HIGH FIELD WIGGLER PERFORMANCE AT PETRA III

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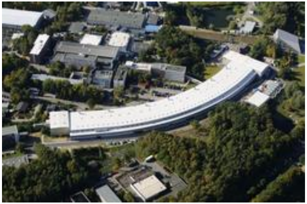
MPY - DESY

Workshop on Low Emittance Rings

CERN, January 2010



OUTLINE

1. QUICK REMINDER: PETRA III

Outline

1. Quick Reminder: PETRA III

2. Review of Wiggler Design and Parameters

Outline

OUTLINE

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OVERVIEW

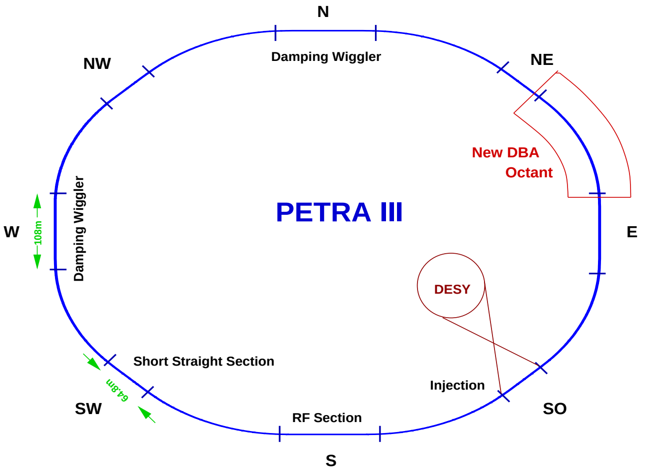


FIGURE: Schematic overview of PETRA III showing the distribution of the main components in the straight sections.

PARAMETERS:

Parameter	Value	Unit
Energy	6.0	GeV
Circumference	2303.952	m
Q_x, Q_y	36.12, 30.28	-
Nat. Chromaticity	-42.7/-42.3	-
Energy Spread (w.(wo) Wiggler)	$1.3(0.8) \times 10^{-3}$	-
Hor. Emittance (w/wo. Wiggler)	1.0 / 4.65	nm rad
Bunch Length (w/wo. Wiggler)	13 / 8	mm
Energy Loss per Turn (w/wo. Wiggler)	6.11 / 1.15	MeV
Damping Times (w.(wo) Wiggler)	15(80)/15(80)/8(20)	ms
Coupling	0.01	
Number of Damping Wigglers	20	-
Number of Undulators	14	-

TABLE: Some Parameters of Petra III.

PETRA III OPTICS OVERVIEW

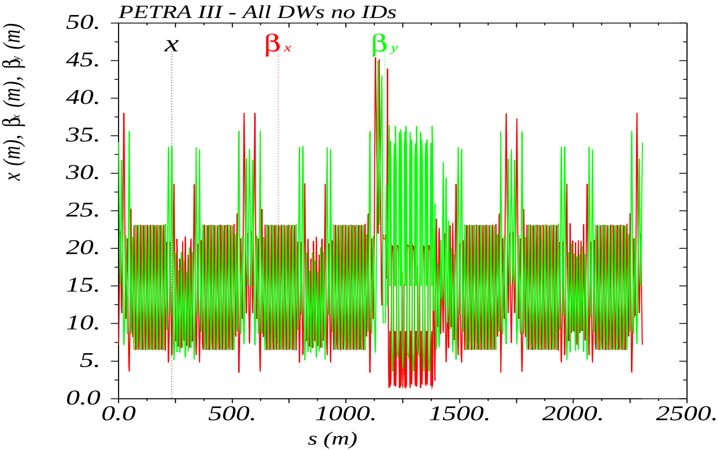


FIGURE: Horizontal and vertical beta functions in Petra III. The optics including all damping wigglers but without undulators is shown.

PETRA III Optics Overview

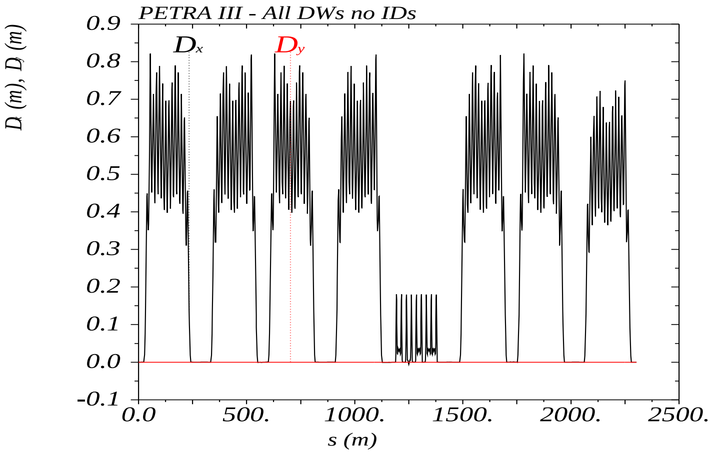


Figure: Horizontal dispersion in Petra III. Dx_{max} = 83.4 cm, Dx_{rms} = 39 cm

Outline

WIGGLER SECTIONS

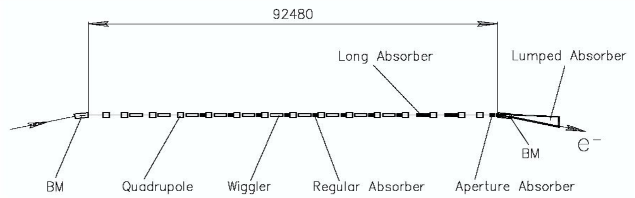
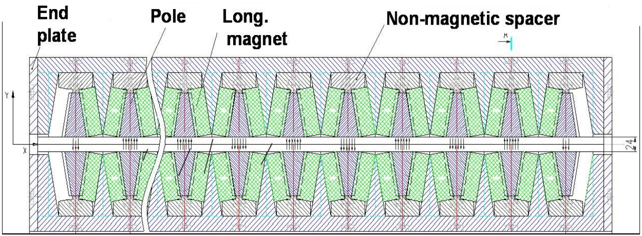


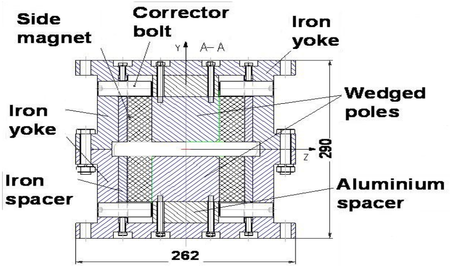
FIGURE: Schematic layout of wiggler sections north an west.

FIGURE: Wigglers in parking position.

- Regular FODO structure
- 10 wigglers per long straight section
- Total length of wigglers: 80m
- Total radiated power: 880 kW @ 200mA

WIGGLER MAGNETIC DESIGN (BINP)





- Peak Field: 1.58 T
- Magnetic Gap: 24 mm
- Period Length: 20 cm
- Pole Width: 8 cm
- SR critical energy 35.8 keV
- Wiggler SR power 42.1 kW @ 200mA

WIGGLER MAGNETIC DESIGN

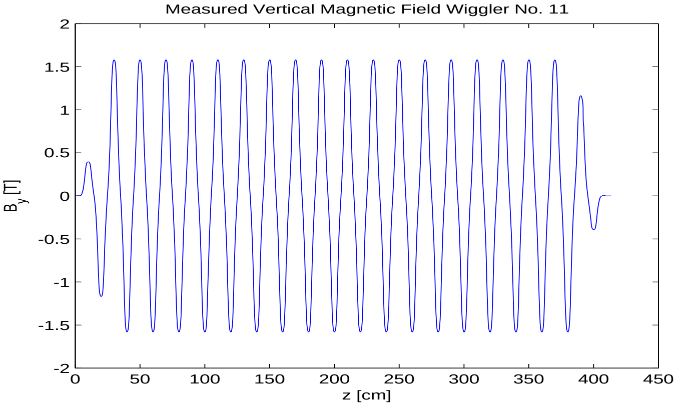


FIGURE: Vertical magnetic field after peak field tuning. $\Delta B/B_{\max} \approx 10^{-4}$

FIELD QUALITY

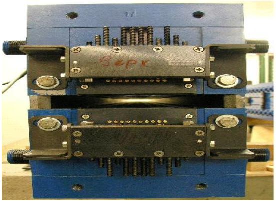


FIGURE: Magic fingers for wiggler tuning.

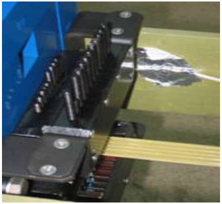
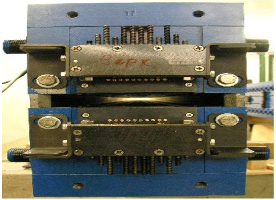


FIGURE: Correction of vertical and horizontal field integral.

- Streched wire mesurements of all wigglers. Accuracy: 5 Gcm (rms).
- Vertical and horizontal first field integral over the good field region.
- Measured at DESY after transport and reassembly. Reproducible within 30 Gcm after dis-/reassemling.
- Vertical/horizontal correction with 10/12 magnets, respectively.
- Constraints put on maximal variation of field integrals as well as on multipole coefficients extracted from fits to the data.

FIELD QUALITY



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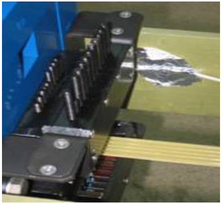

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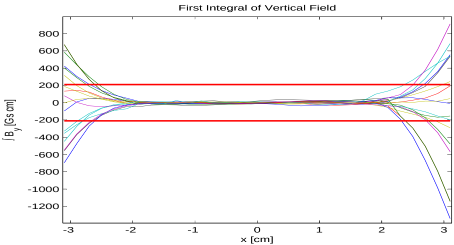

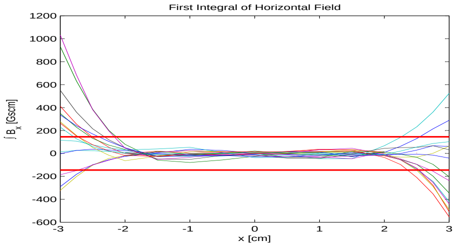

FIGURE: Streched wire measurements of first field integrals. Red lines mark the limits put on the variation in the good field region.

VACUUM SYSTEM AND ABSORBER DESIGN

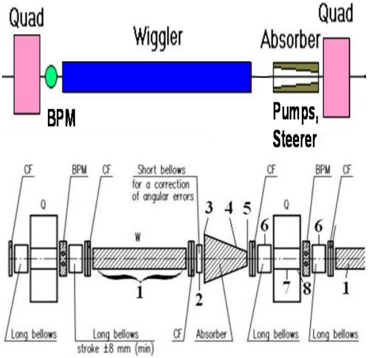

FIGURE: Schematic layout of the vaccum system.

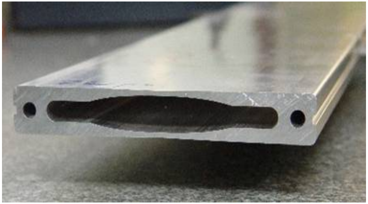

FIGURE: Wiggler vacuum chamber.

- NEG coated water cooled wiggler vacuum chamber.
- Pow. Dens. $\sim$ 1mW/mm^2, $P_{tot} < 100$ W.
- Copper absorbers, iterated optimization of tapers in view of impedance budget.
- Smallest vertical aperture 9 mm (odd absorbers).
- Regular absorbers: < 26 kW each

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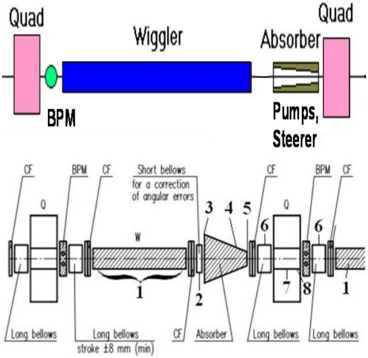

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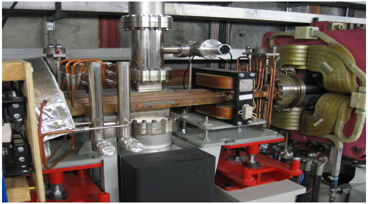

FIGURE: Regular absorber.

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Vacuum System and Absorber Design

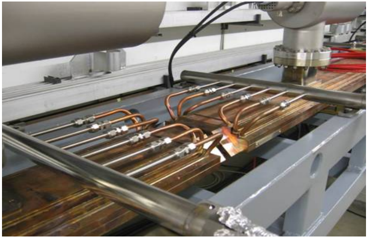


Figure: Long absorbers 9 and 10.

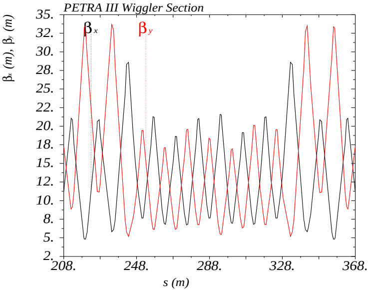
Figure: Final absorber.

Figure: New chamber in modified quadrupole QN9.

- 2 long absorbers: 4.5 m
- 90 kW power deposition.
- Final absorber behind first dipole: 6 m
- 120 kW
- New chambers for dipole and modified quadrupole.

Outline

Influence on Optics



- Regular FODO structure.
- Wigglers described by matrix element in MadX.
- Matrix derived from tracking.
- Asymmetry due to absorbers at the end of section.

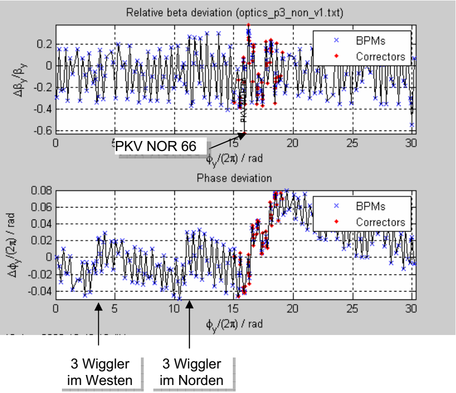
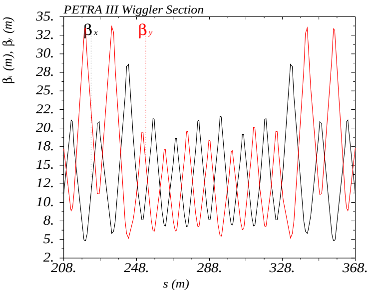


FIGURE: Measured beta and phase beating with 3+3 wigglers installed compared to the optics for the bare machine.

INFLUENCE ON OPTICS



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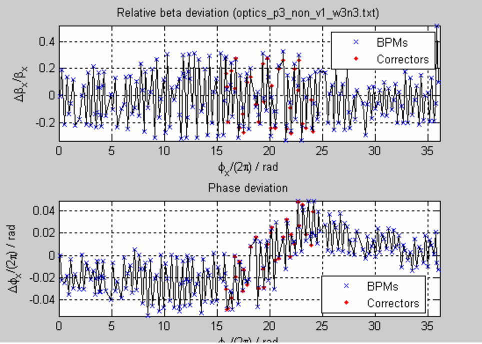
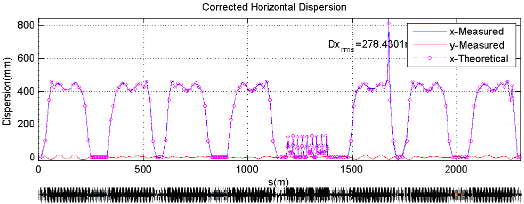
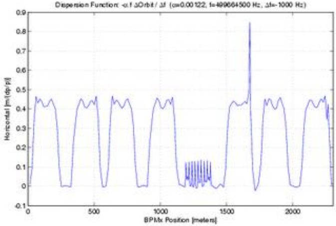


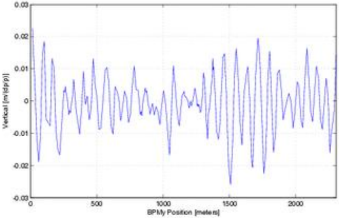
FIGURE: Measured Beta and phase beating with 3+3 wigglers installed compared to the optics including wiggler matrix descriptions.

Matrix description works well!

DISPERSION CONTROL

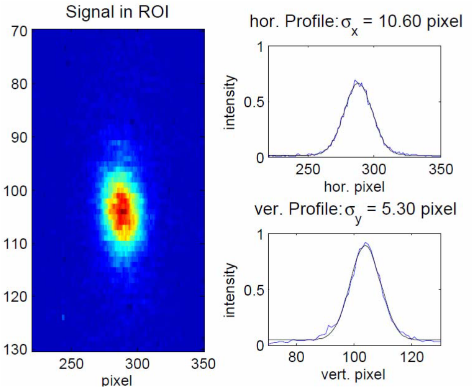






- Constraints on residual dispersion in wiggler sections:
  $D_x < 18$ mm,
  $D_y < 5$ mm
- Careful combined orbit and dispersion correction necessary.
- Control of vertical dispersion using skew quads.

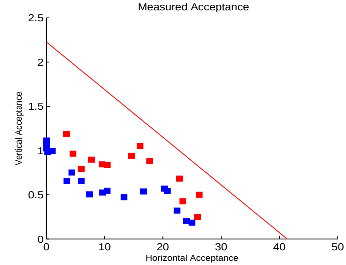
MEASURED EMITTANCE

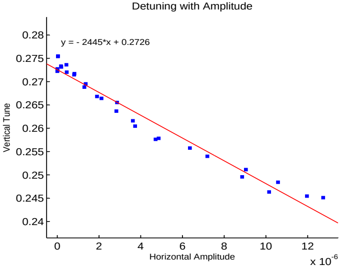


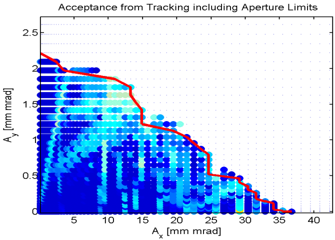
Calculated horizontal width:
$\sigma_x = 44\ \mu m$,
Calculated emittance:
$\varepsilon_x = 0.9$ nm rad

- Estimated vertical emittance: $\varepsilon_y < 20$ pm rad
- Clear decrease in lifetime after dispersion tuning: 1.5 h @ 1.4 mA
- Expected Touschek lifetime: 2 h @ 2.5 mA

NONLINEAR DYNAMICS



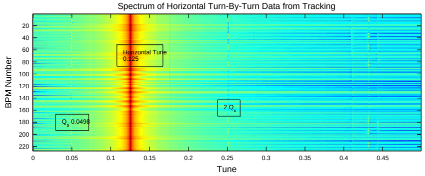


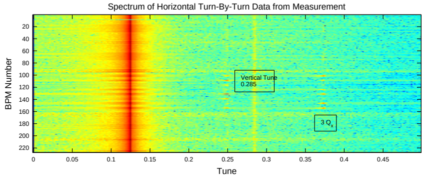


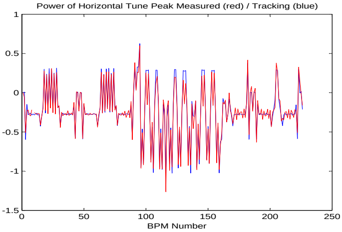
- Injected beam size: 350 nm rad, 10% coupling.
- Required acceptance for injection: $\sim$ 18 mm mrad (aiming at 30)
- Vertical: $\sim$ 1 mm mrad
- Detuning with amplitude: dominant cross term $\partial Q_y/\partial J_x$
- MadX (pure sextupole): $\sim$ -2400, SixTrack with wigglers: $\sim$ -2100
- Momentum acceptance > 1.5% as required for Touschek lifetime.

NONLINEAR DYNAMICS

- Recent multiturn measurements with all Bpms (with R. Bartolini).
- Good agreement with tracking results.
- Also confirms good control of linear optics.
- Investigation of coupling and nonlinear resonances ongoing.

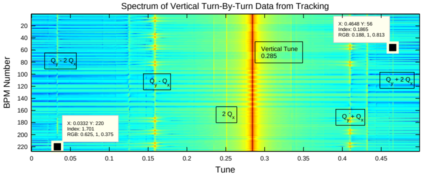


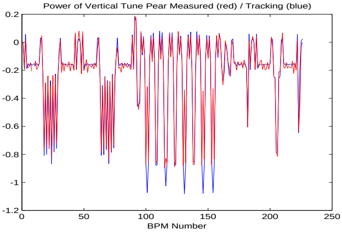


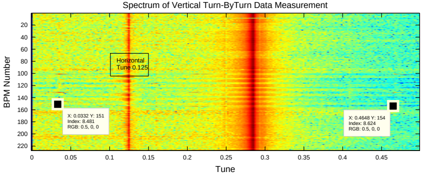


NONLINEAR DYNAMICS

- Some more lines appear in the vertical spectrum.
- Machine model has still to be improved.
- Careful compensation of bpm nonlinearities required.
- Comparison with machine without wigglers?

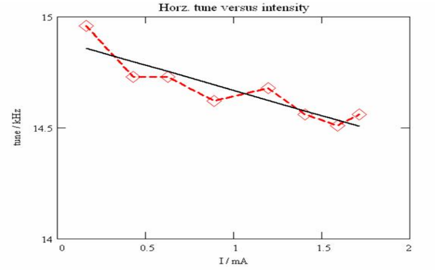


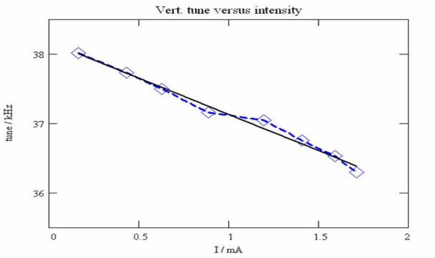




TUNE SHIFT WITH INTENSITY

- Transverse kick parameter $k_\perp$ (V/pC/m)
- Budget 4800 for 2.5 mA
- Impedance model: 750 (horizontal)
- $\sigma_z = 12$mm,
  RF-Voltage: $\sim$ 15 MV
- $\Delta Q_x / \Delta I = -0.0017 \Rightarrow 860$





- Budget 4800 for 2.5 mA
- Impedance model: 2610 (vertical)
- $\Delta Q_y / \Delta I = -0.008 \Rightarrow 3950$
- 33% larger than model, still within budget.
- More than 2.5mA have been stored in single bunch!

TEMPERATURE MEASUREMENTS AT ABSORBERS

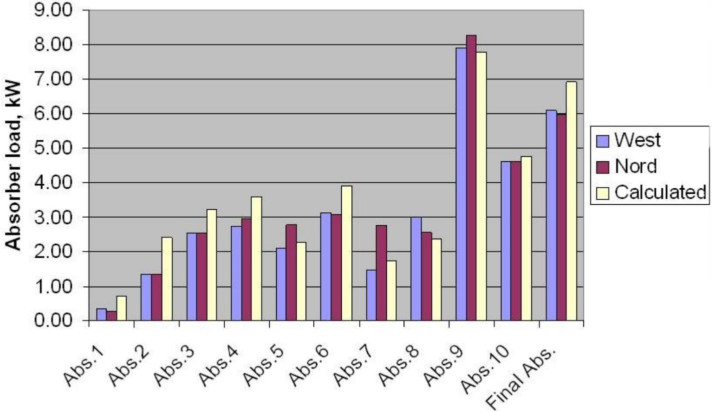


FIGURE: First measurements of power load on absorbers with 6+6 wigglers installed. Good agreement with theory (Mind however Abs. 7!). Measurements with all wigglers not yet evaluated.

Outline

Conclusions

Parameter	Design	Achived
ε_x (nm rad)	1	1
ε_y (pm rad)	10	< 20
Current (mA)	100	89
Orbit Stability	10%	x o.k. / y almost
Single Bunch Current (mA)	2.5	2.5

Table: Achievements in commissioning of PETRA III since April 2009.