Damping Wigglers in PETRA III

WIGGLE2005, Frascati 21-22.2.2005
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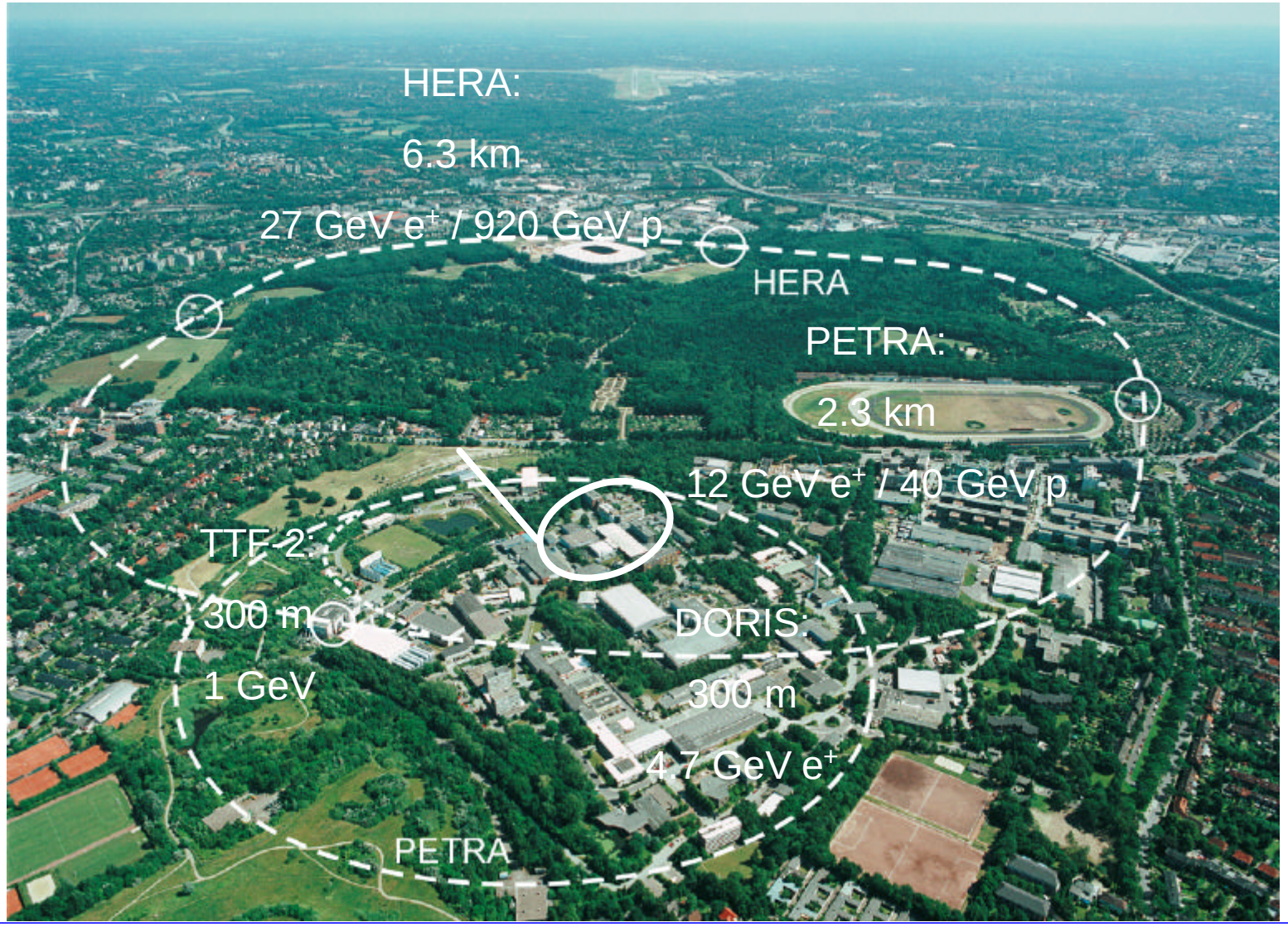
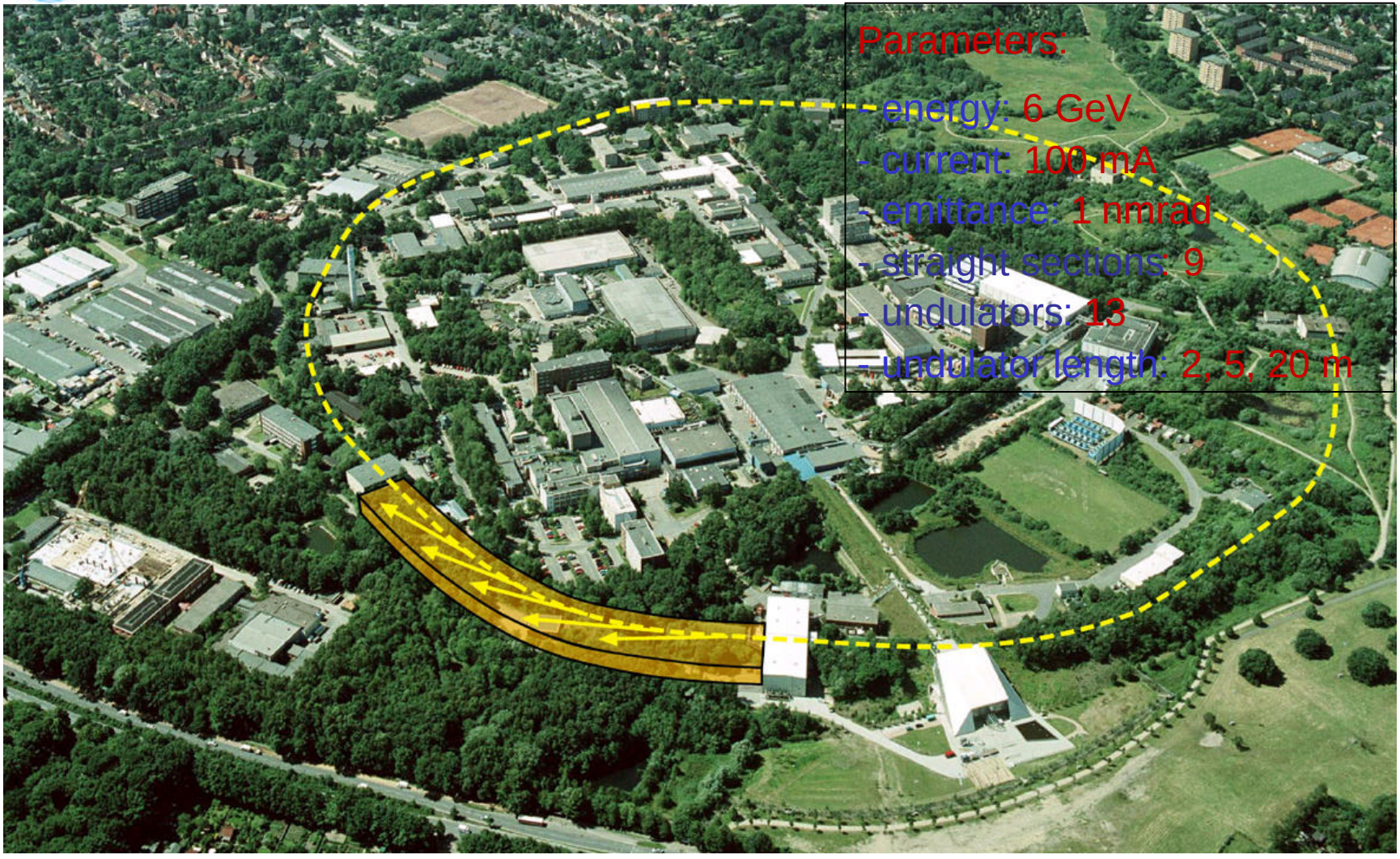
Introduction
Damping Wiggler Parameters
Nonlinear Dynamics with DW
Operational Aspects
Summary

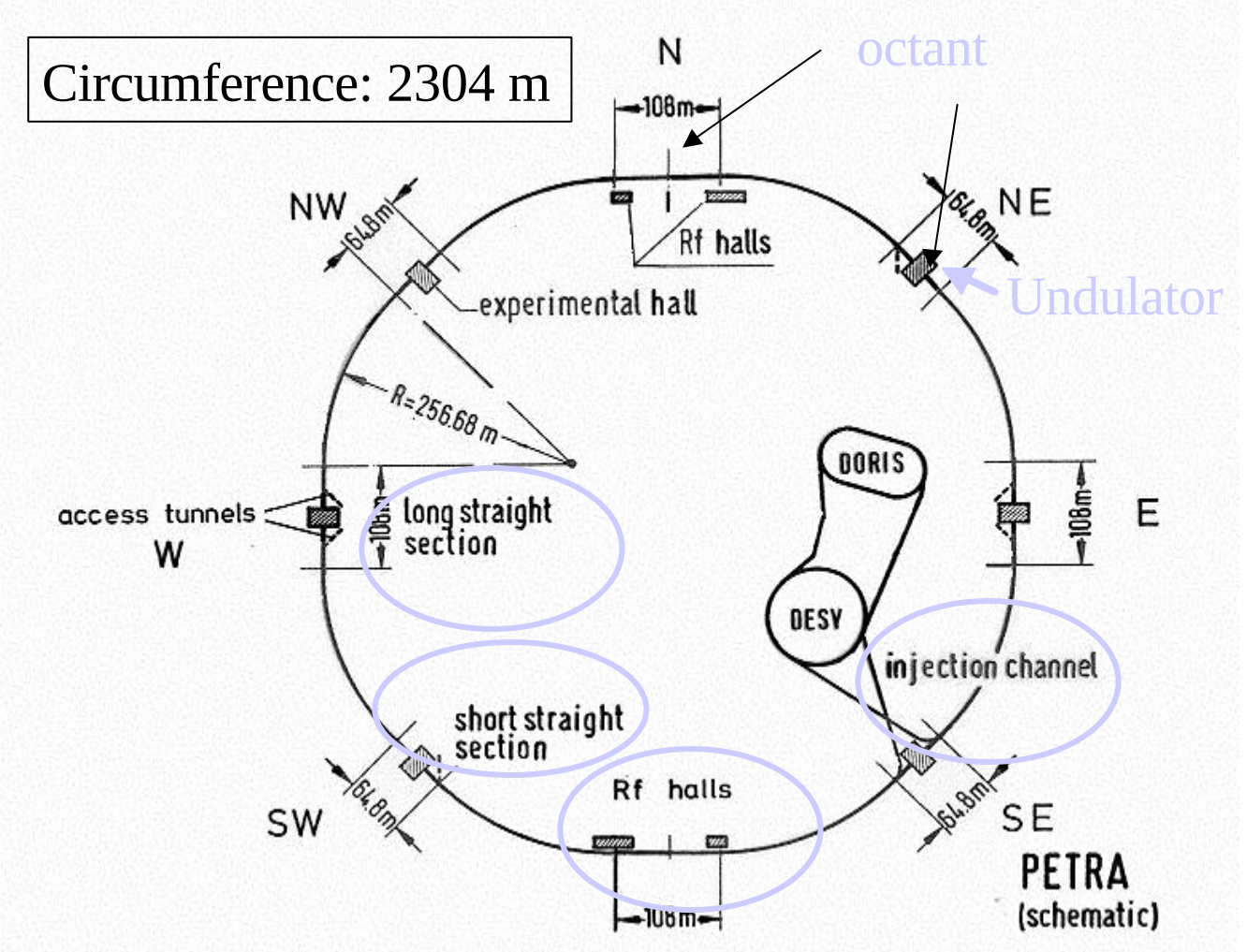
DESY and its Accelerators



PETRA III


Parameters:
- energy: 6 GeV
- current: 100 mA
- emittance: 1 nmrad
- straight sections: 9
- undulators: 13
- undulator length: 2, 5, 20 m

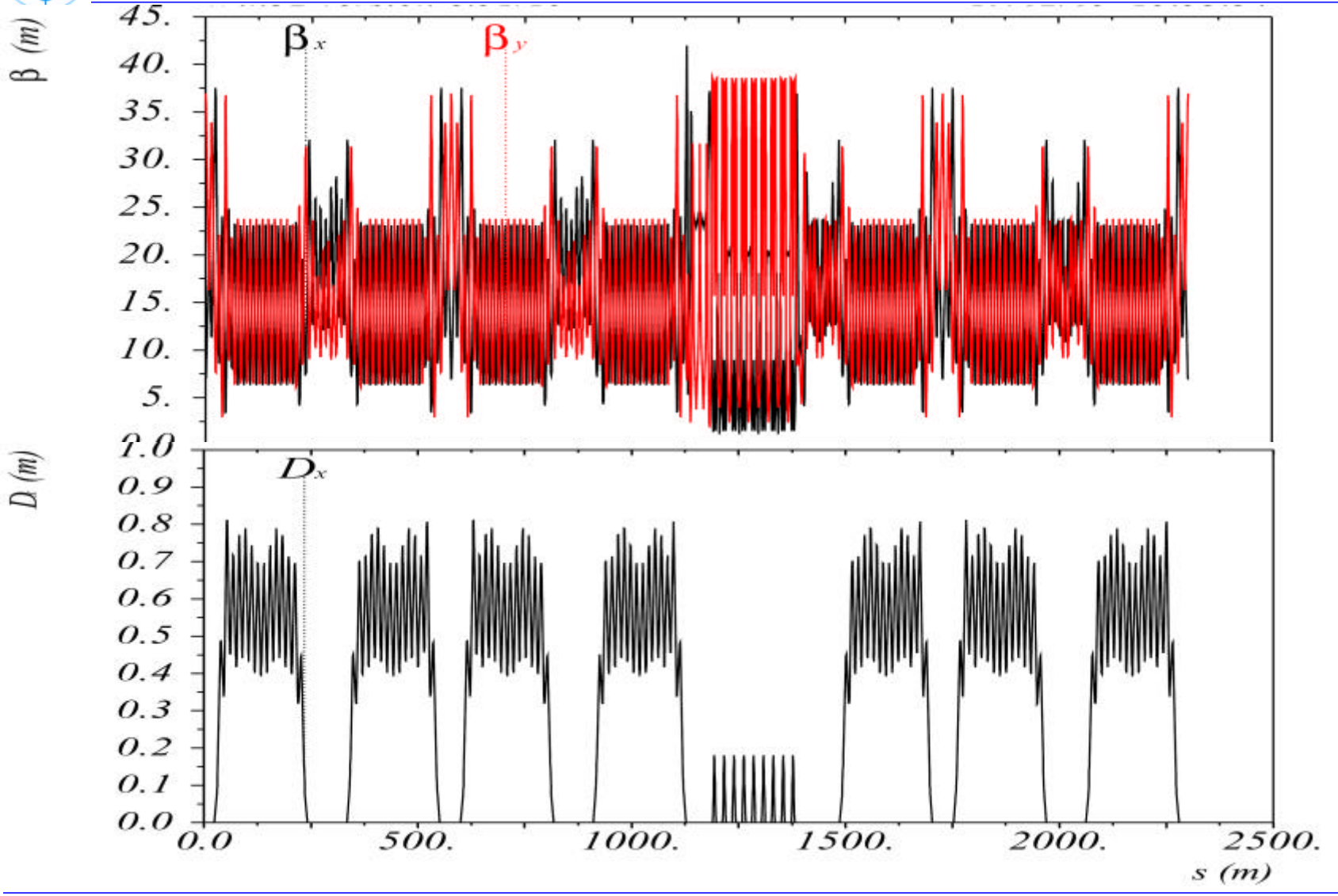
PETRA II - Overview



PETRA III Parameters

	Without Wiggler	With Wiggler	
Tune	35.87 / 31.25		
Nat. Chromaticities	-45 / -47		
I2	6.3e-2	2.6e-1	
Energy Loss/turn	1.15 MeV	4.66 MeV	
Hor. Emittance	4.65 nm rad	1.2 nm rad	
Energy Spread	0.083 %	0.0126%	
Bunch length	8.3 mm	12.7 mm	
Damping times	80/80/40 ms 10400/5200 turns	20/20/10 ms 2600/1300 turns	
Rev. Frequency	130.118 kHz		
Acceptance	30 µm / 2.2 µm / 1.5 %		

PETRA III Optics



Emittance Constituents

Optics

$$e \propto \frac{I_5}{I_2 - I_4}, \quad I_5 = \int \frac{H}{|r^3|} dl, \quad I_2 = \int \frac{1}{r^2} dl$$

Ring Geometry

$$e_{x,ring} = \frac{1}{I_{2,A} + I_{2,N} + I_{2,W} + I_{2,U}} \left(I_{2,A} e_{x,A} + I_{2,N} e_{x,N} + I_{2,W} e_{x,W} + I_{2,U} e_{x,U} \right)$$

Given by user constraints

For small emittance you need:

- Large bending radius
- Small bending angle per cell
- Small horizontal beta-functions

Wiggler Requirements

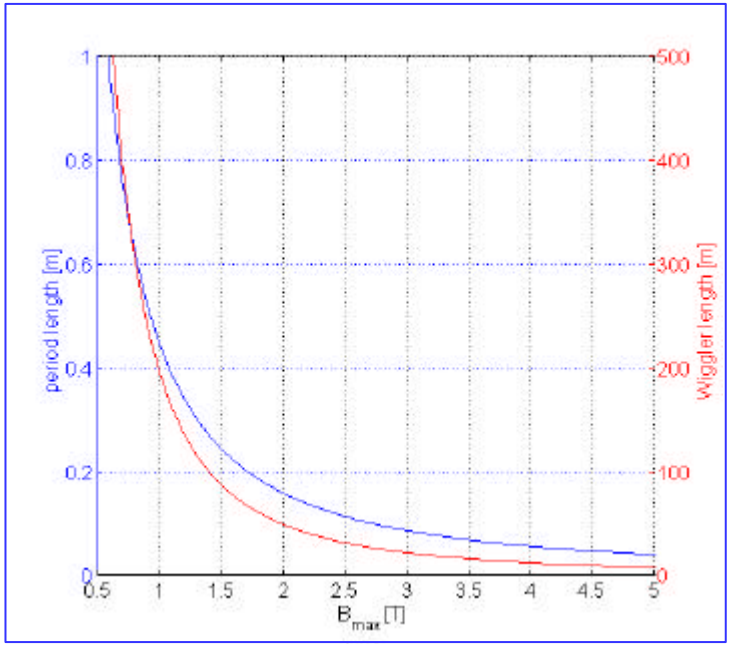
$$e_{x,ring} = \frac{1}{I_{2,A} + I_{2,N} + I_{2,W} + I_{2,U}} \left(I_{2,A} e_{x,A} + I_{2,N} e_{x,N} + I_{2,W} e_{x,W} + I_{2,U} e_{x,U} \right)$$

$$e_{x,W} \cong 3.5 - 13 \times 10^{-2} B_{\max}^3 \, l^2 \langle b \rangle \quad [\mathrm{nm}]$$

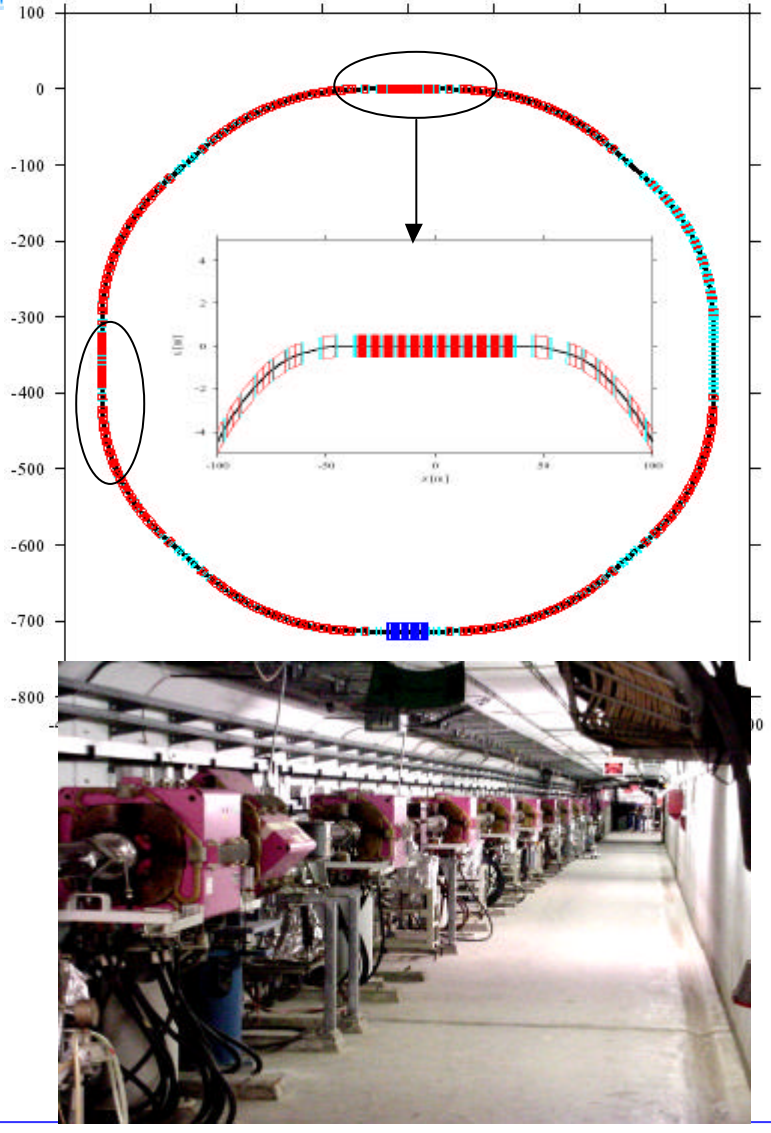
$$I_{2,W} \propto \int B^2 dl$$

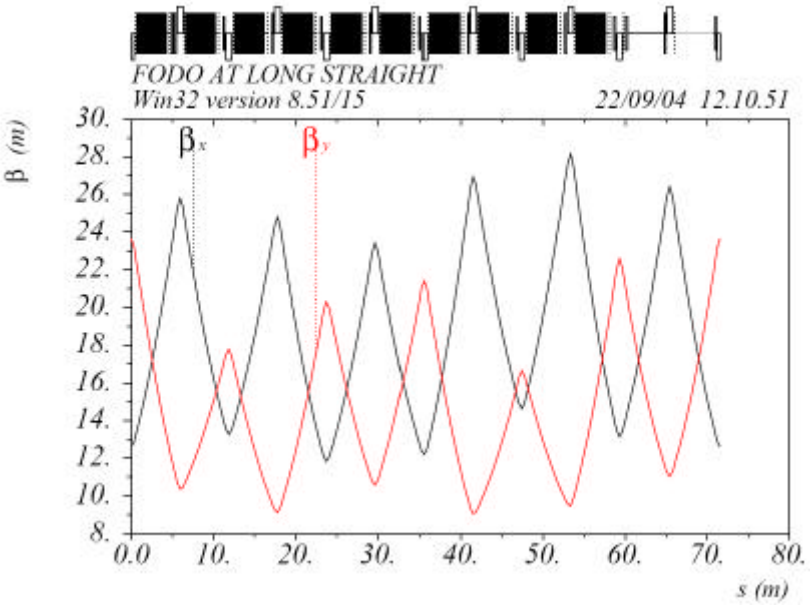
depends on wiggler field shape

- Total field integral:
  $\int B^2 m$: ≈ 98 $T^2 m$
- Maximum field and period length
  $B^3 \lambda^2 :\approx 0.2$



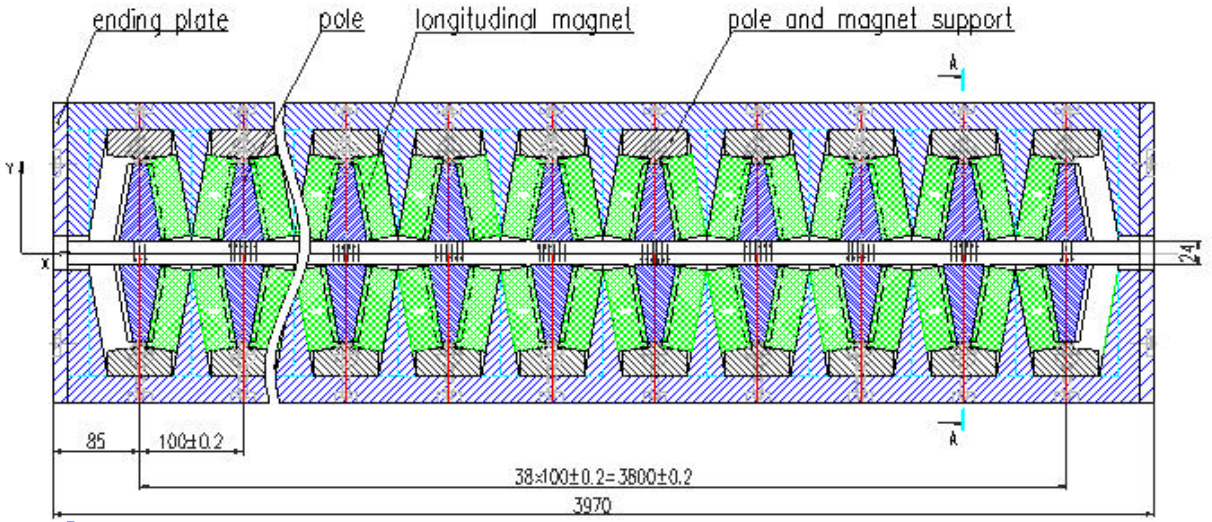
PETRA 3 Damping Wigglers



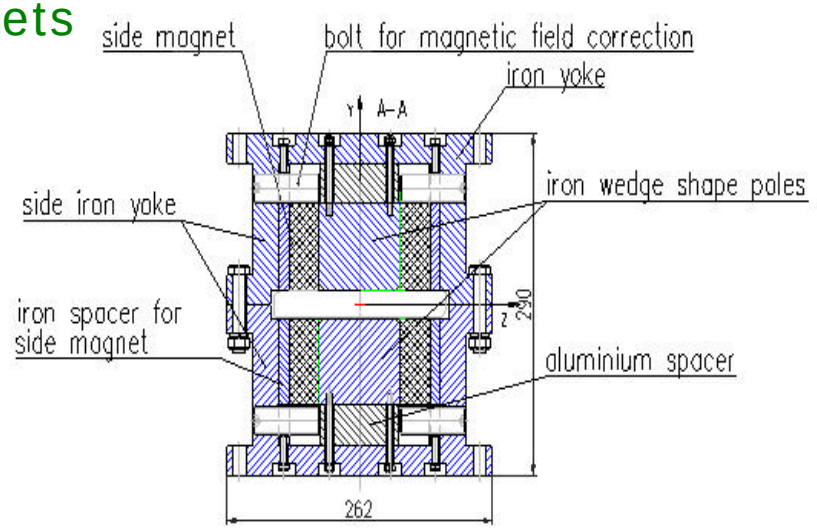


Period:	20 cm
Field amplitude:	1.56 T
Field quality @ 1 cm:	<10-3
Total length:	80 m
Total radiation power:	887 kW

Wiggler Magnet Design (P. Vobly, BINP)

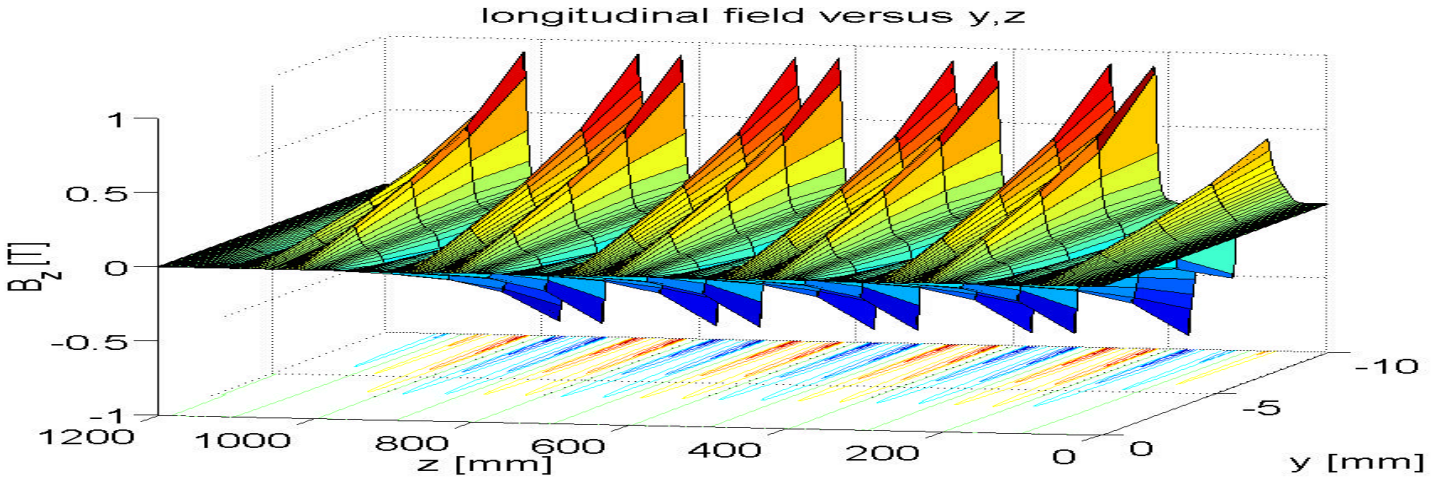


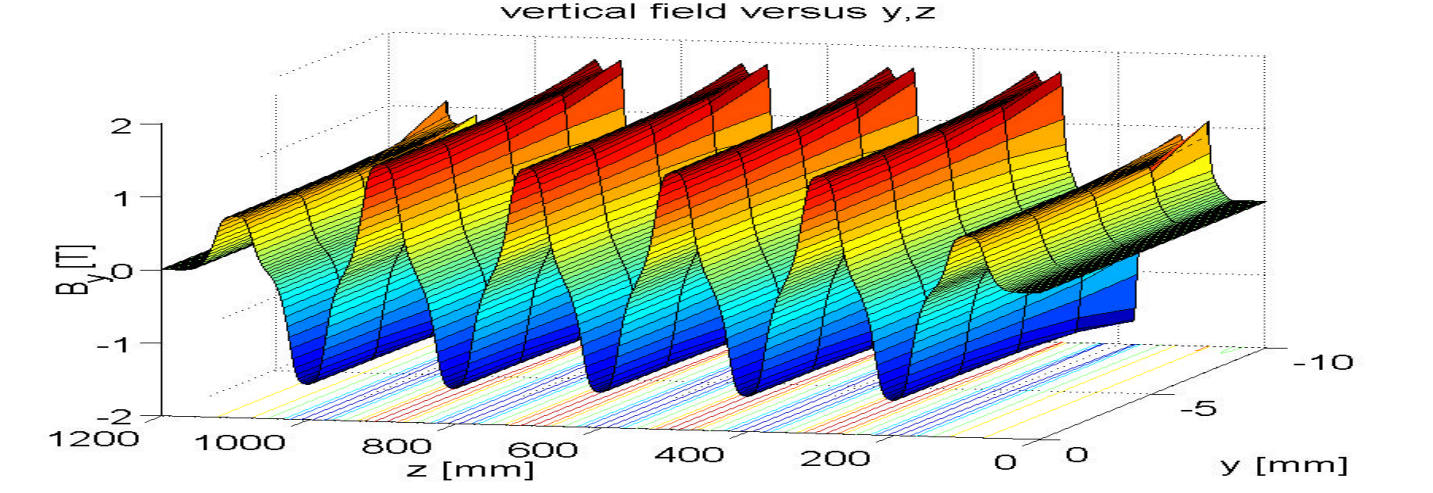
Blue - iron, **Green** – permanent magnets



- Magnetic symmetry leads to magnetic potential of wedge-like plate equals zero
- No coupling between poles

Wiggler Field

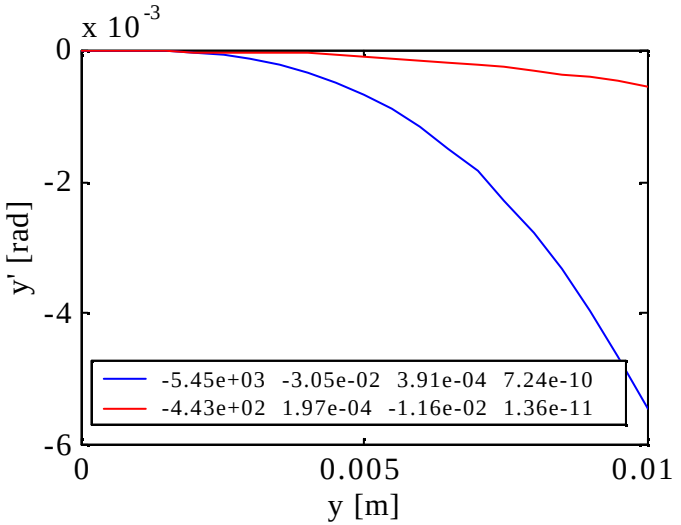


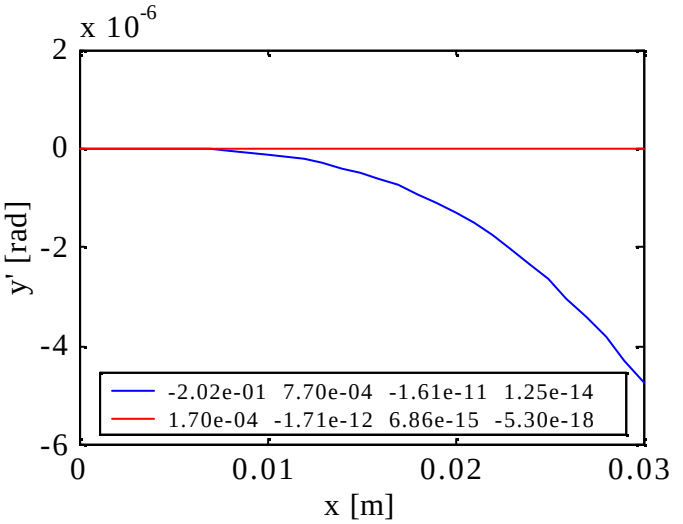


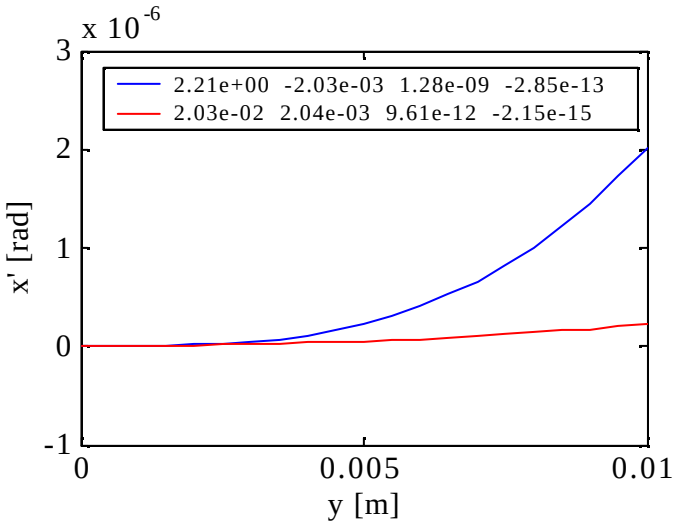
Wiggler Treatment

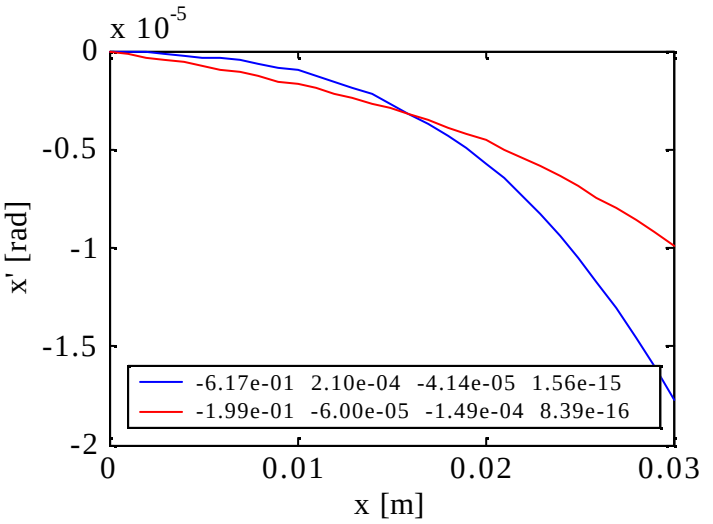
- Linear Optics, Emittance Calculations, Closed Orbit Simulations:
  - Hard-edge dipole model in MAD
  - Linear 6×6 matrix based on field data
- Nonlinear dynamics
  - Field calculations with RADIA, …
  - Field fitting (Halbach formulae) with usually 9 harmonics
  - Symplectic integration of analytical field description
  - Generating function (G. Wüstefeld) for tracking studies
  - End field not yet implemented
  - Field errors as additional multipoles based on field integral measurements

Nonlinear motion after 1 wiggler / 7 undulator periods

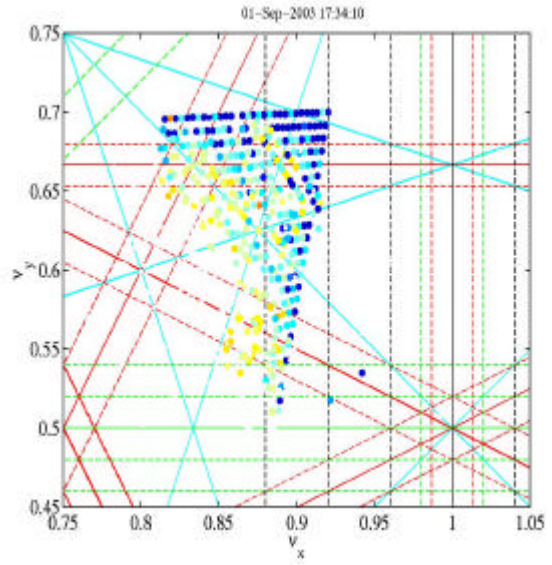


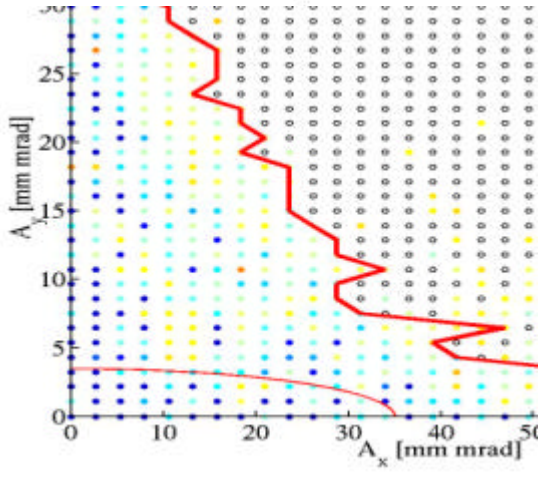




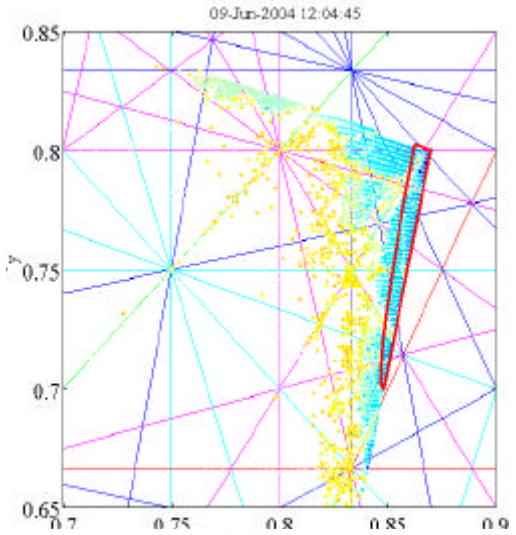


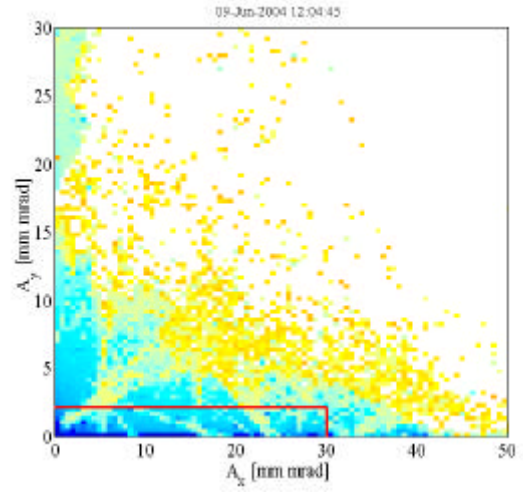
Wiggler and Undulator



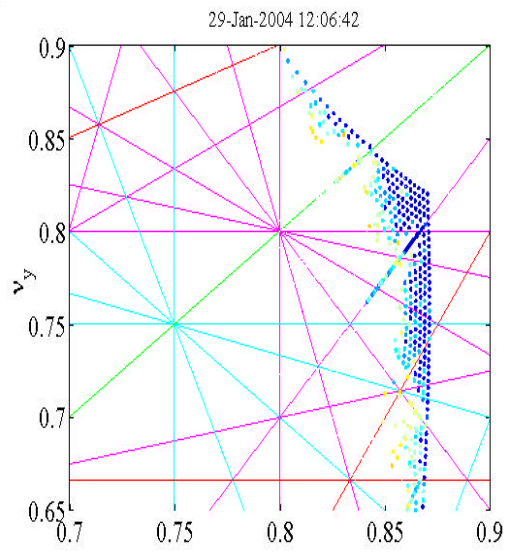


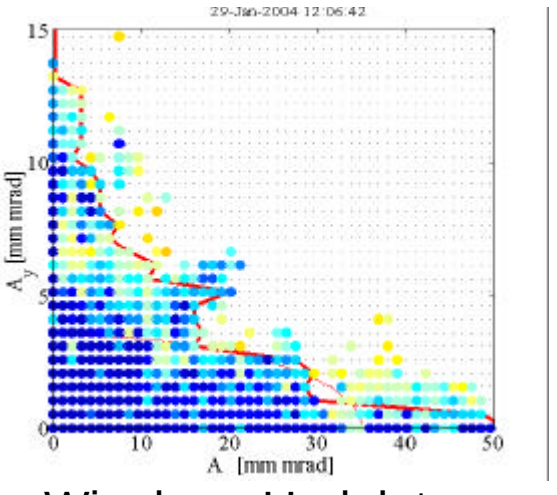
No Wiggler





Wiggler

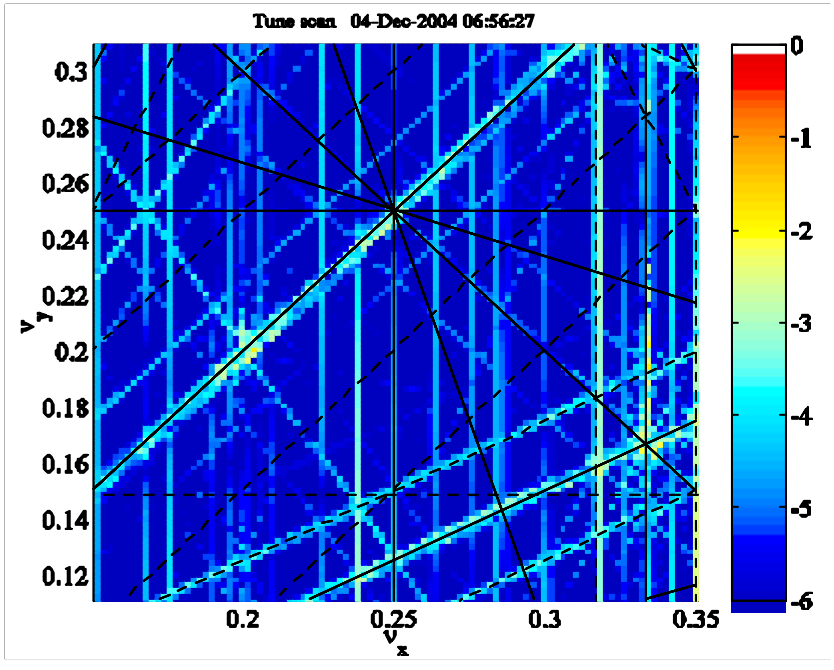




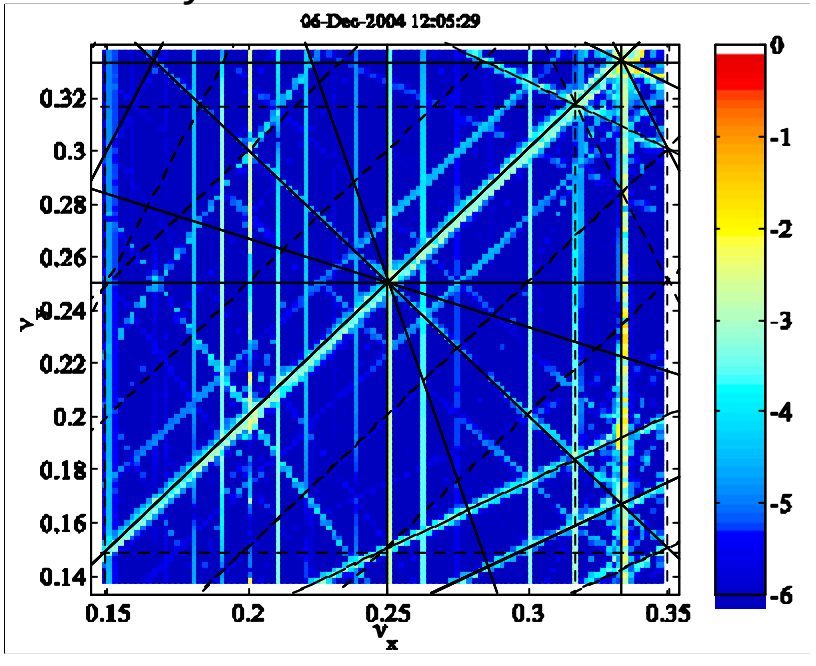
Wiggler + Undulators

Resonances

tune scan with initial status x=5mm y=1mm delta=0.1%



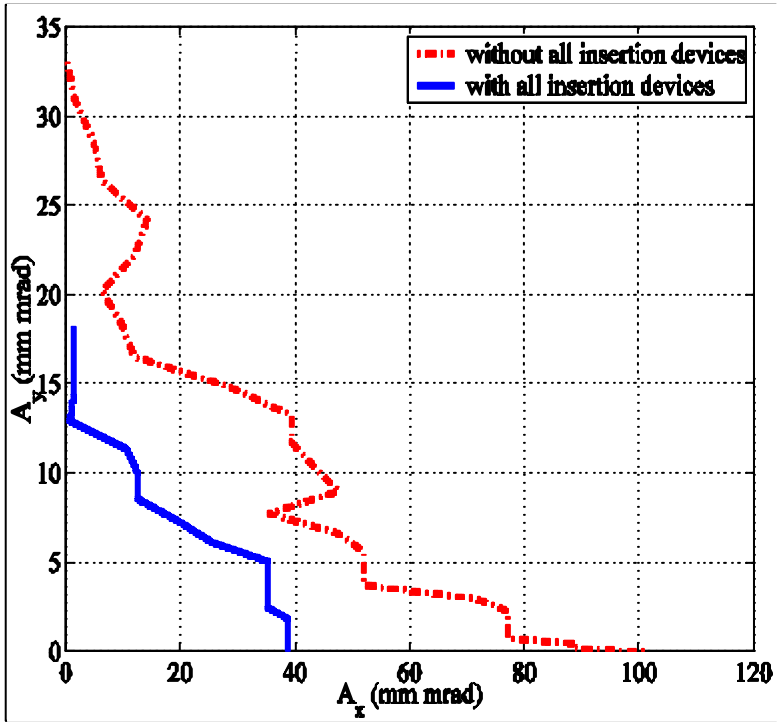
Wigglers and undulators



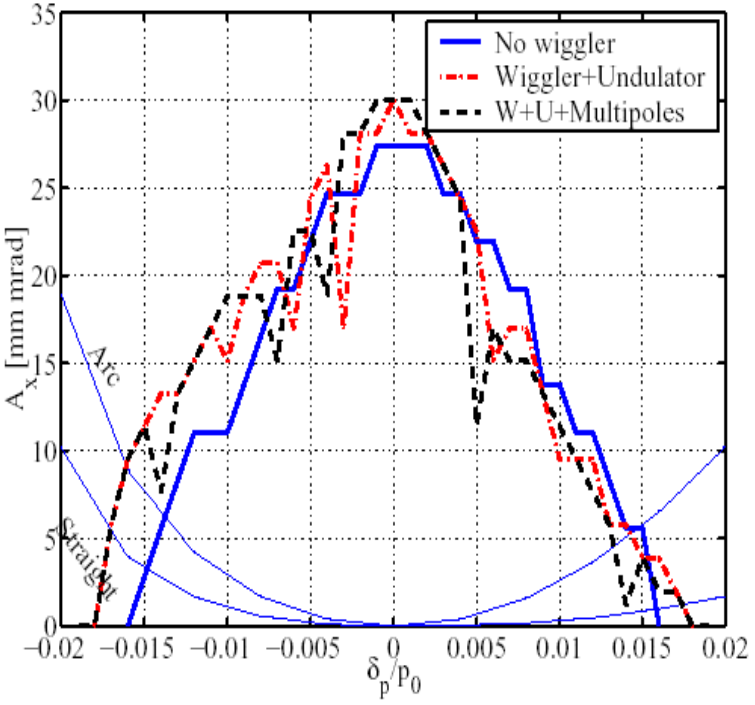
No Wigglers and undulators

DA with/without all insertion devices

Transverse

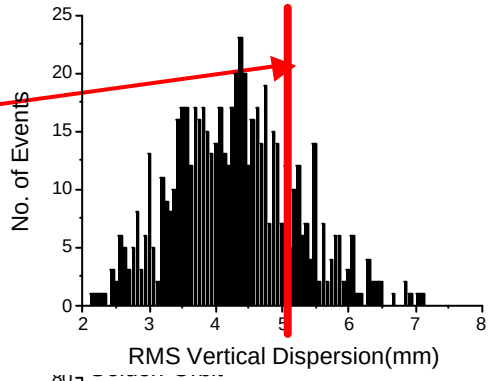


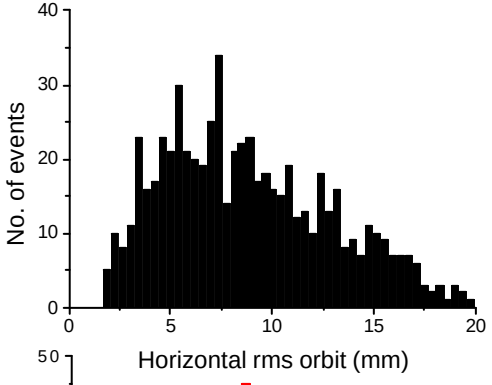
Longitudinal

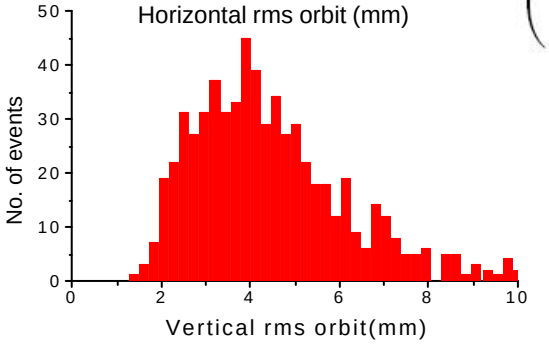


Operational Issues: Emittance Control

	D_x [mm]	D_y [mm]
Wiggler section	18	5
Undulator section	33	7
FODO arcs		58
DBA arcs	22	31

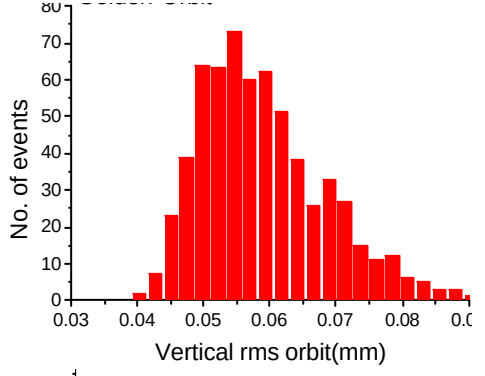


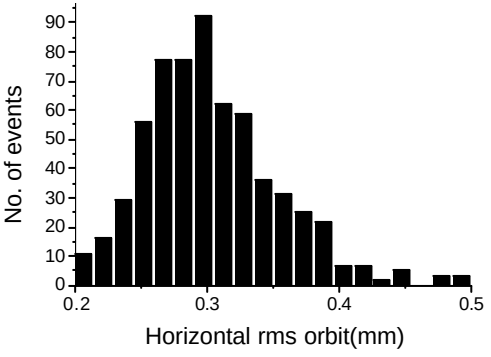




Combined
orbit & dispersion correction

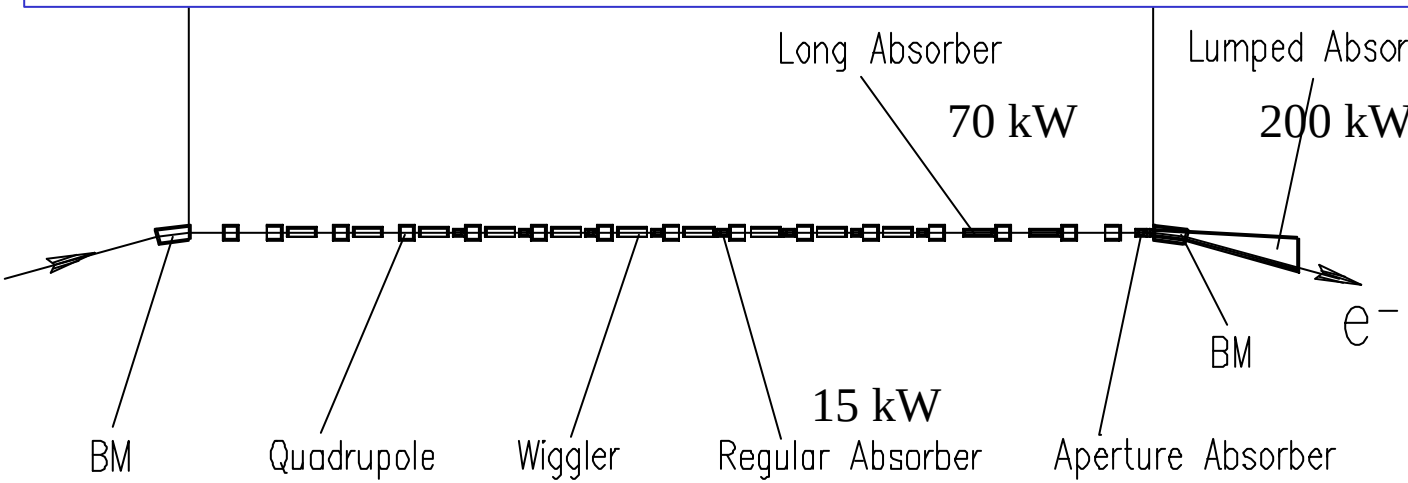
$$\begin{pmatrix} \alpha\vec{u} \\ (1-\alpha)\vec{D_u} \end{pmatrix} + \begin{pmatrix} \alpha\mathbf{R} \\ (1-\alpha)\mathbf{S} \end{pmatrix} \vec{\theta} = 0$$



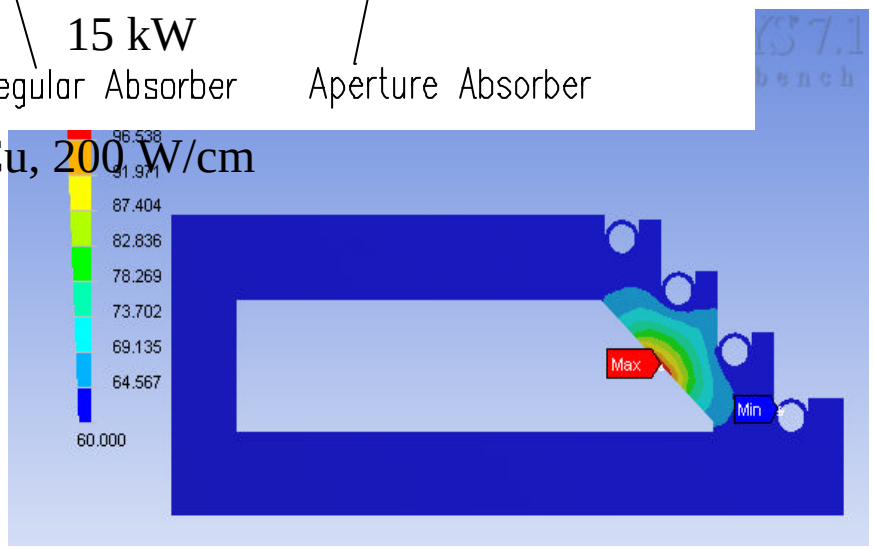


Operational Issues: Wiggler SR Power Absorbers (BINP)

440 kW @ 200 mA, E_c=36 keV
Opening angle: 5 mrad horizontal, 0.085 mrad vertical



Cu, 200 W/cm



Schedule

2004: TDR published

2004-2006: Finalize technical design

Procure hardware

Continue machine studies at PETRA II

2007: End of HERA HEP

Reconstruction of PETRA

2008: Commissioning of PETRA III

2009: Beam to users

Summary

- PETRA III closes the gap between DESY's DORIS III and existing high energy 3rd generation light sources, Ideal partner for the X-FEL project

- **Ideal test bed for LC damping ring issues**
  - **Wiggler dominated**
  - **Large injected beam with frequent injection**
  - **Small vertical emittance**
  - **State of the art beam stability**
  - **State of the art diagnostics**
  - **e^+/e^- possible**

- **BUT: Synchrotron radiation facility**