

A decorative blue curved shape on the left side of the slide, resembling a stylized arrow or a corner element, with a white outline.

Proposal for a Transparent Off-Axis Injection Scheme for BESSY II

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- I. Introduction**
- II. Traditional Injection – 4 Kicker Bump – not Transparent**
- III. Alternative Injection Schemes with Single Non-Linear Kicker – Potentially Transparent**
- IV. Limitations and Ultimate Injection Scheme?**
- V. Summary**

Injection is transparent if

users don't see any perturbation of the photon beam

is $\sigma/10$ still the figure of merit?

is off-axis injection transparent?

how transparent is swap-out injection?

injection efficiency approaches 100%

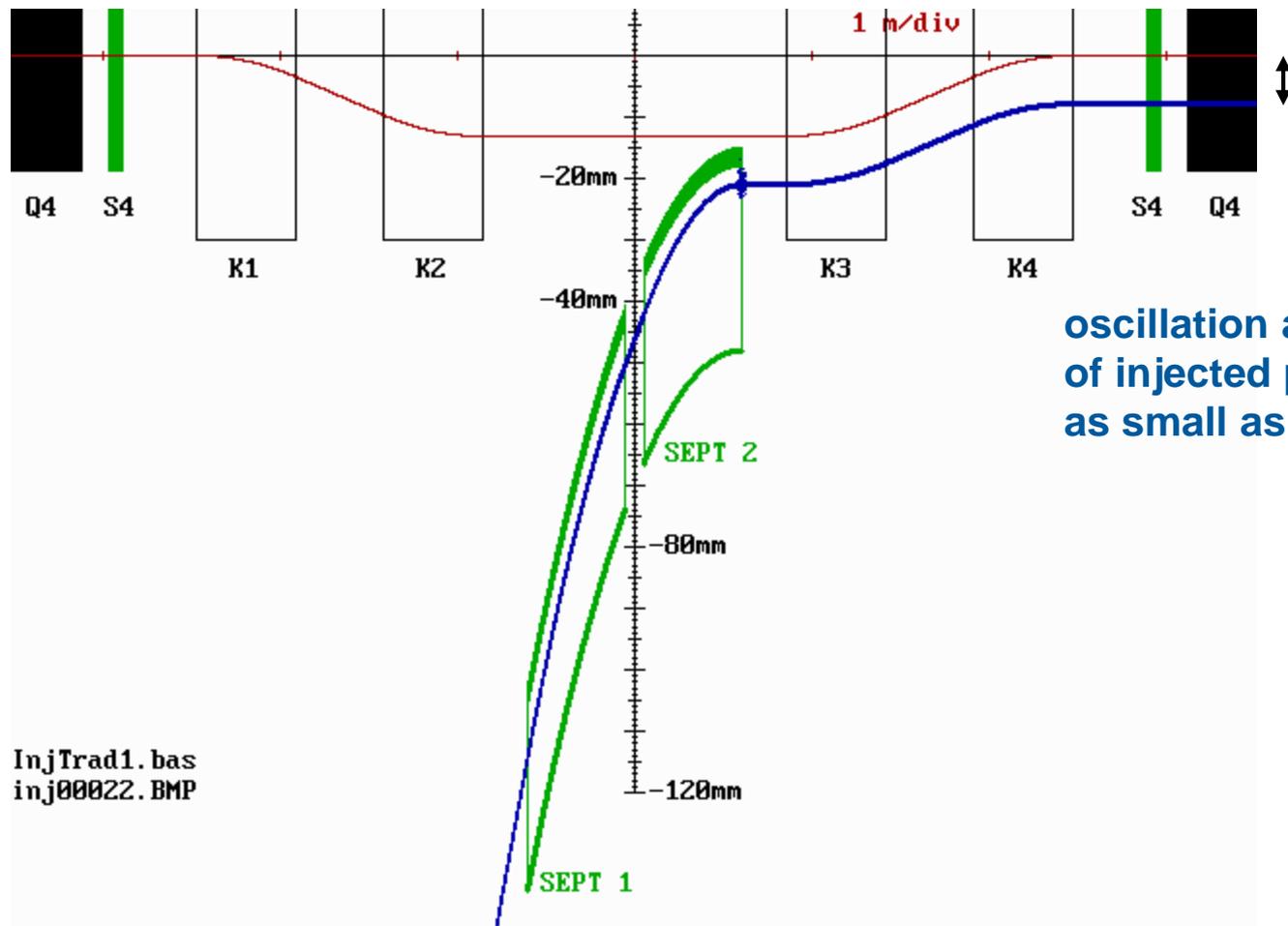
radiation safety

protection of sophisticated IDs

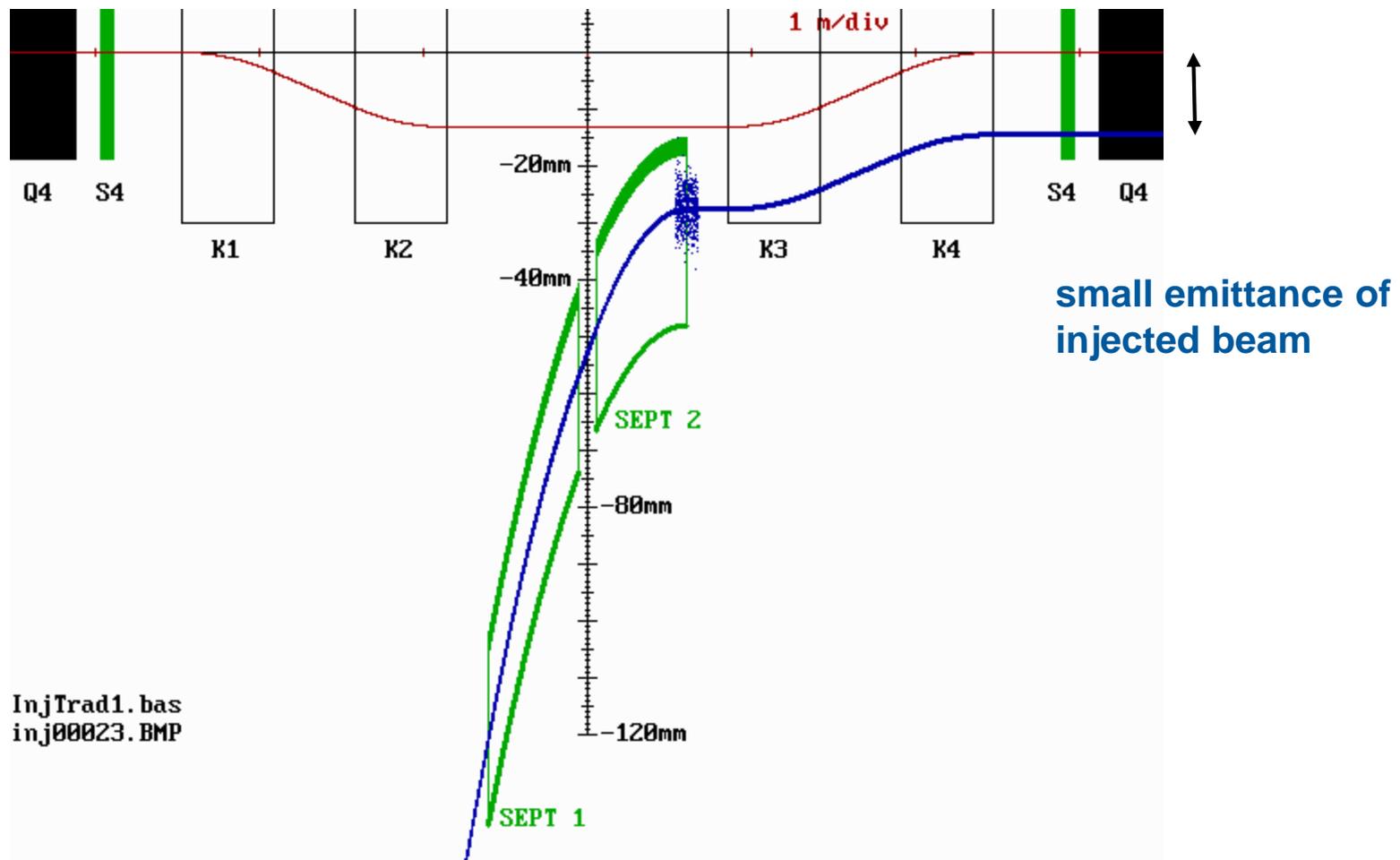
and of lattice elements with permanent magnets

What makes it so difficult?

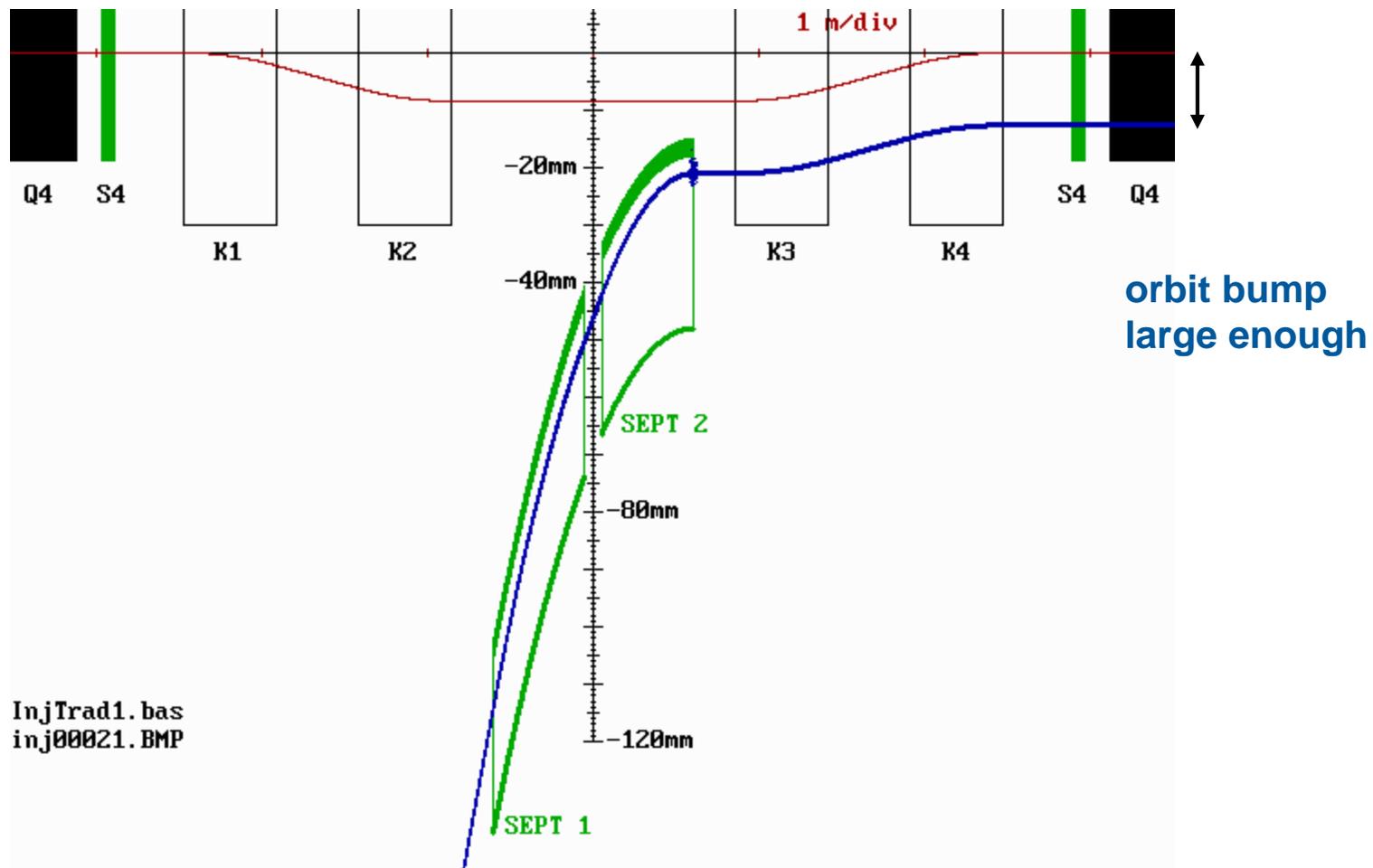
II. Traditional Injection Scheme with 4 Kicker Bump and Septum Magnet



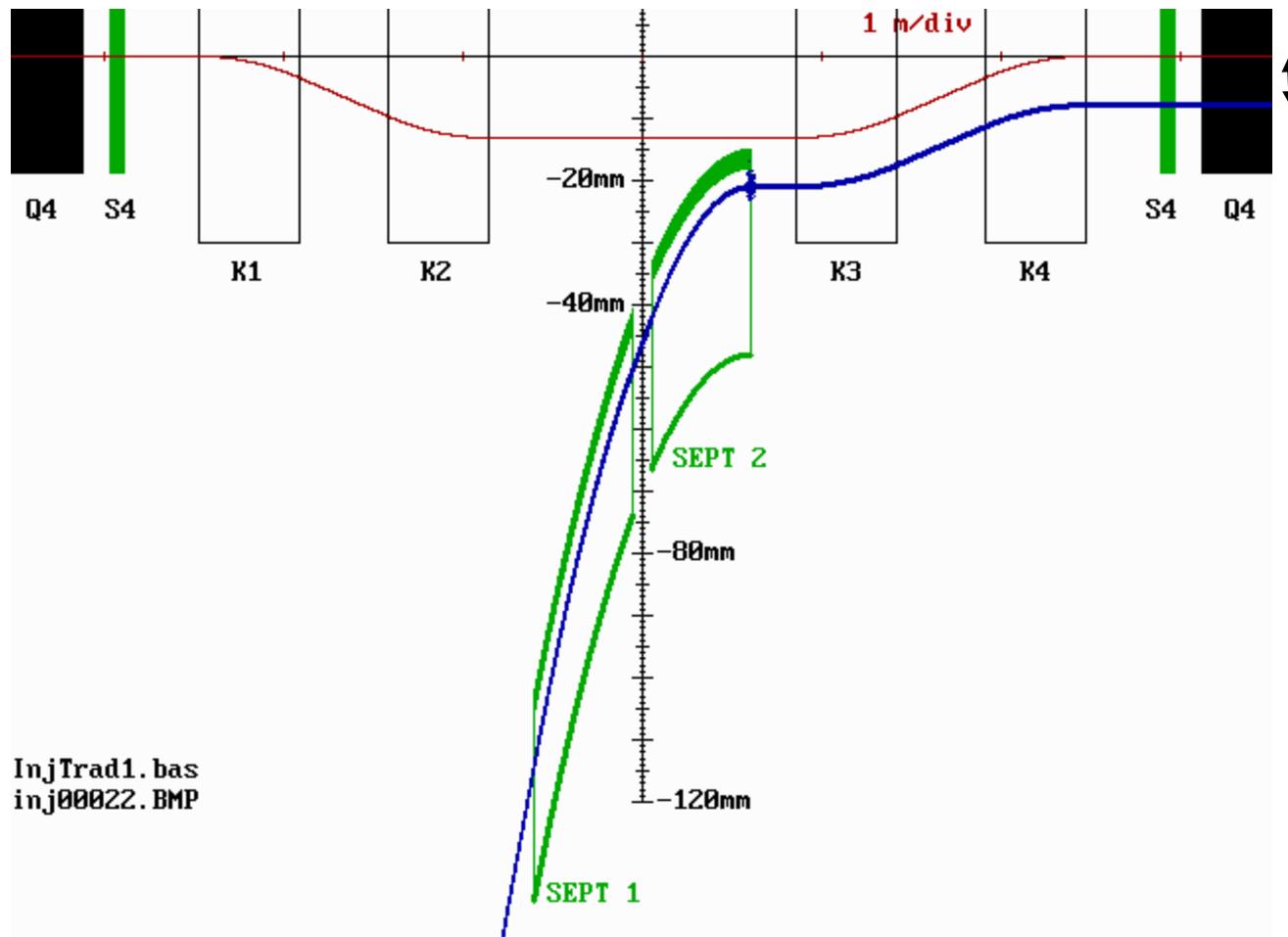
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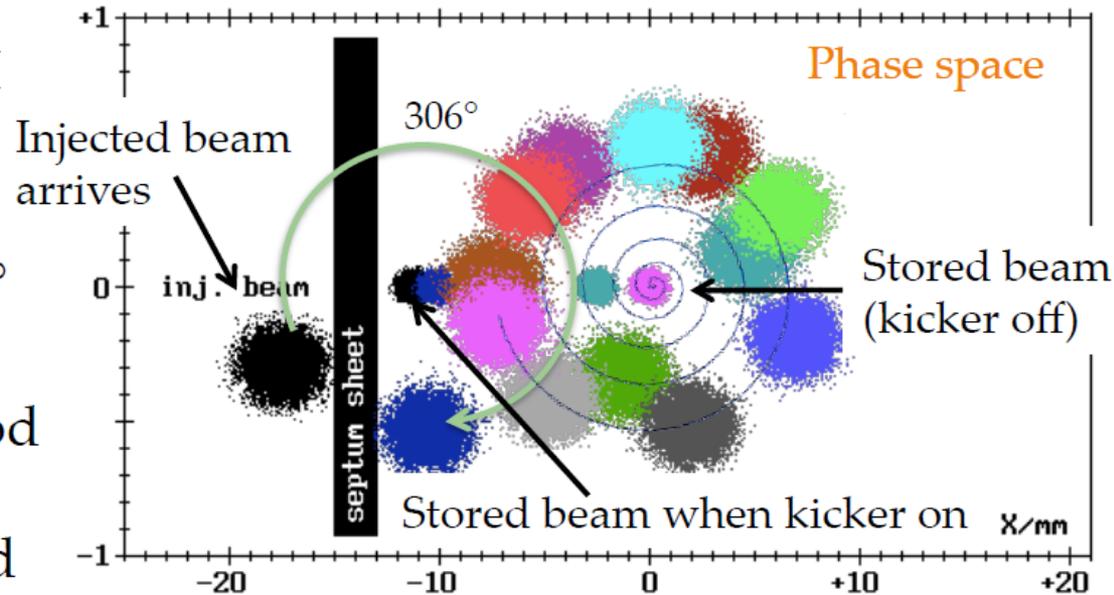
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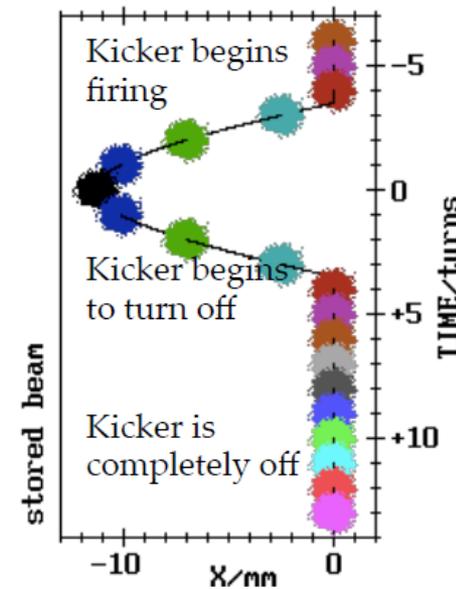
With smaller and smaller beam sizes the oscillation amplitude of injected electrons is determined by the 2-3 mm thick septum blade

II. 4 Kicker Orbit Bump and Correct Timing

- Simulated injection: BESSY II
- Tune: 17.85
 - Fractional tune = 0.85
 - Phase adv. = $17 \times 360^\circ + 306^\circ$
- Damping time is very long compared to revolution period but eventually the beam will spiral towards the origin (and shrink in size – see Lecture 15)...
- Once the beam is damped the same process can be repeated again because the phase space outside the core is free again.
- It is vital that the kicker turns off completely before the injected bunch hits the septum



Displacement versus time (turns) of stored beam



Key factors for 100% injection efficiency:

- dynamic aperture large enough (transverse and longitudinal, IDs, ...)
- emittance of injected beam small enough (transverse and longitudinal, beam stability in synchrotron)
- stable hardware operation (injection/extraction kicker, septa and bumper, timing and amplitudes)
- good optics and beam matching between injector and storage ring

Why does the traditional injection scheme create beam perturbations?

- fast orbit bump is never closed and purely one dimensional – despite many attempts the adjustment of 4 kicker pulses to be identical has never been achieved (pulse shape, timing and amplitude jitter, coatings of ceramic chambers, special shims, feed-forward correction, ...)
- septum magnet stray field has been reduced significantly – alternatively the effect can be nearly cancelled with feed forward compensation. Will this be good enough for the small beam sizes foreseen in the future?

We need alternative injection schemes: like on-axis-off-momentum injection (taking advantage of the large momentum acceptance or with double/triple RF-system), on-axis swap-out injection or off-axis injection with a single non-linear kicker magnet.

III. Single Non-Linear Kicker Injection Scheme

PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS 10, 123501 (2007)

New injection scheme using a pulsed quadrupole magnet in electron storage rings

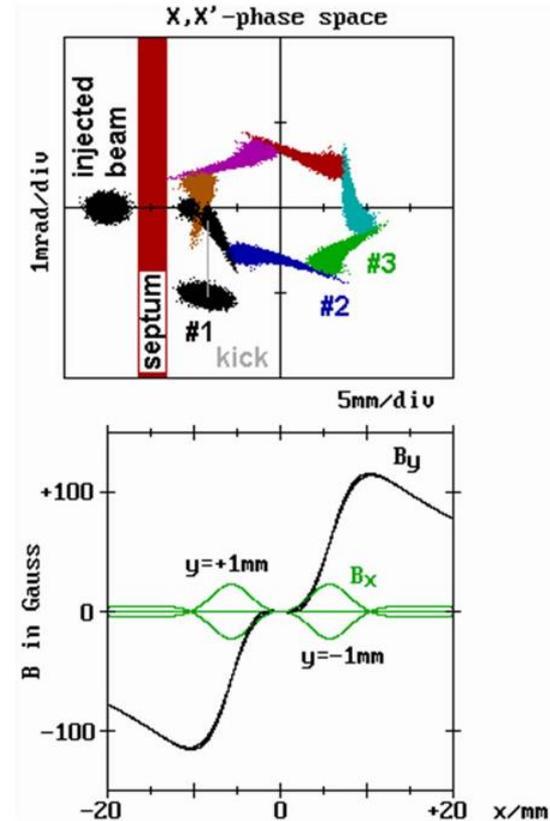
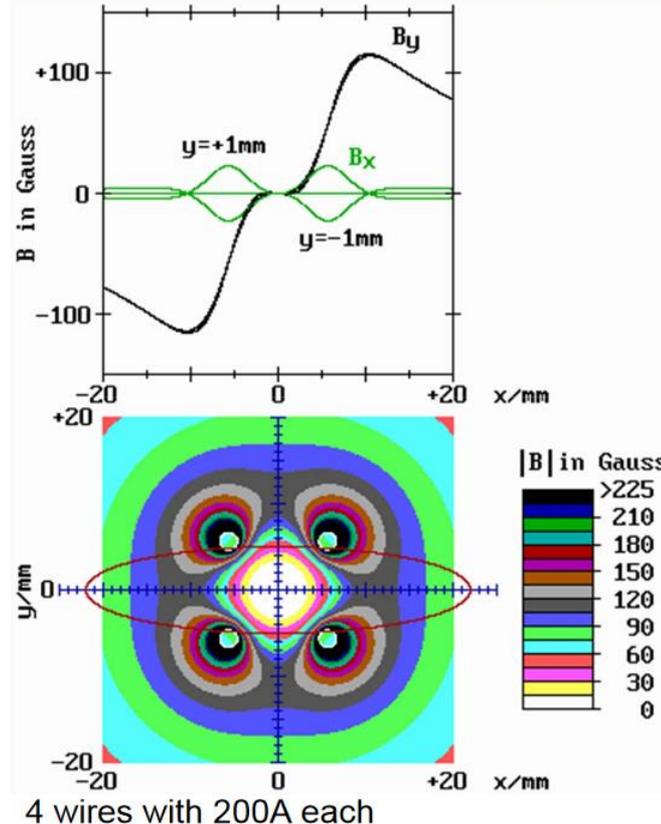
Kentaro Harada,* Yukinori Kobayashi, Tsukasa Miyajima, and Shinya Nagahashi

Photon Factory, High Energy Accelerator Research Organization, 1-1 Oho, Tsukuba, Ibaraki 305-0801, Japan
(Received 30 July 2007; published 21 December 2007)

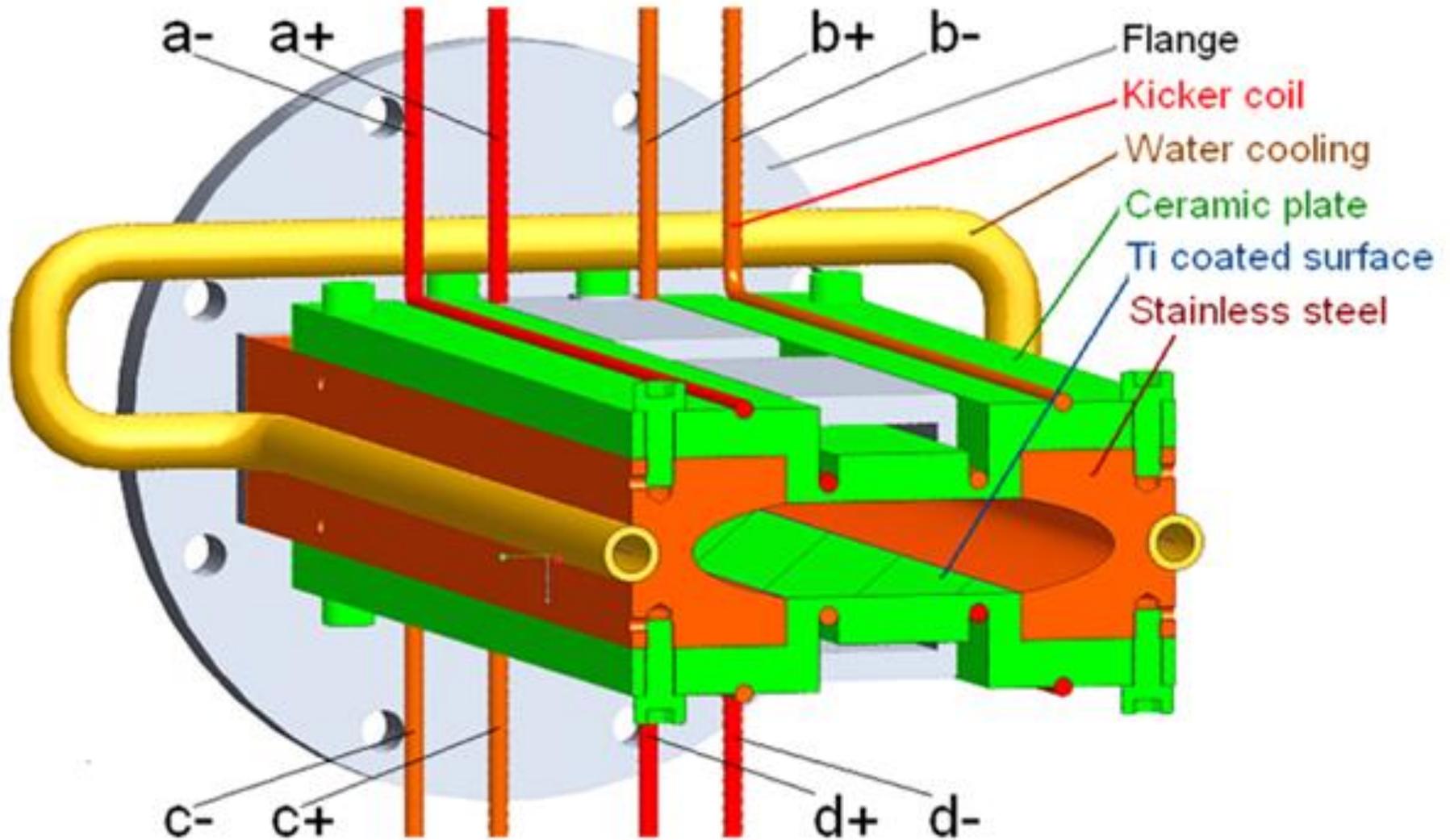
In-vacuum stripline-type design

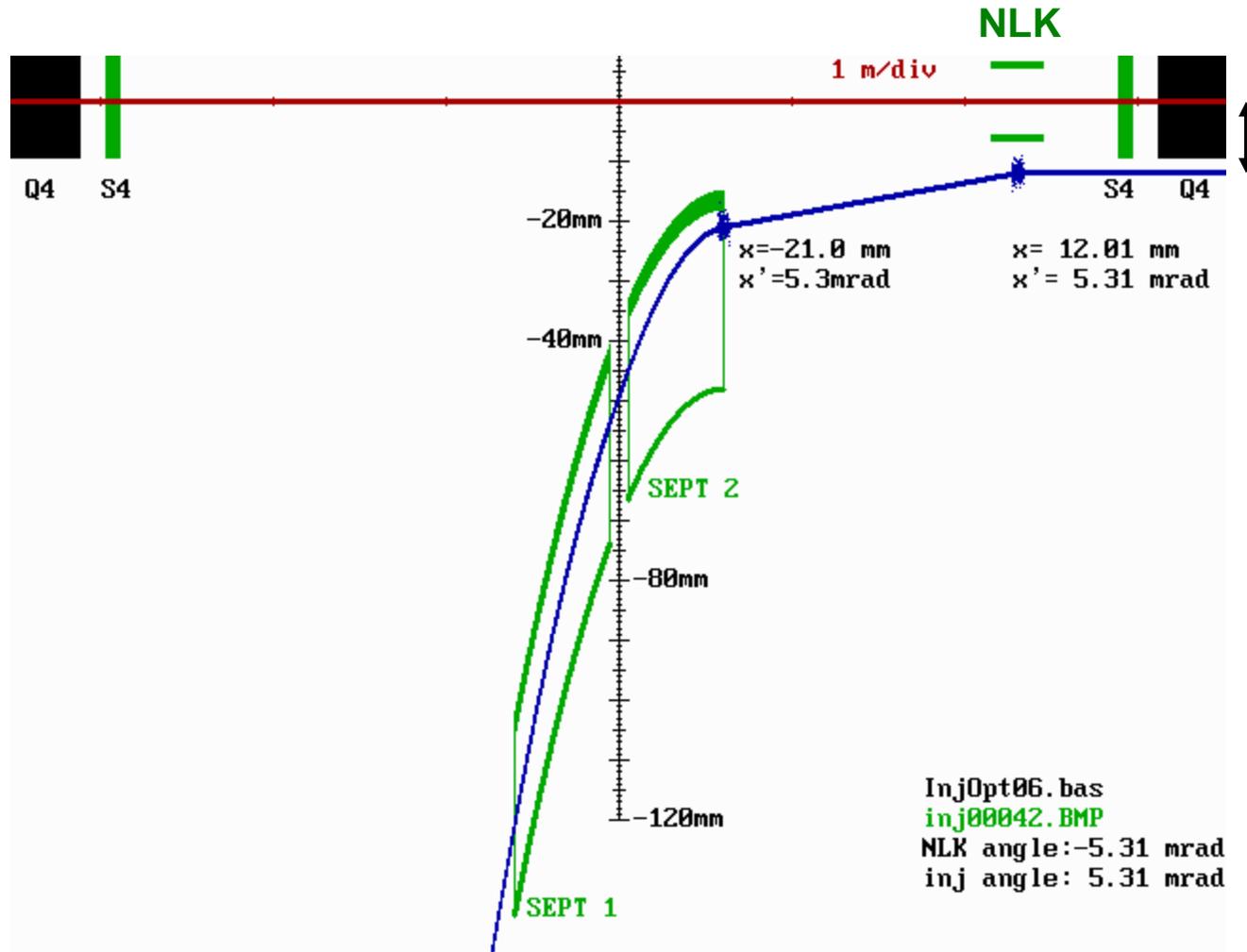
logical improvement:
Replacement of pulsed quadrupole or sextupole magnet by more suitable magnet (NLK, the non-linear kicker magnet)

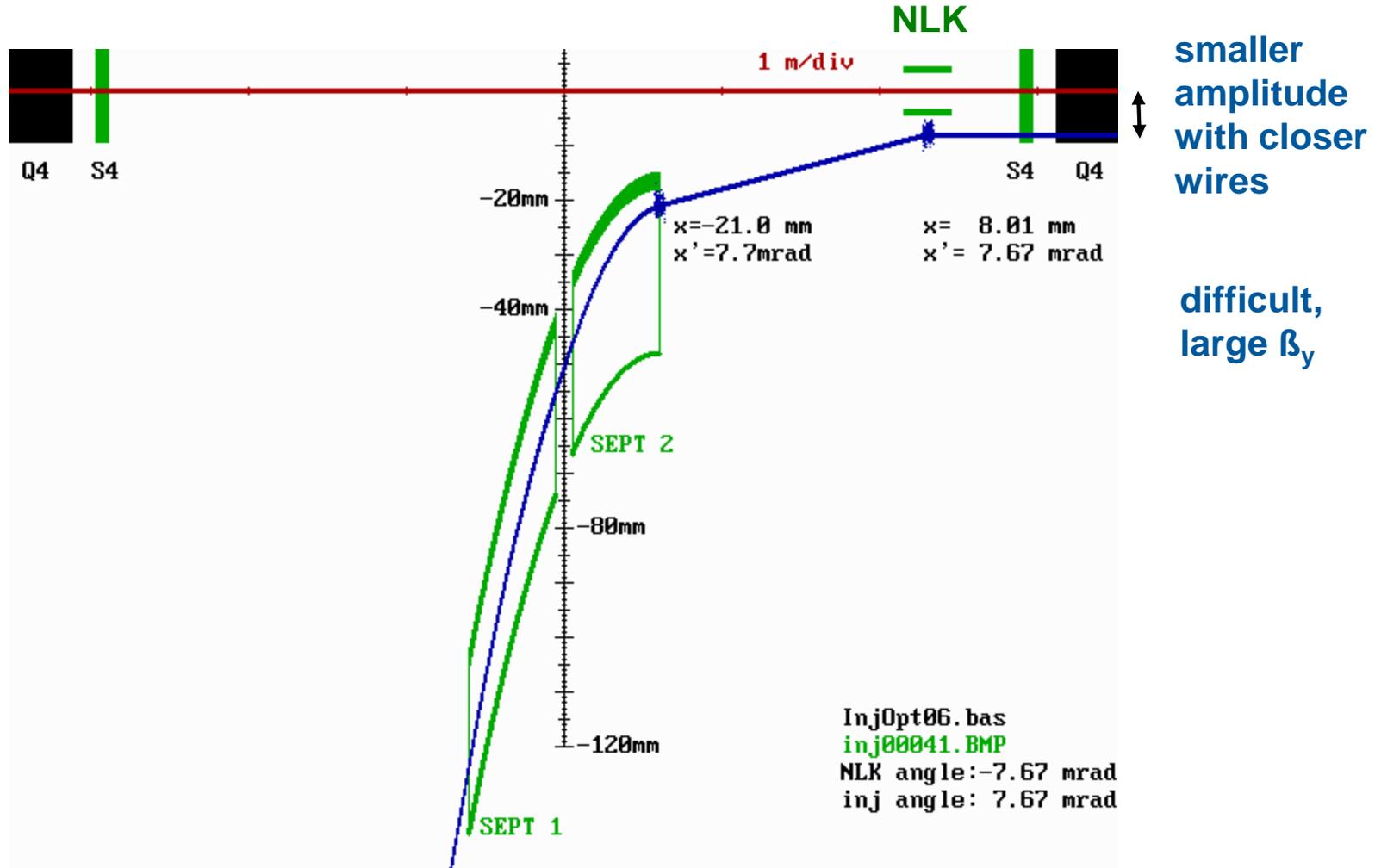
ESLS workshop,
Diamond, 2007

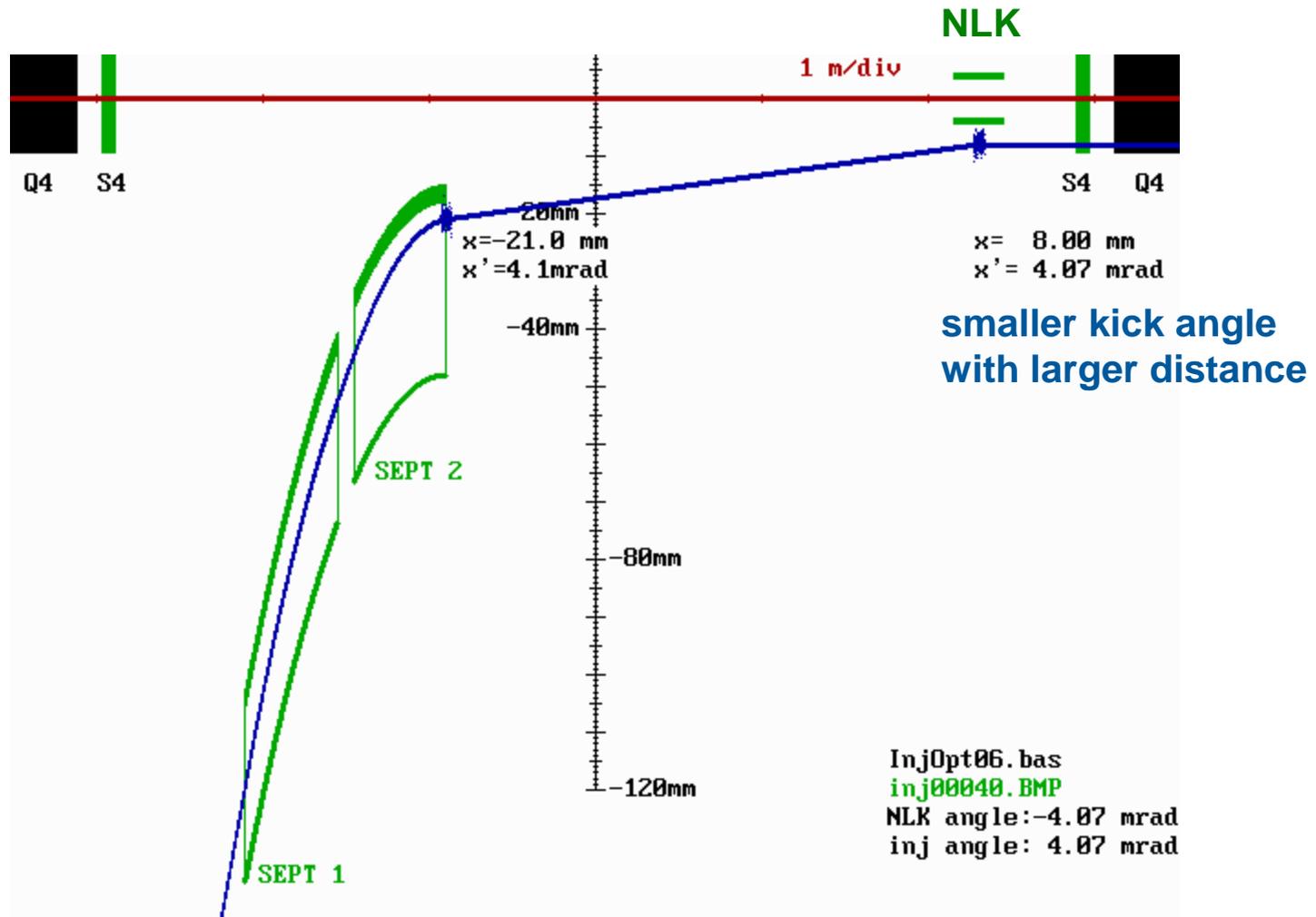


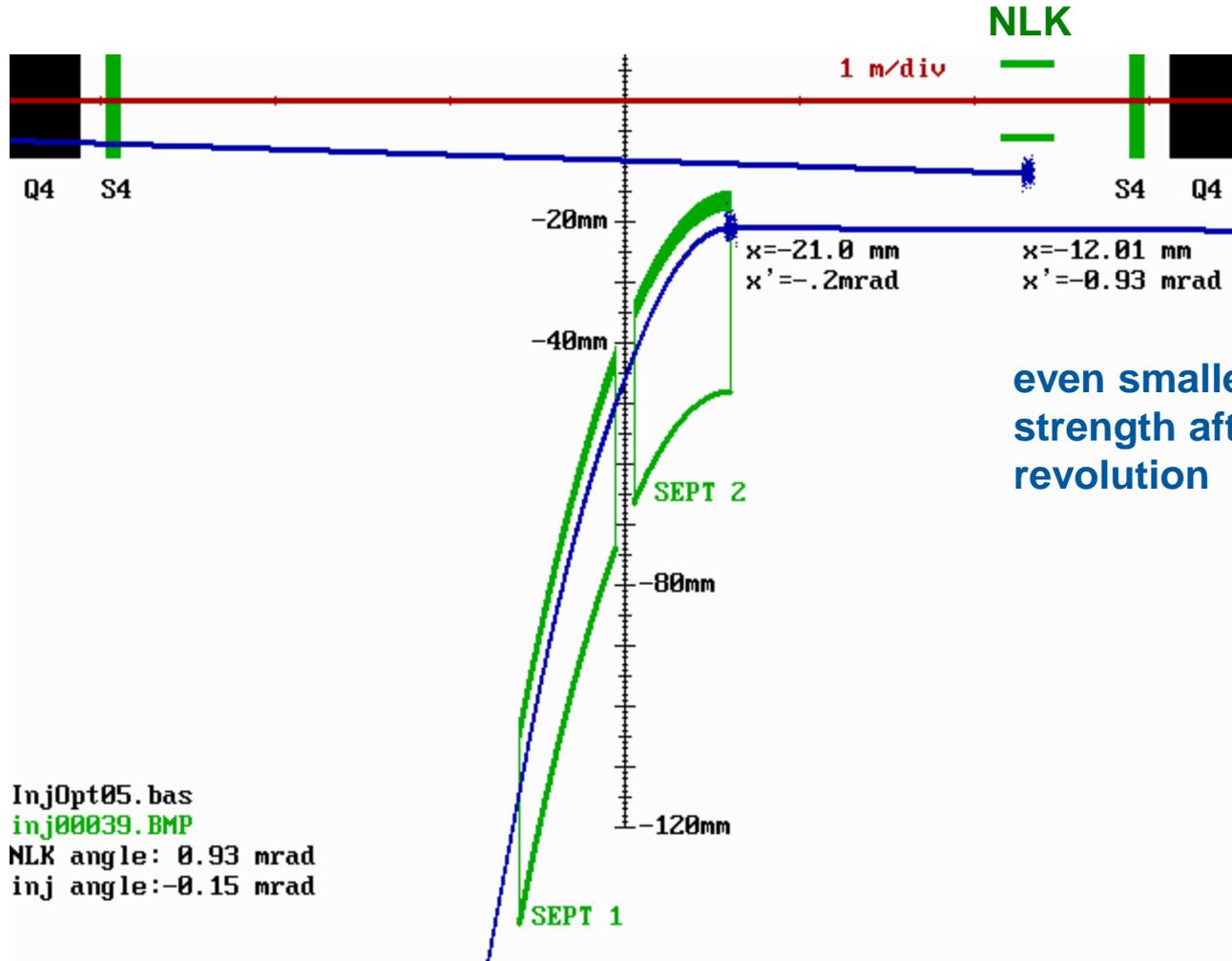
III. BESSY II Non-Linear Kicker (NLK)

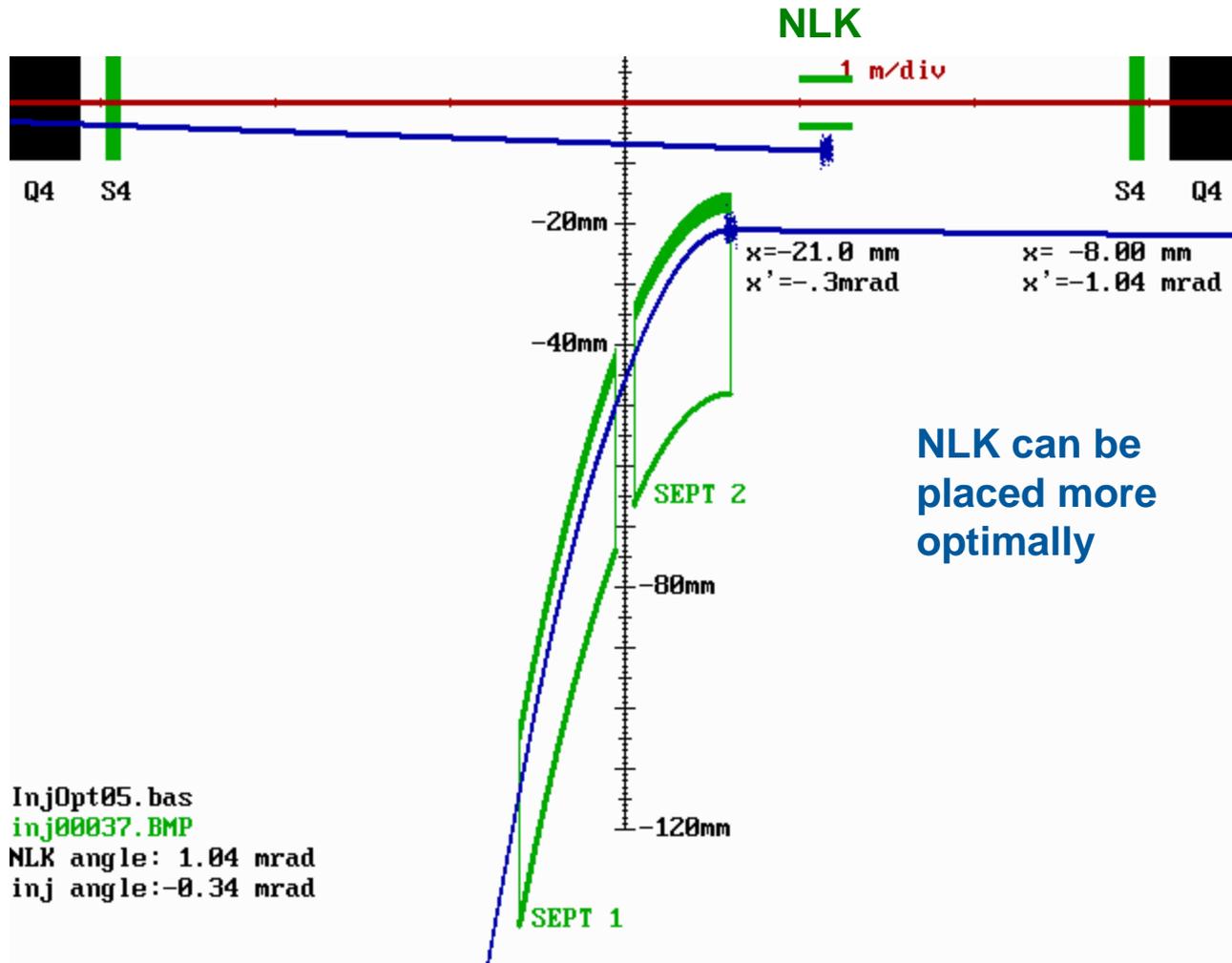




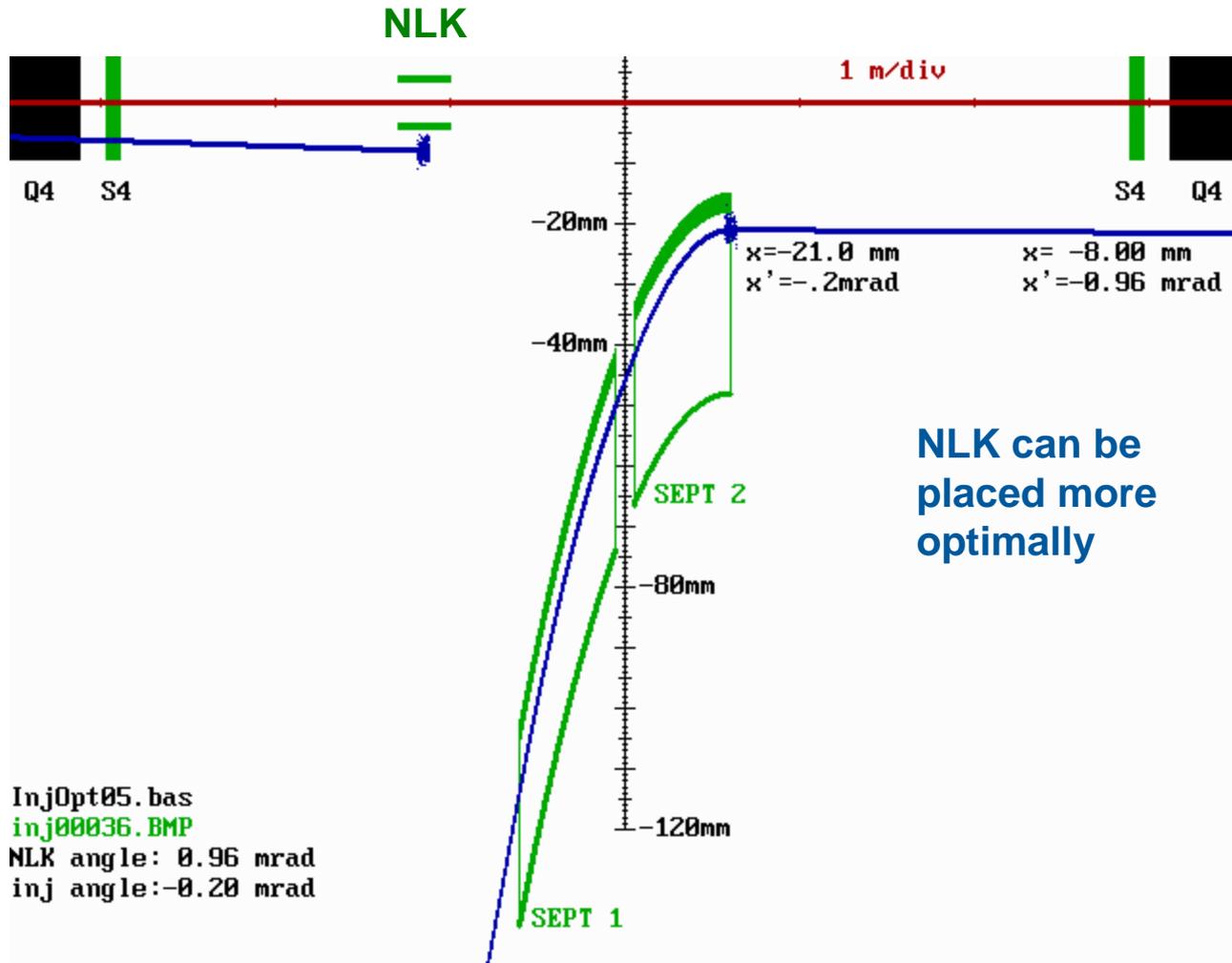




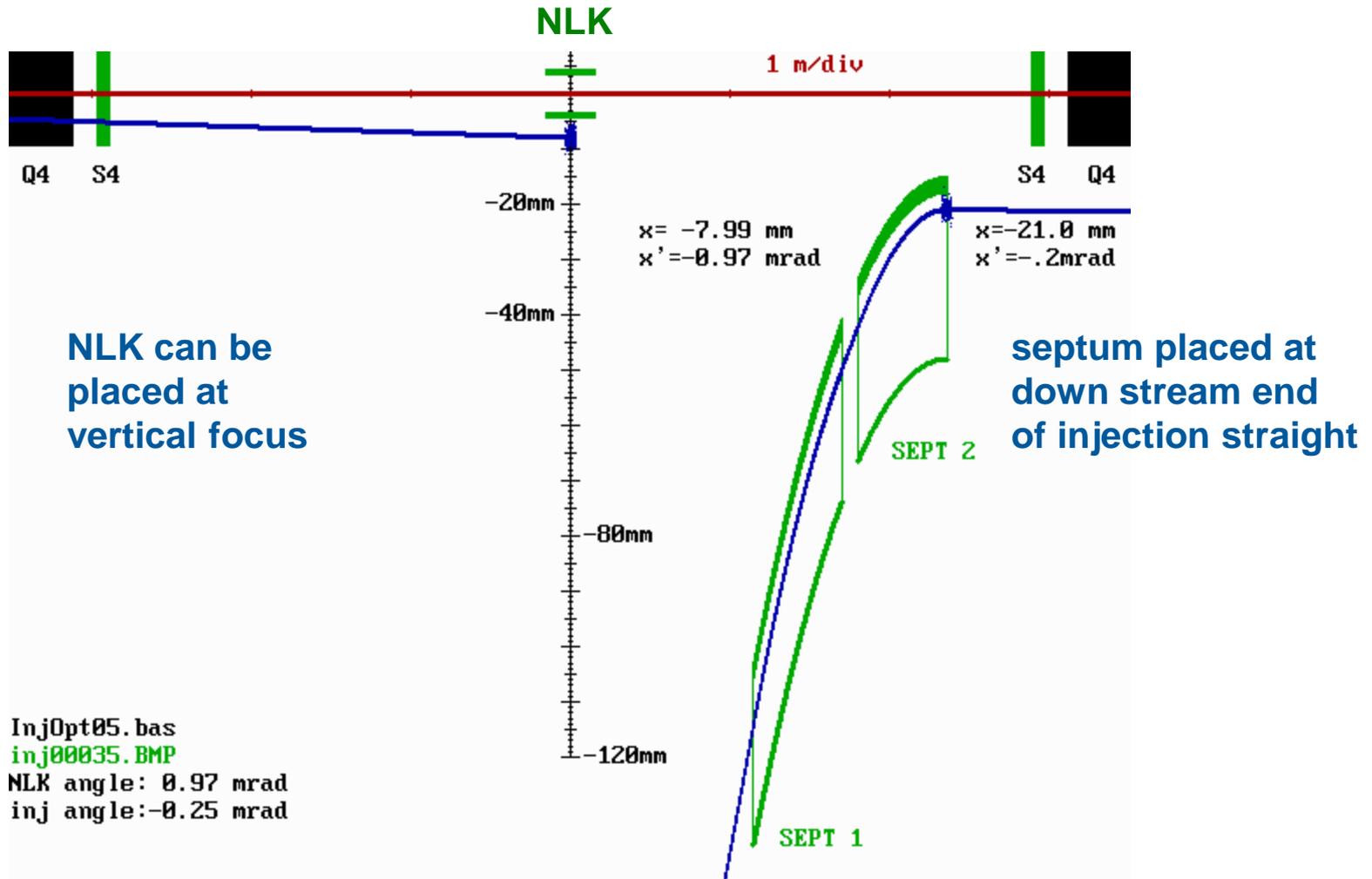




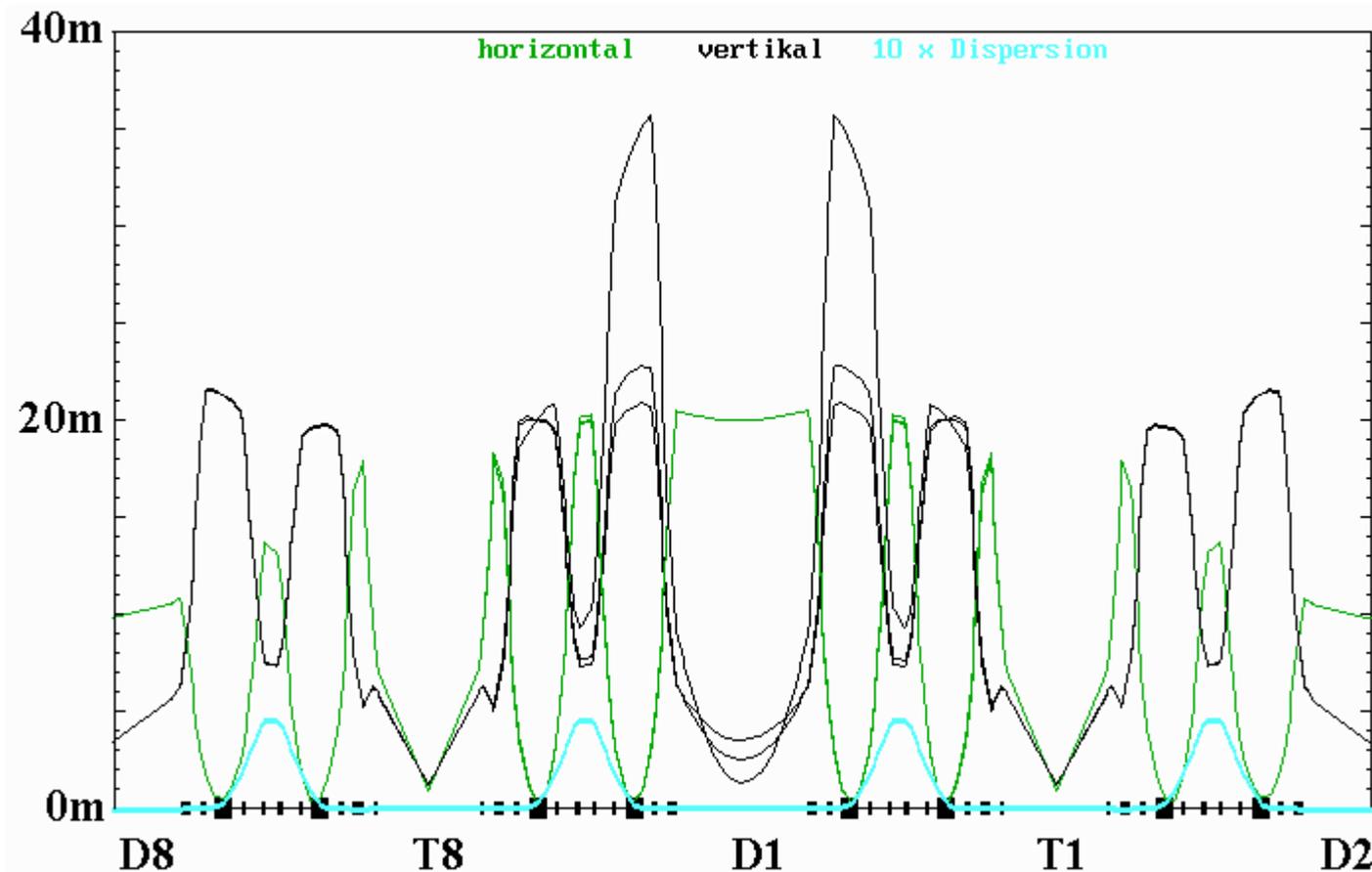
NLK can be placed more optimally



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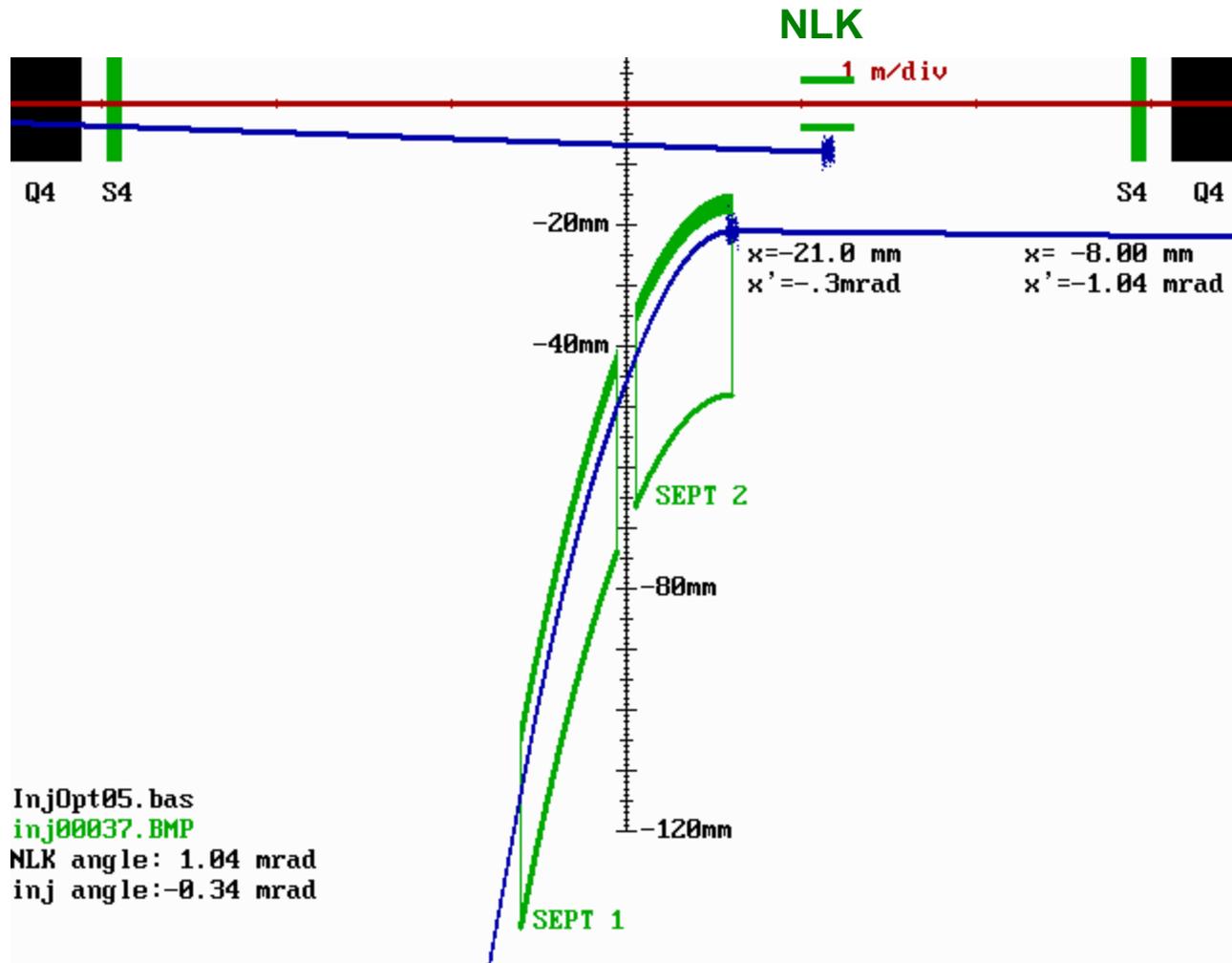


Larger β_x and smaller β_y in the center of the injection straight

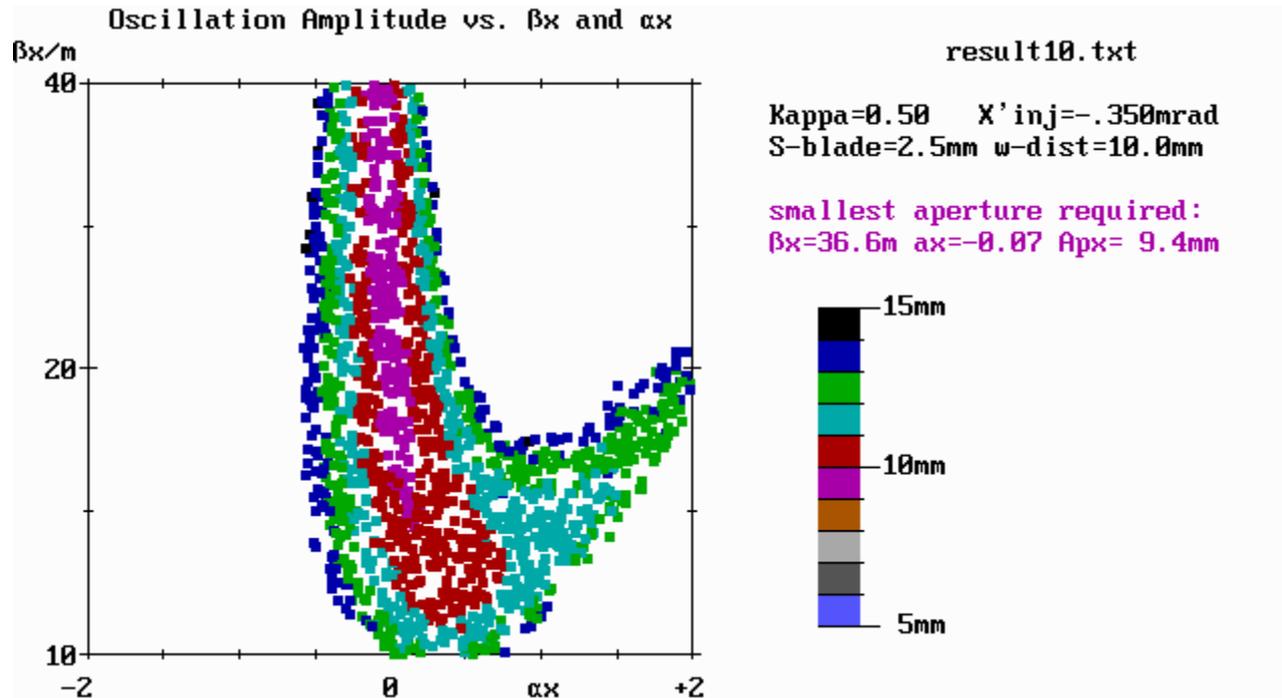


smaller β_x in D-strights mitigates impact of strong APPLE II undulators
 smaller β_y in injection straight allows for smaller vertical gap of NLK

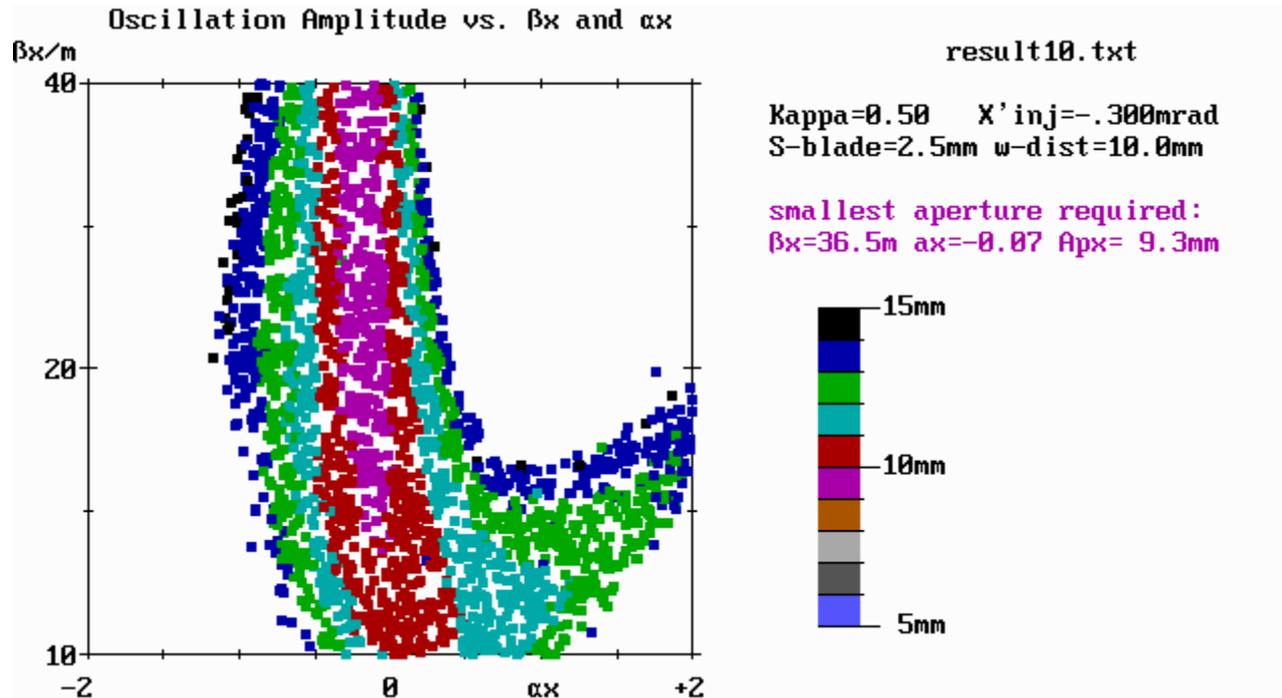
III. Simulations for BESSY II with this Injection Geometry



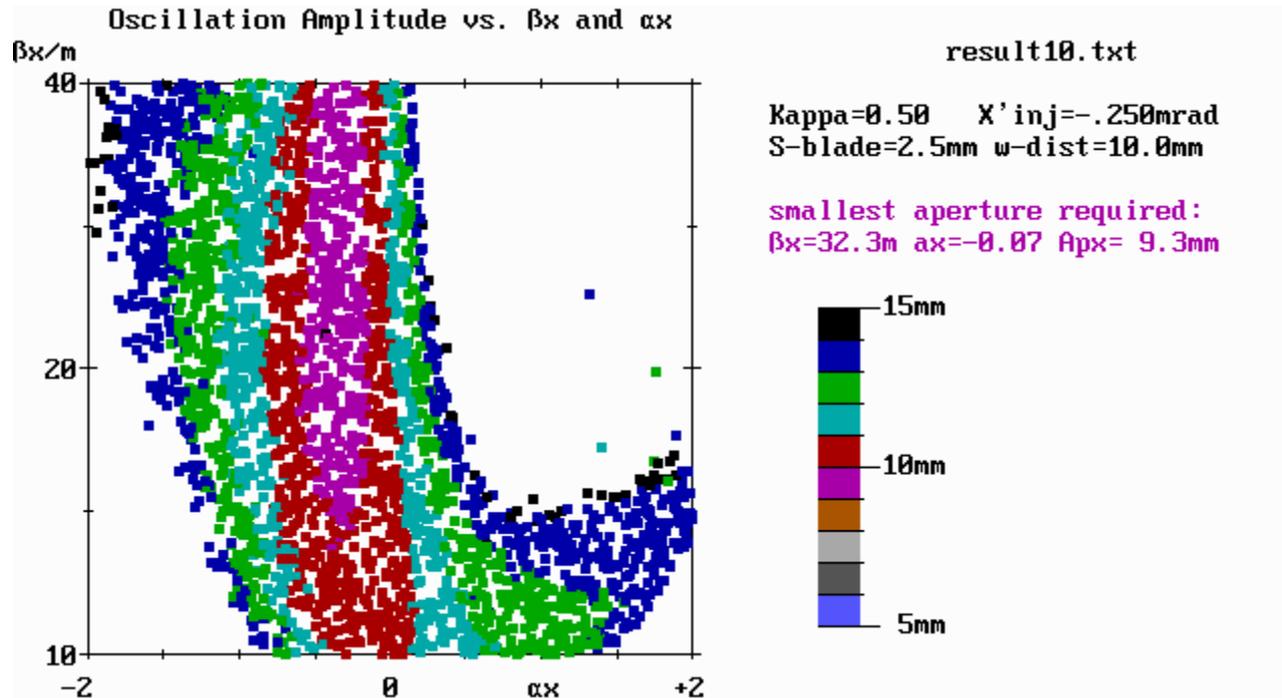
aperture requirement vs β_x and α_x
with injection angle -0.35 mrad



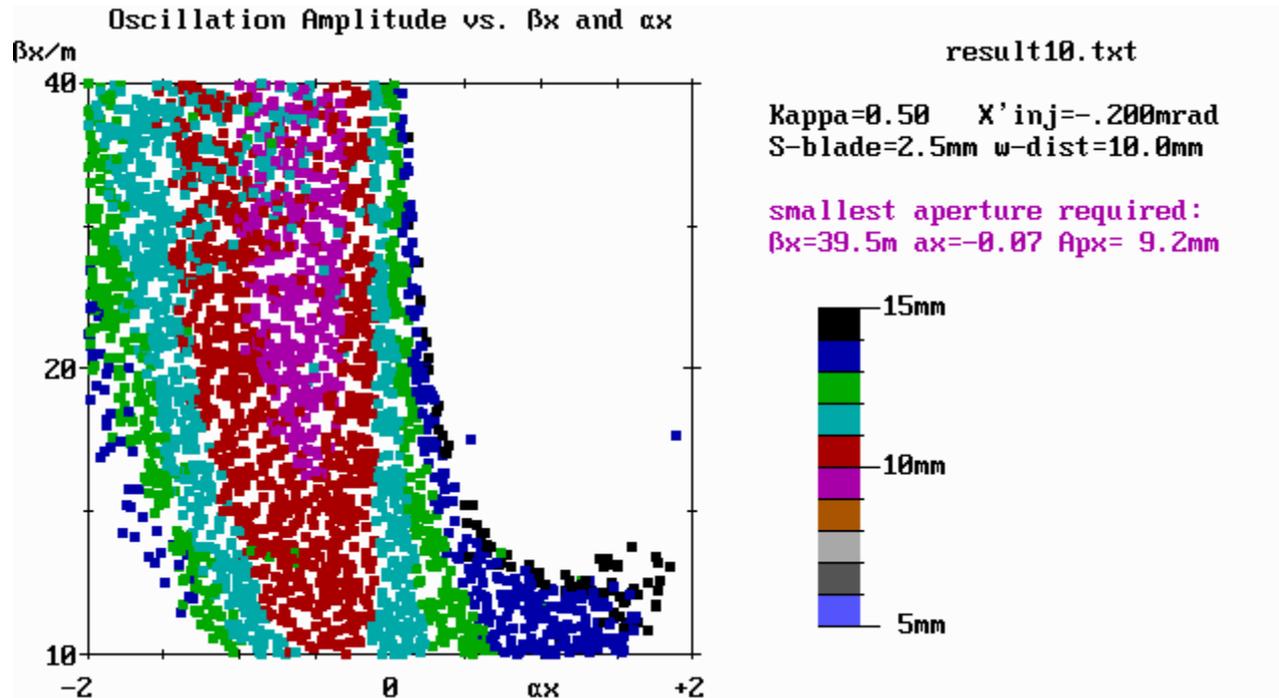
aperture requirement vs β_x and α_x
with injection angle -0.30 mrad



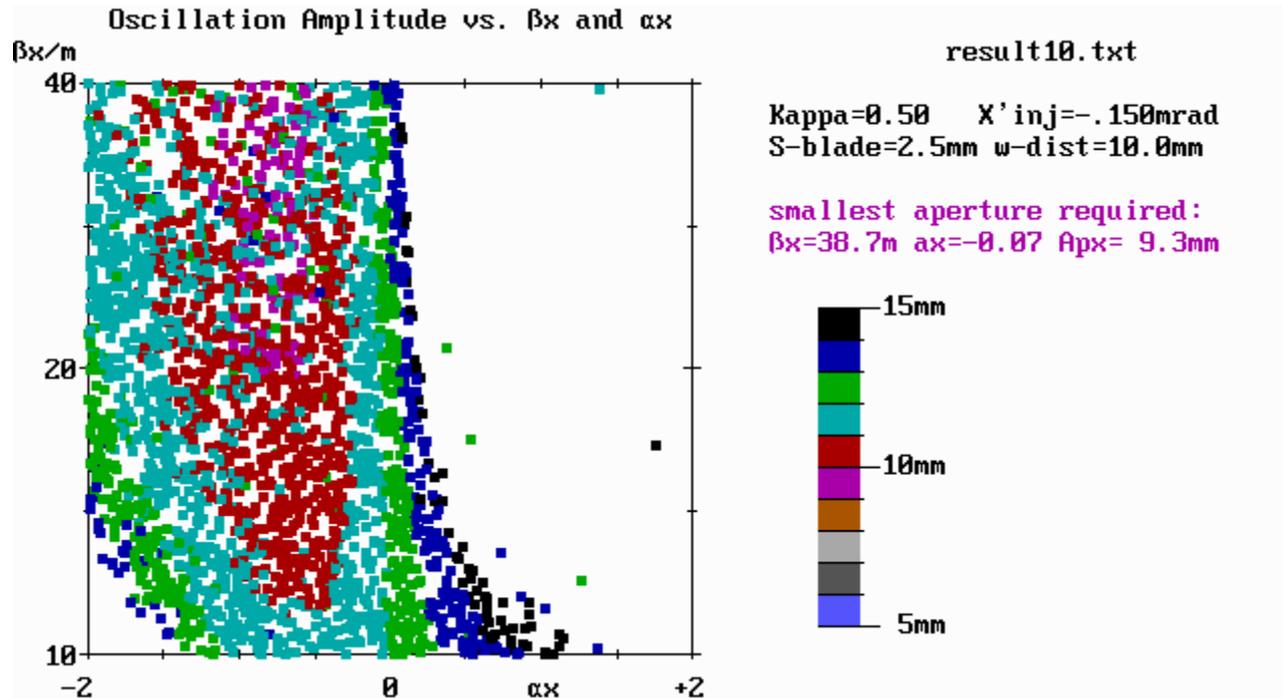
aperture requirement vs β_x and α_x
with injection angle -0.25 mrad



aperture requirement vs β_x and α_x
with injection angle -0.20 mrad



aperture requirement vs β_x and α_x
with injection angle -0.15 mrad



IV. Limitations and Ultimate Injection Scheme?

In the 4 kicker orbit bump injection scheme the thickness of the septum blade eats up most of the valuable dynamic aperture, less so for single NLK injection

Low emittance rings demand low emittance injectors – synchrotron in the storage ring tunnel (Swiss Light Source) – or LINAC (MAXIV)

What would be helpful:

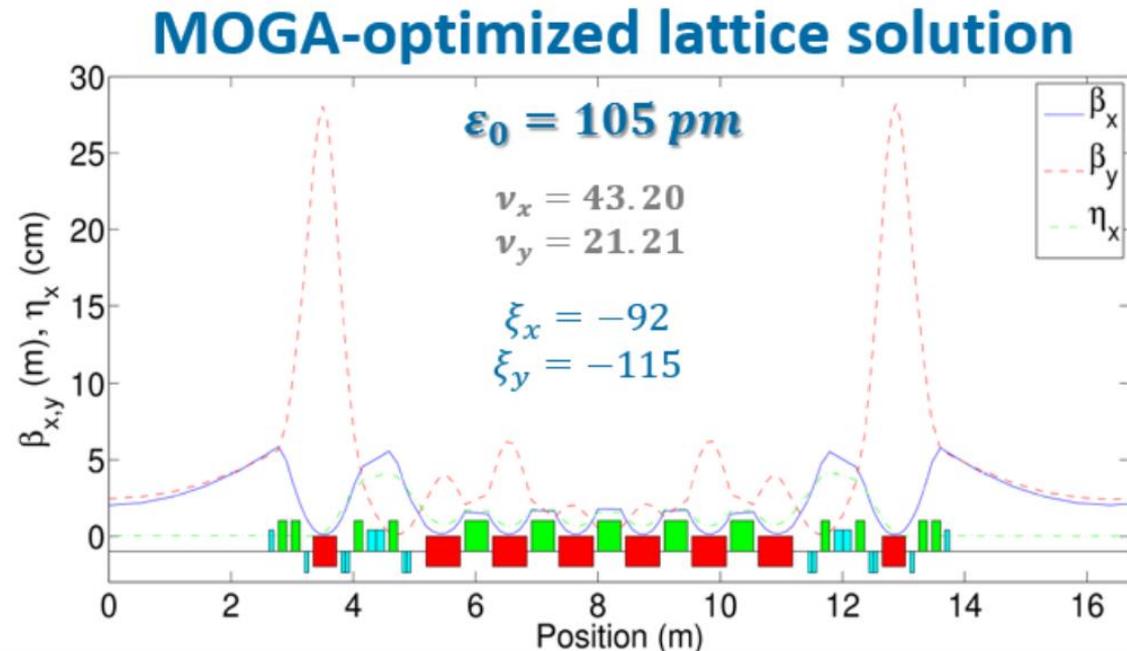
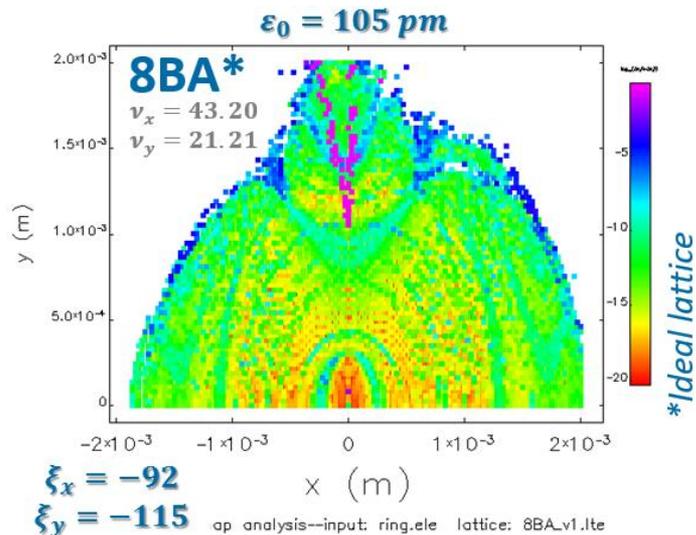
Septum magnet without blade – the non-linear kicker for example, any multipole magnet

→ beam injected under smaller angles

Smaller vertical gap of NLK – would we accept 1 mm vertical aperture over 50 cm?

→ 2 mm off-axis injection

ALS-U, 8BA-lattice – can β_x be larger and β_y smaller in injection straight without sacrificing emittance and aperture? Is swap-out injection the only way?



M. Venturini, LER Workshop, Oct. 2016,
Soleil, Paris, France

Off-Axis injection into electron storage rings can be performed transparent and with high efficiency if:

- **an alternative to the 4 kicker injection scheme is used**
- **emittance of the injected beam approaches the emittance of the stored beam**
- **sufficient dynamic aperture available**
- **septum blade as thin as possible**
- **NLK operated with smaller vertical vacuum gap**

Swap-Out injection will not be fully transparent – amplitude and timing jitter of kicker magnets

Neither will be the off-axis injection even if the stored beam remains perfectly stable

users have to live with that

In the future high injection efficiency will become even more important:

- **radiation safety**
- **protection of sophisticated IDs**
- **protection of lattice elements with permanent magnets**

High injection efficiency - challenge for all alternative injection schemes

any questions?