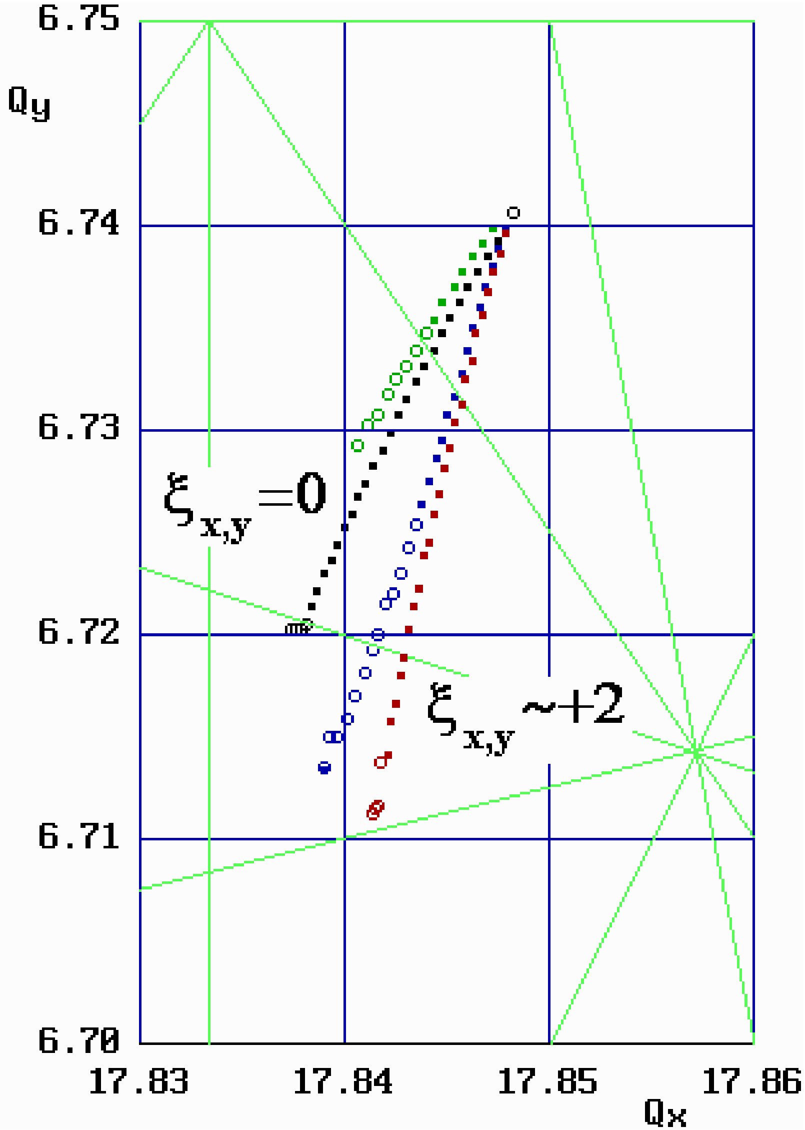
After Re-Shimming of the U125ID5R



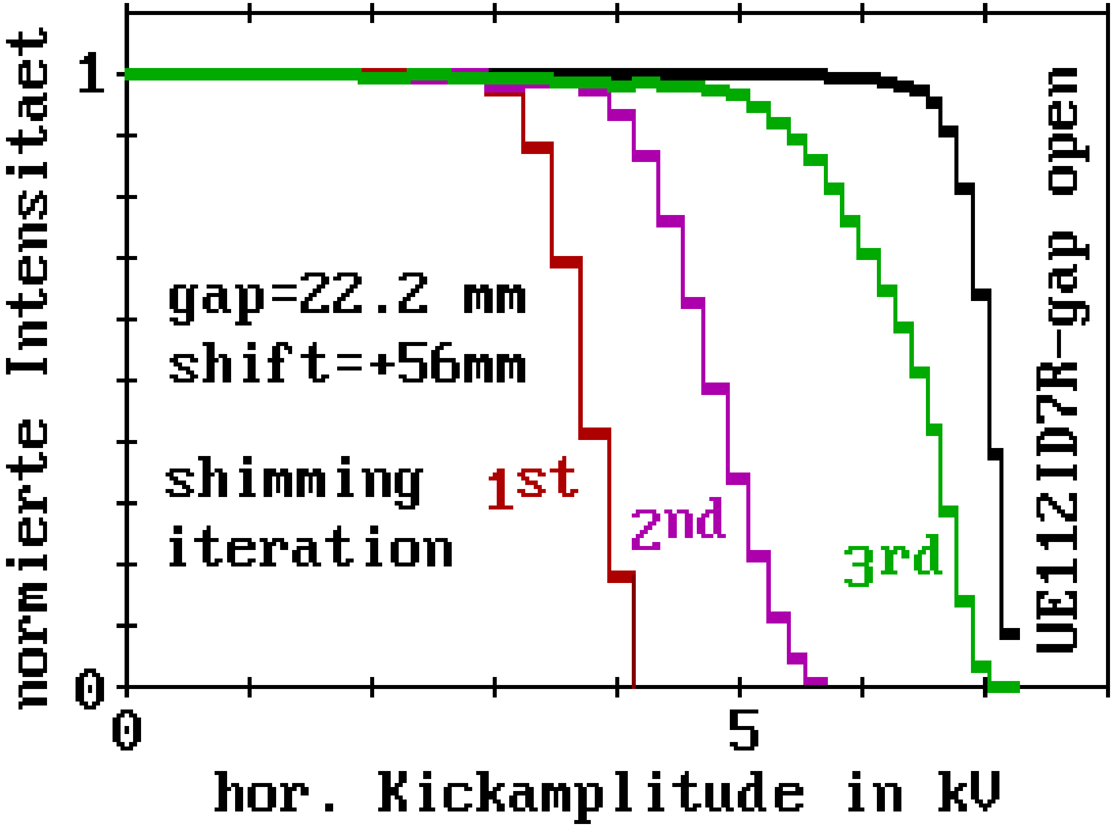


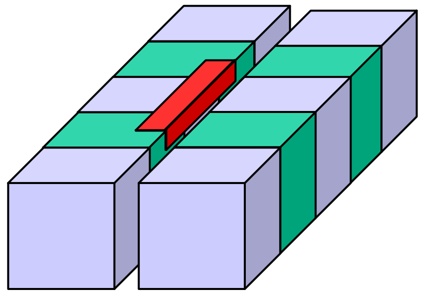
Shimming of the UE112ID7R

APPLE II-type undulator: λ=11.2 cm, B_{max}>1T; E=1.72 GeV, $ß_x$=14m

strong non-linear impact of ID
high sensitivity of beam

partly compensated for by L-shims – iterations required – found good shimming strategy



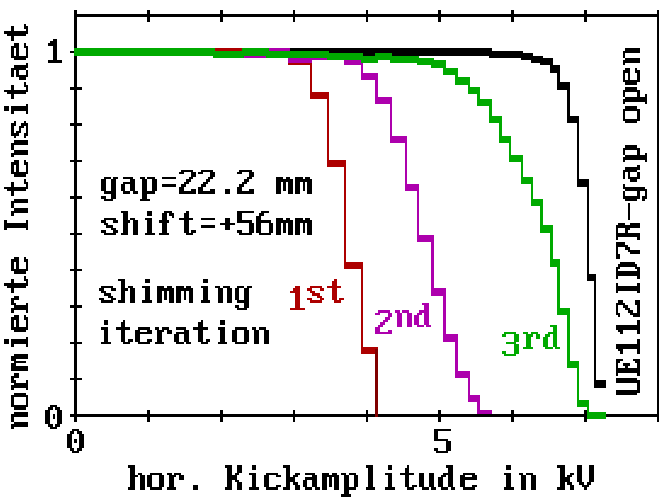


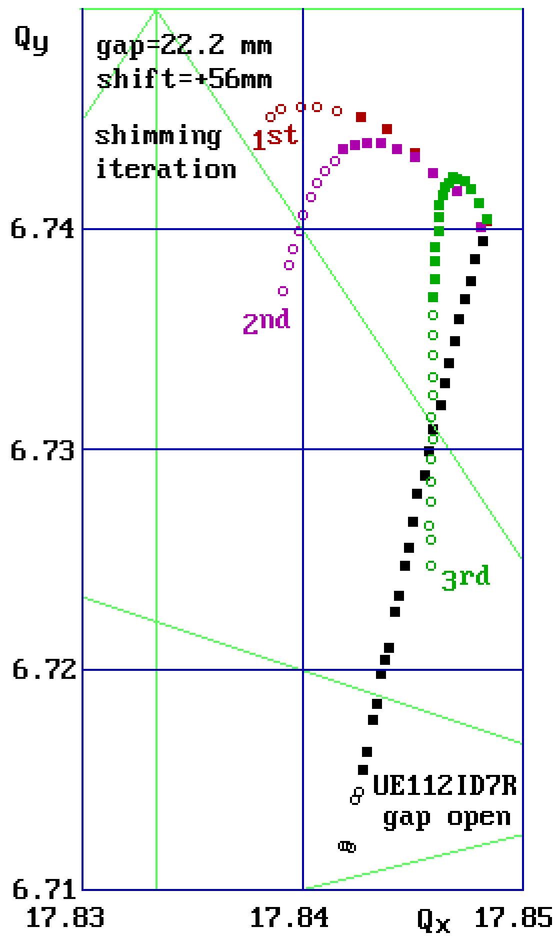
increase of horizontal aperture with L-shims as proposed by J. Chavanne, et al., EPAC 2000

passive shimming for elliptical mode

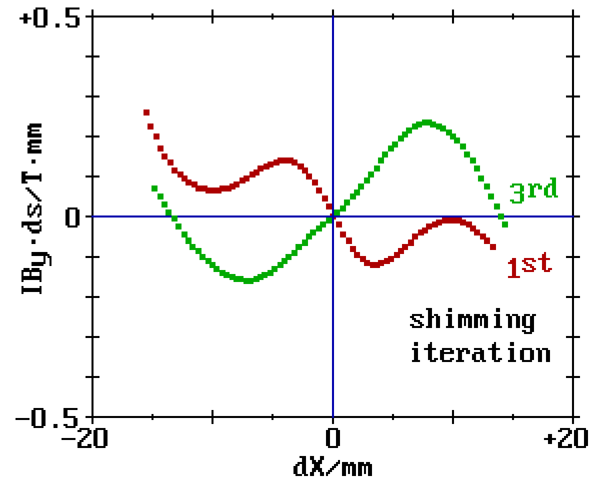
Shimming of the UE112ID7R

increase of the horizontal aperture by improved shimming of ID





measured effective field integral



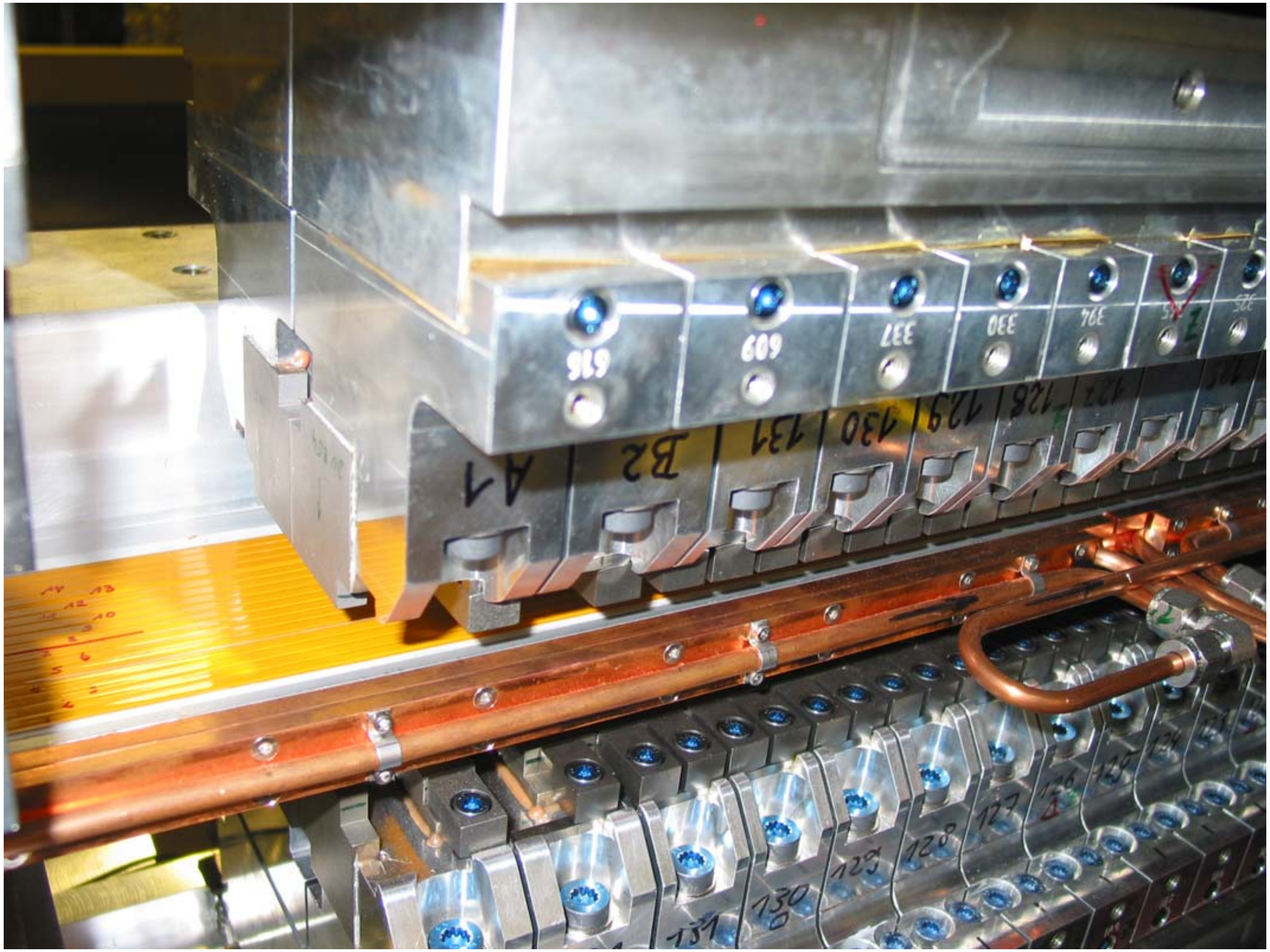
$$I_y^{eff}(x) \approx L \cdot B_0 \cdot \sin(\frac{x}{\lambda}) \approx$$

$$\frac{L \cdot B_0}{\lambda} x - \frac{L \cdot B_0}{\lambda^3}\frac{x^3}{3!} + \frac{L \cdot B_0}{\lambda^5}\frac{x^5}{5!} - \ldots$$

amplitude dependent detuning for different shimming iterations – open symbols indicate beam loss of more than 2%

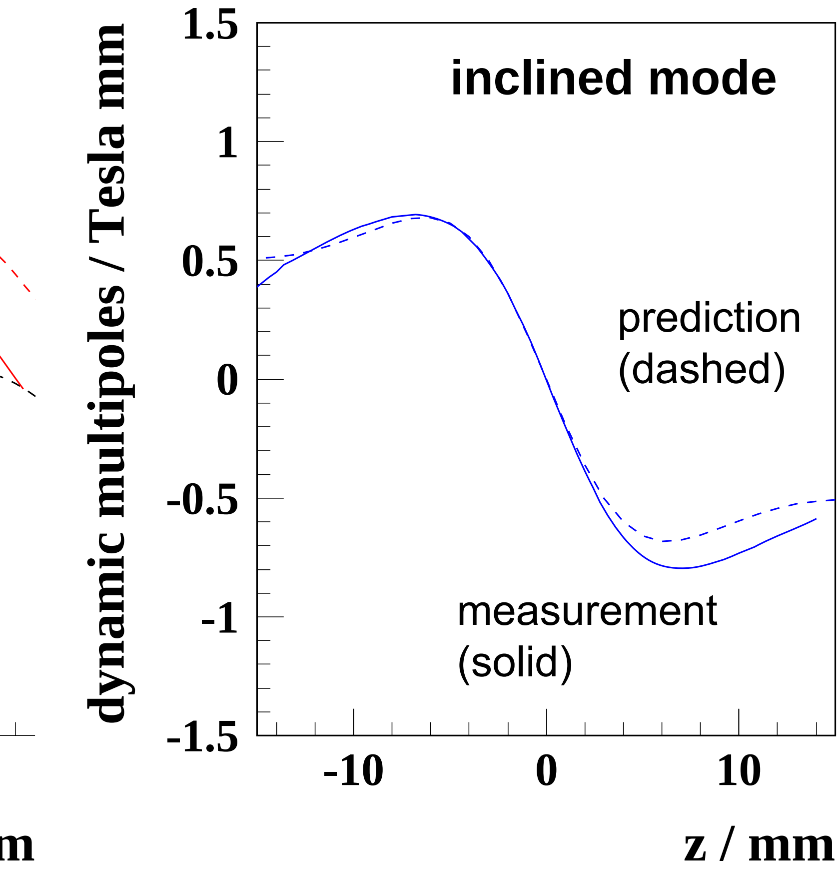
increasing λ is better than reducing B_0

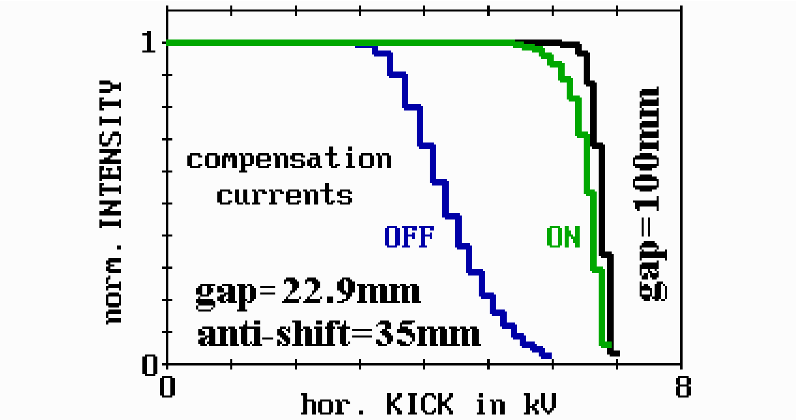
active compensation of dynamic field componentsin the linear/inclined mode

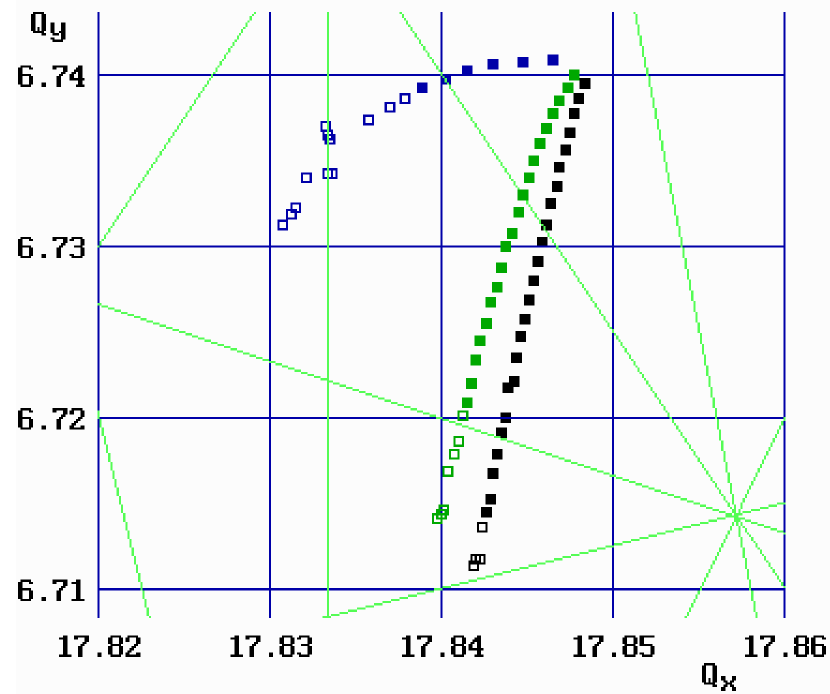


32 flat wires along the ID-chamber with 16 individual PS

UE112ID7R

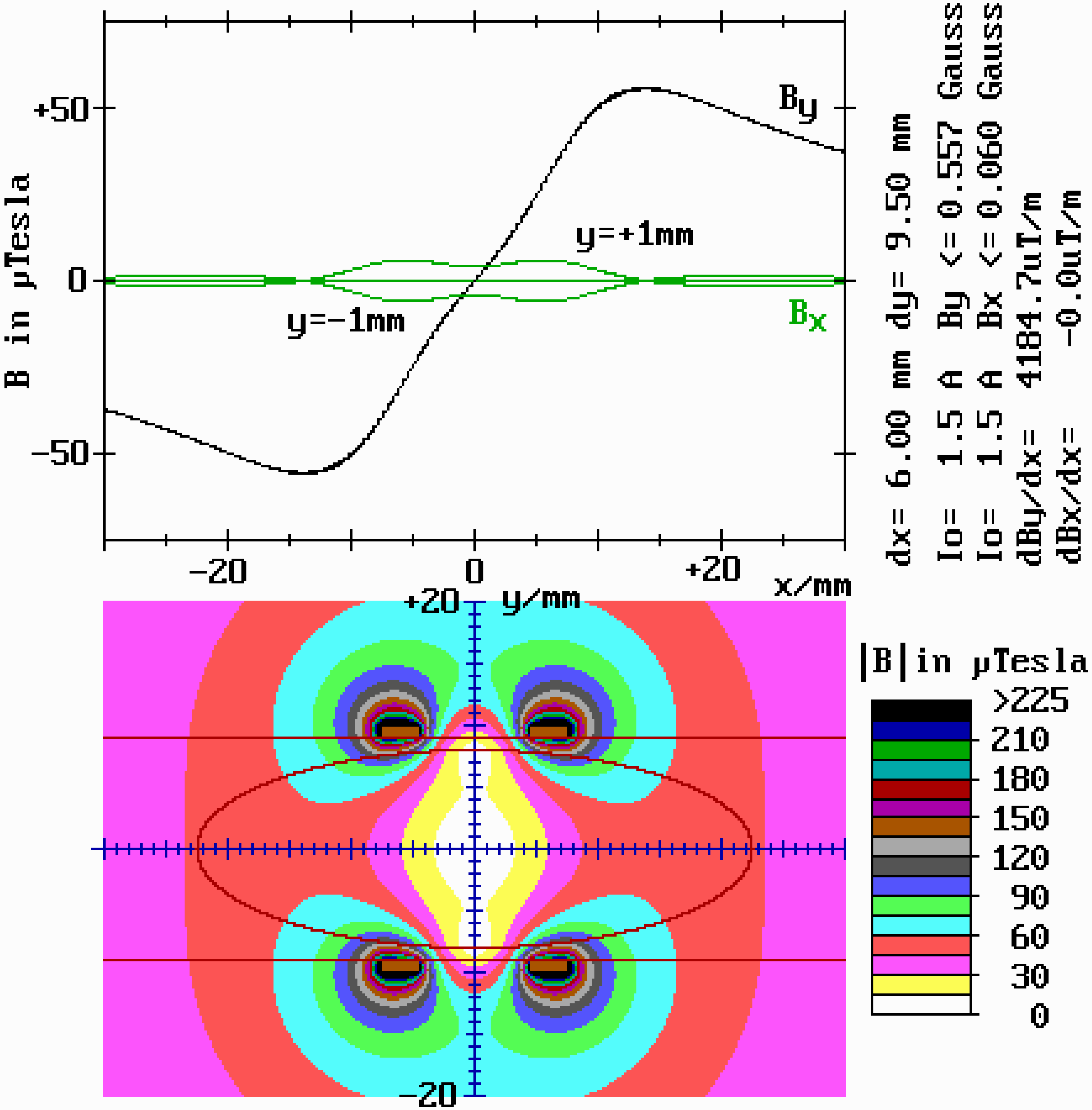


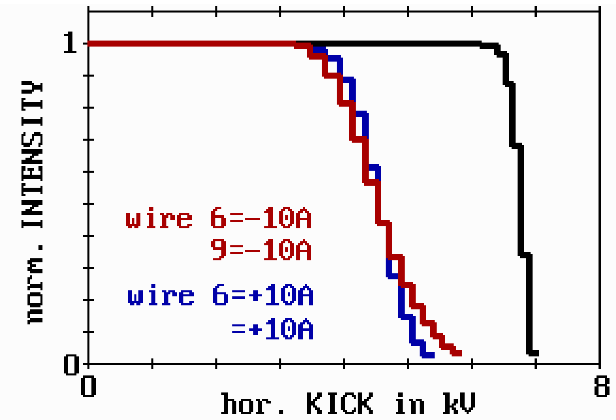


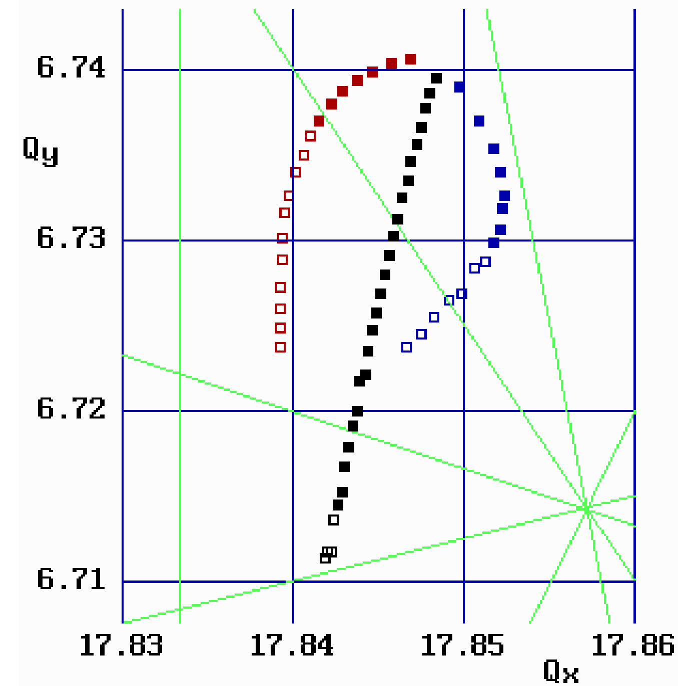


successful active compensation

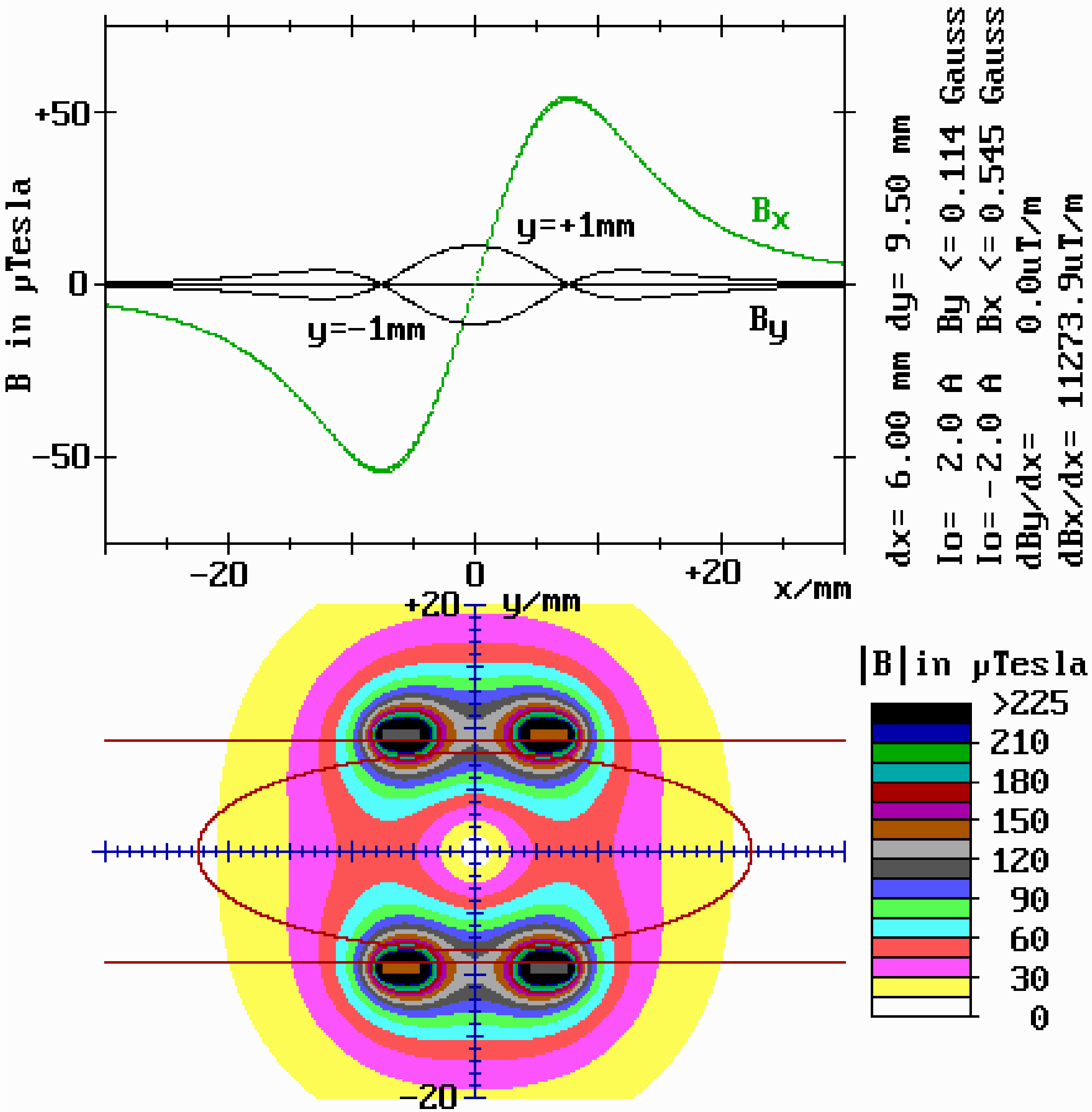
Non-Linear Lens

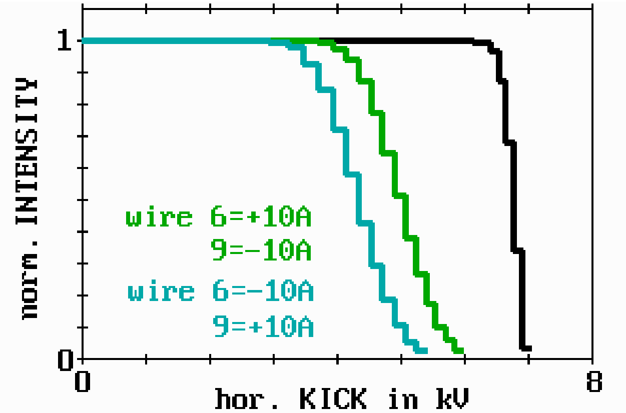


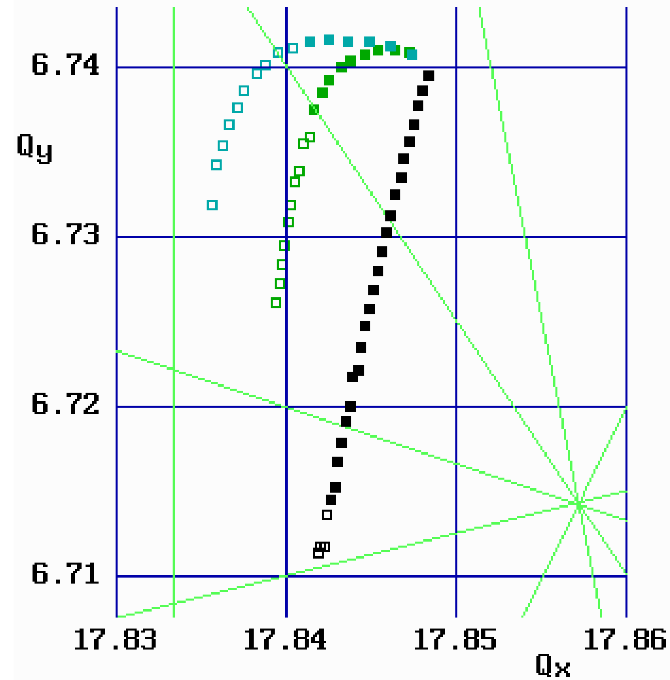




Non-Linear Lens







IDs can reduce the horizontal aperture injection efficiency is much smaller than 90 %

U125 – the planar undulator:

- perfect compensation of static field components has not removed these problems
- the $3Q_x + 2Q_y = 67$-resonance should not be driven by the dynamic field components – in lowest order driven by decapoles - related to the horizontal correctors on the sextupole magnets

UE112 – APPLE II-type undulator:

- in the elliptical mode the passive shimming works and has to be improved – compensation of dynamic field components by the active system
- in the linear mode active compensation very successful – will be implemented as feedforward system

Non-linear lenses created with the 32 wires of the active compensation system:

- will be used to assess impact of non-linear fields on beam dynamics
- compare observations with theory