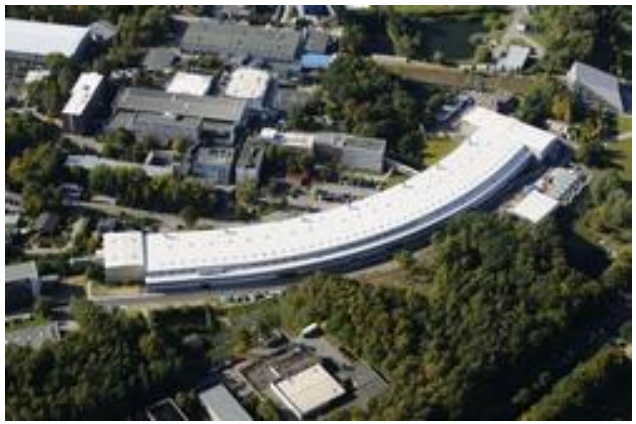
Experience with Damping Wigglers at PETRA III.

Alexander Kling

MPE - DESY

USR Workshop, Huairou, Beijing
November, 2012



OVERVIEW.

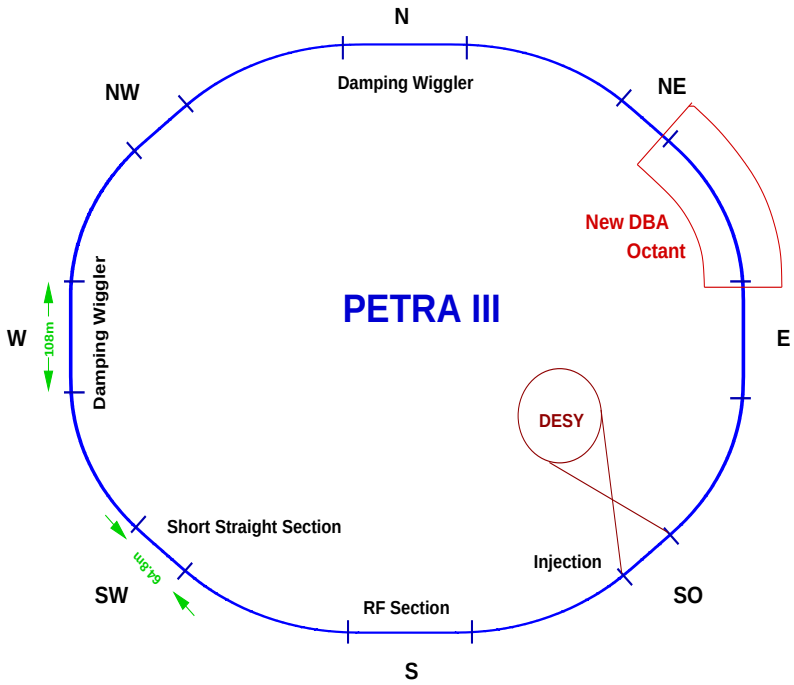


FIGURE: Schematic overview of PETRA III showing the distribution of the main components in the straight sections.

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	1.3×10^{-3}	-
Number of Damping Wigglers	20	-
Number of Undulators	14	-
Hor. Emittance (w/wo. Wiggler)	1.0/4.65	nm rad
Coupling	0.01	

TABLE: Some Parameters of Petra III.

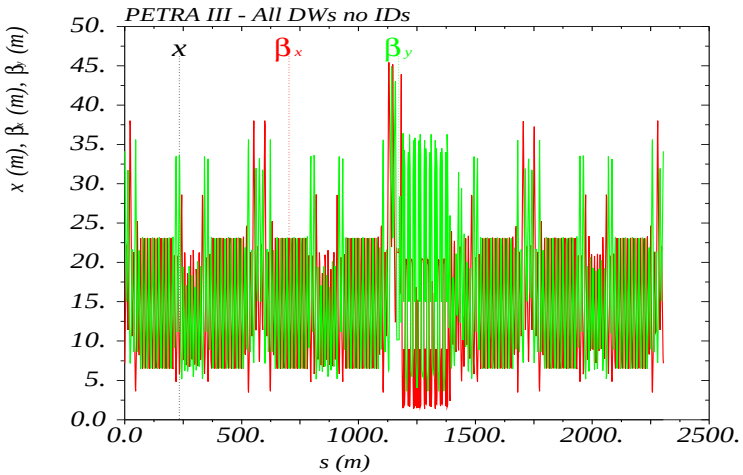
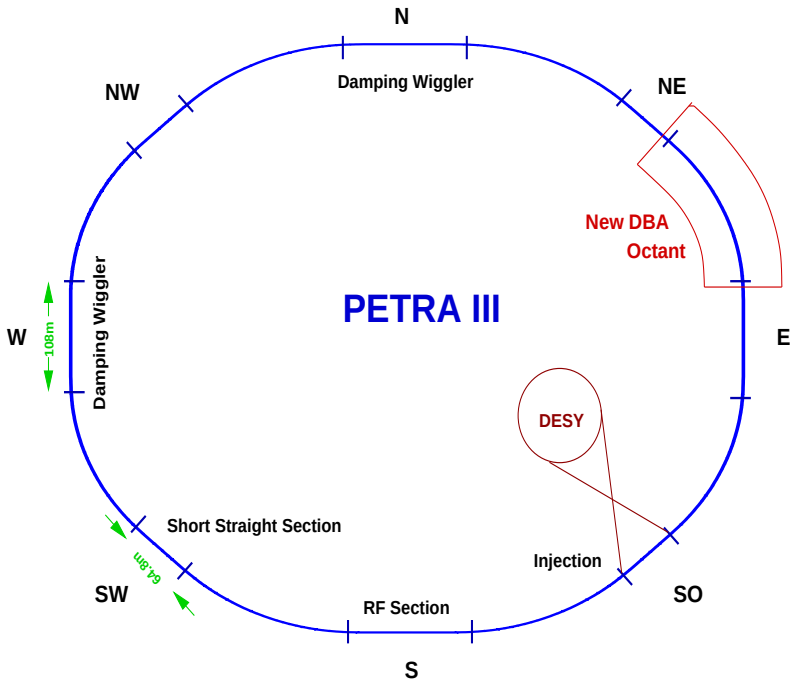


FIGURE: Beta functions in Petra III. The optics includes all damping wigglers (no undulators).

OVERVIEW.



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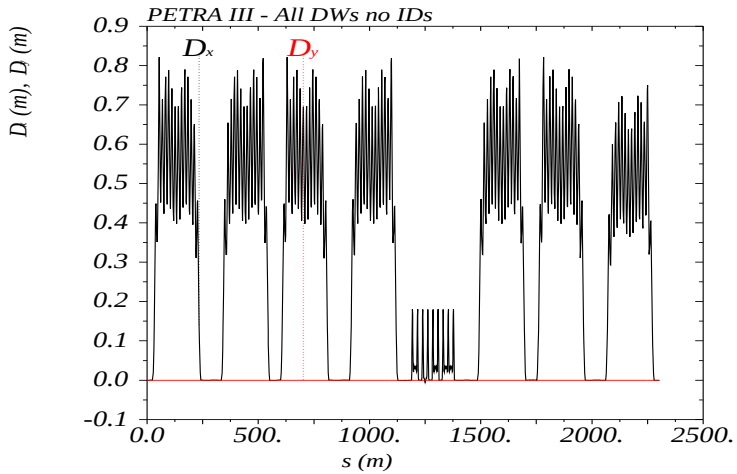


FIGURE: Horizontal dispersion in Petra III.

WIGGLER SECTIONS.

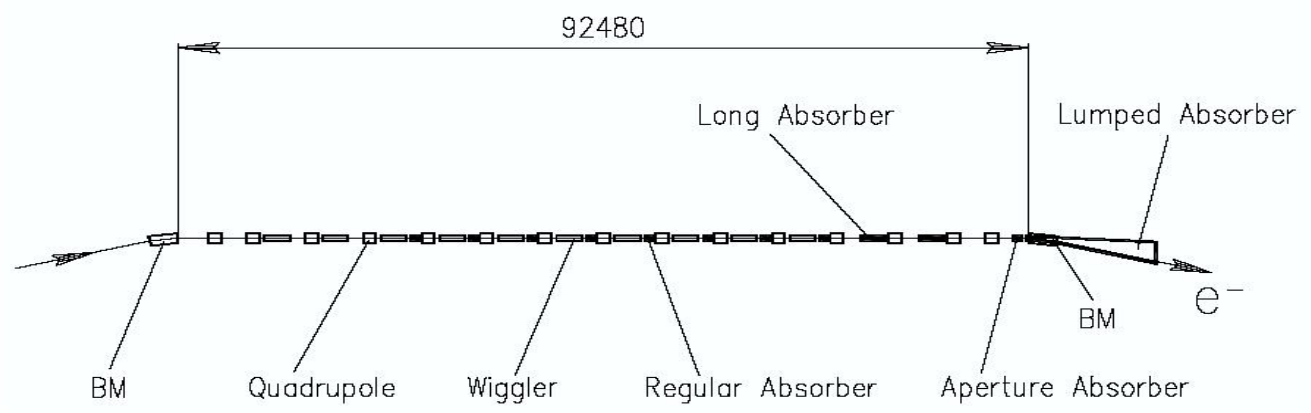
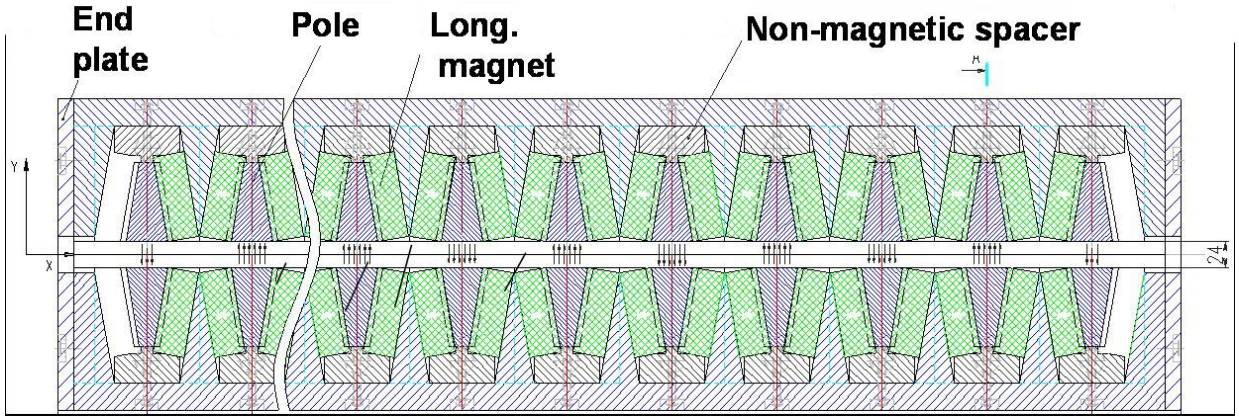


FIGURE: Schematic layout of wiggler sections north and west.

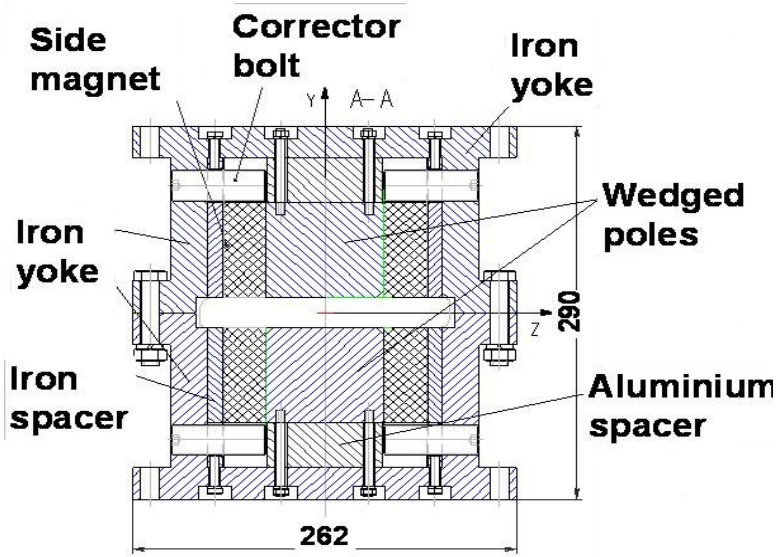
FIGURE: Wigglers in parking position.

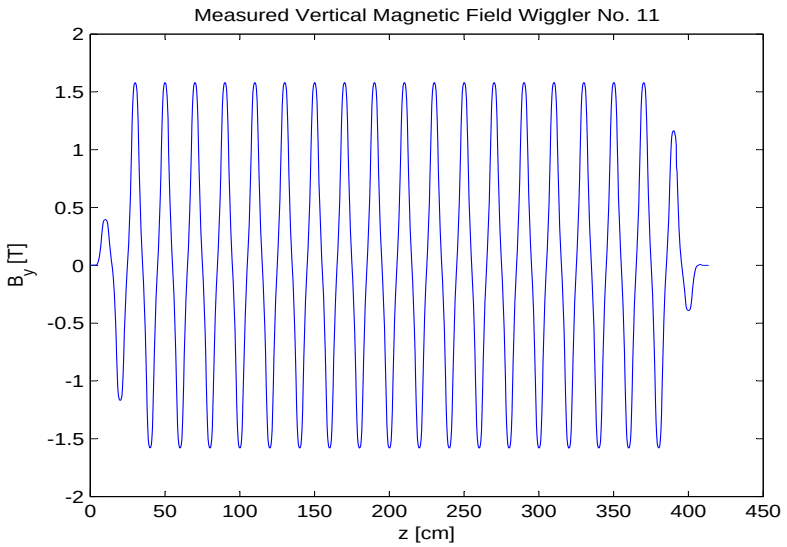
- Regular FODO structure
- 10 wigglers per long straight section
- Total length: 80m
- Total radiated power: 880 kW @ 200mA

WIGGLER MAGNETIC DESIGN.



- Peak Field: 1.58 T
- Period Length: 20 cm





FIELD QUALITY.

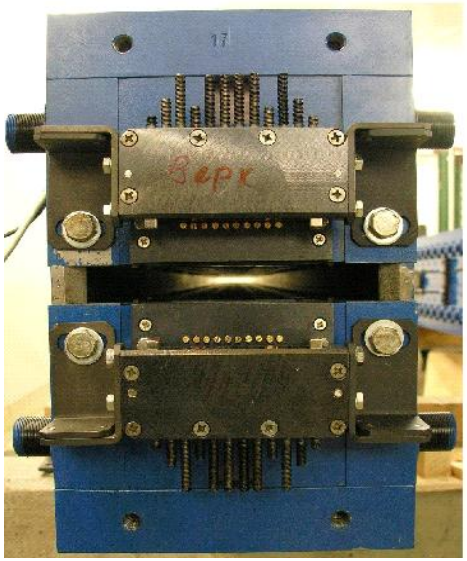


FIGURE: Magic fingers for wiggler tuning.

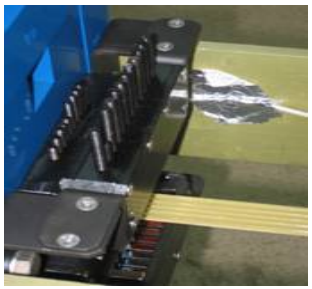
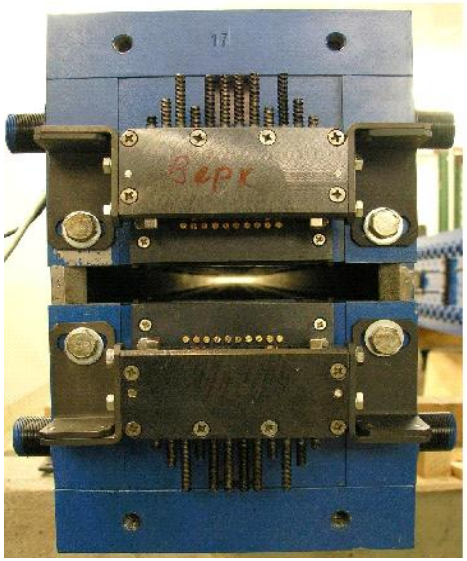


FIGURE: Correction of vertical and horizontal field integral.

Some Remarks about the Specs:

- $\varepsilon_x = 4.65 \rightarrow \varepsilon_x = 1.0$
  - $\int B^2 dl \approx 100\ \mathrm{T^2m}$
  - $\lambda = 0.2\mathrm{m}$, $B_0 = 1.58\mathrm{T}$ and $l_{tot} = 80\mathrm{m}$
- Aperture Requirements:
  - 3 mm mrad @ 25 m $\beta_{max} \Rightarrow$ 17mm vertical aperture
  - add absorbers, chamber and tolerance $\Rightarrow$ 24mm magnetic gap
  - $\pm$ 30 mm horizontal aperture
- Field Quality:
  - 10^{-3} @ 10mm
  - Variation of the vertical integrated field < 420 Gcm for $\pm$20mm
  - Variation of the horizontal integrated field < 285 Gcm for $\pm$20mm
  - Upper limits for multipole coefficients (normal and skew) specified

FIELD QUALITY.



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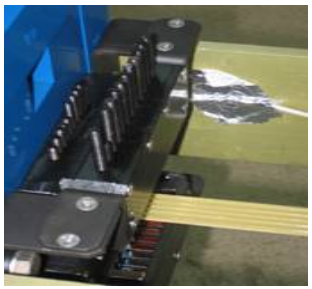
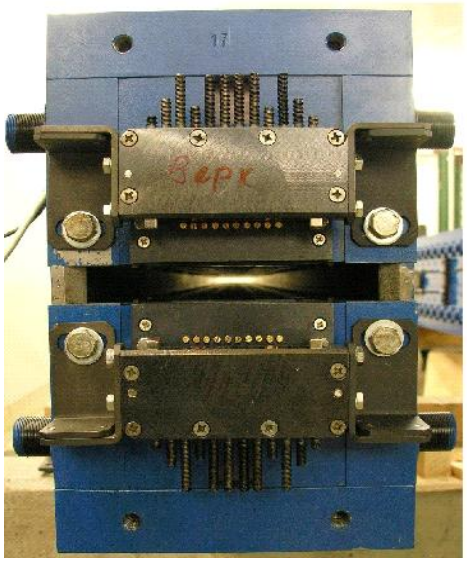


FIGURE: Correction of vertical and horizontal field integral.

Magnetic tuning with magic fingers:

- vertical correction with 10 magnets: 6x6 mm^2, minimal gap 24mm
- horizontal correction with 12 magnets: 7x18mm^2, minimal gap 65mm
- first integrals tuned down to: $\pm$30 Gcm vertical $\pm$50 Gcm horizontal

FIELD QUALITY.



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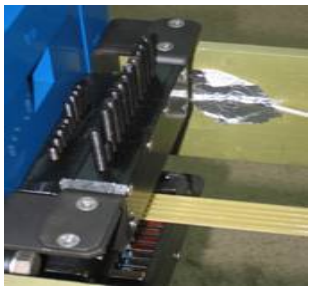

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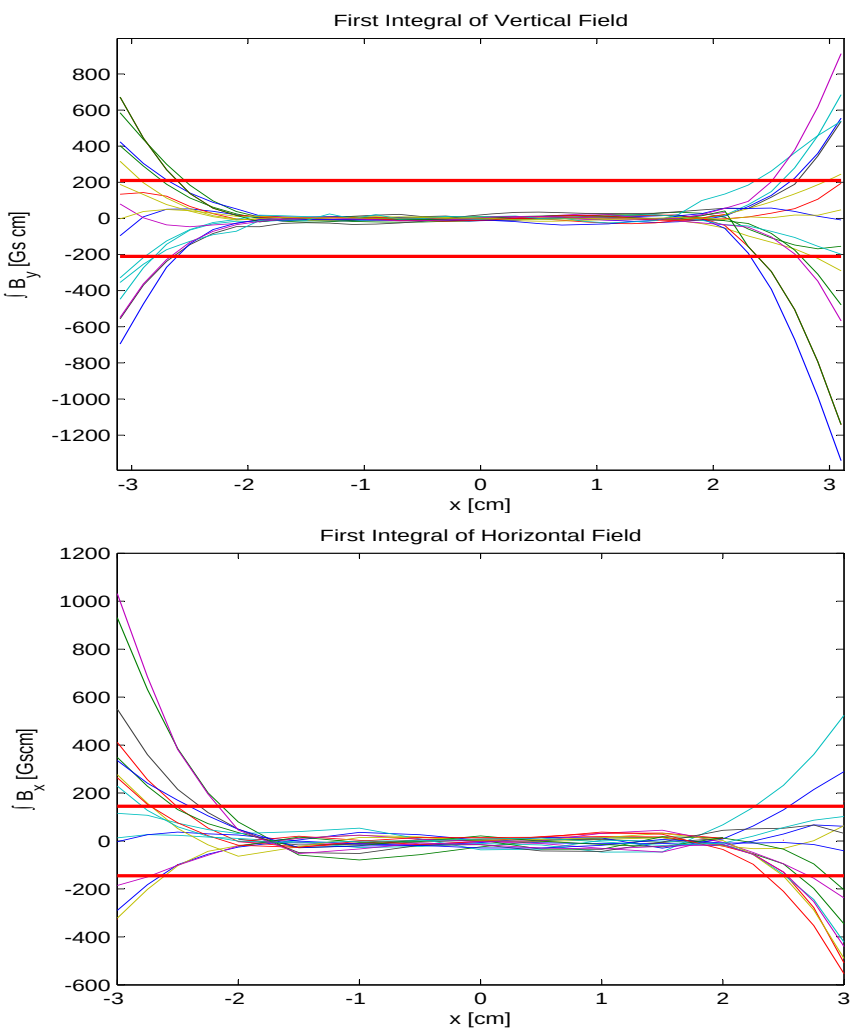


FIGURE: Streched wire measurements of first field integrals. Red lines mark the limits put on the good field region.

VACUUM SYSTEM AND ABSORBER DESIGN.

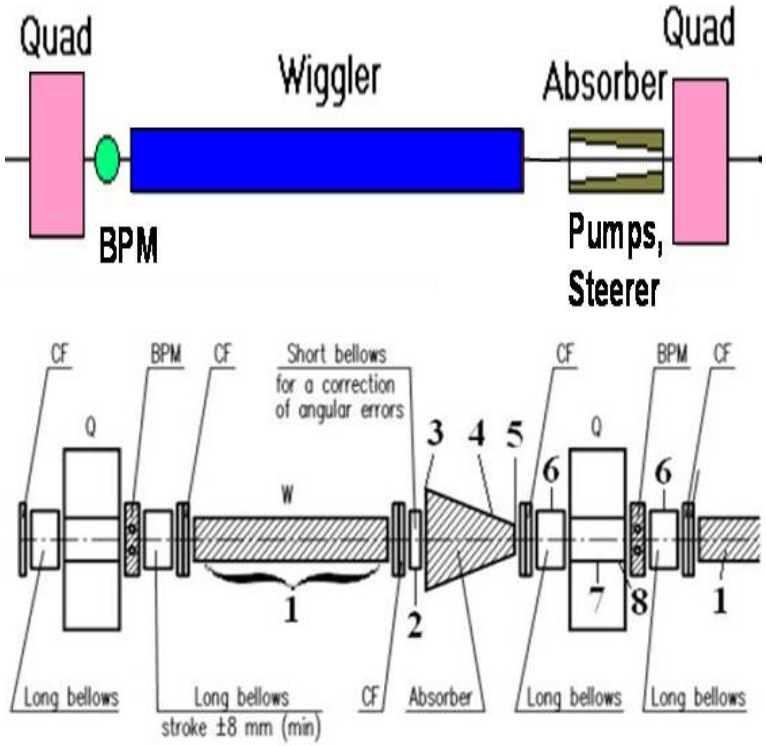


FIGURE: Schematic layout of the vaccum system.

- aluminium wiggler vacuum chambers
- NEG coated
- water cooled

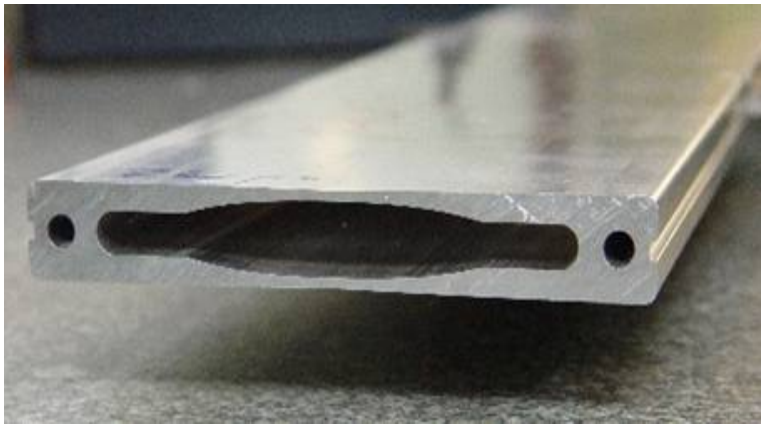
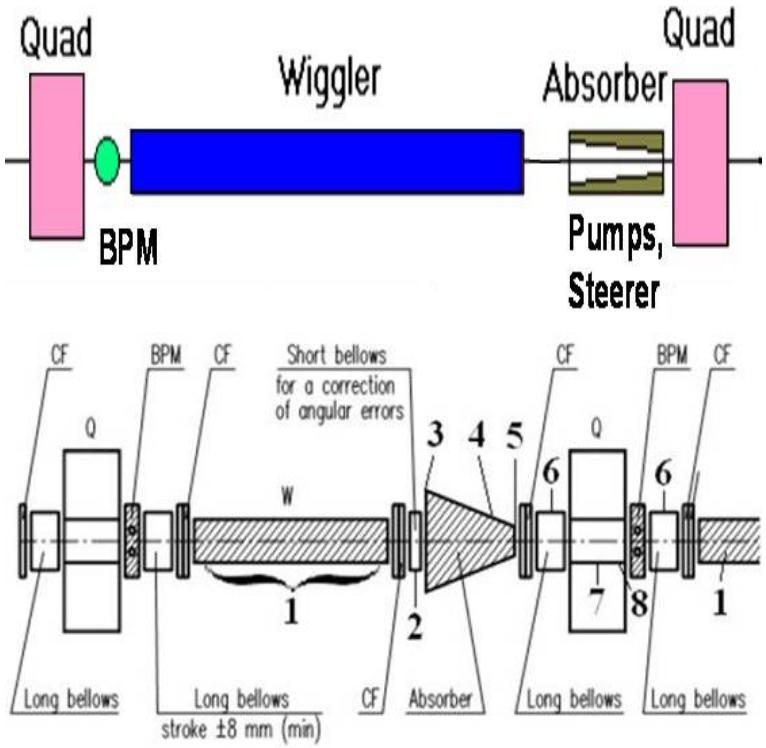


FIGURE: Wiggler vacuum chamber.

VACUUM SYSTEM AND ABSORBER DESIGN.



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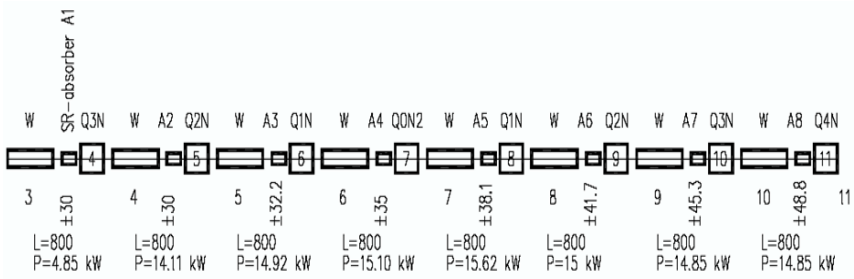


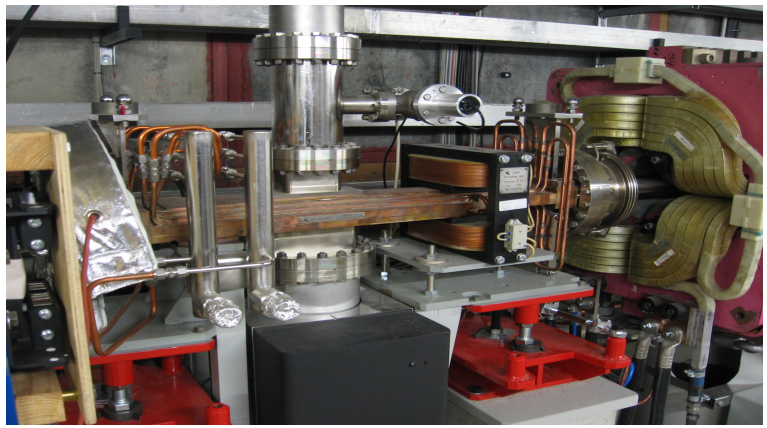
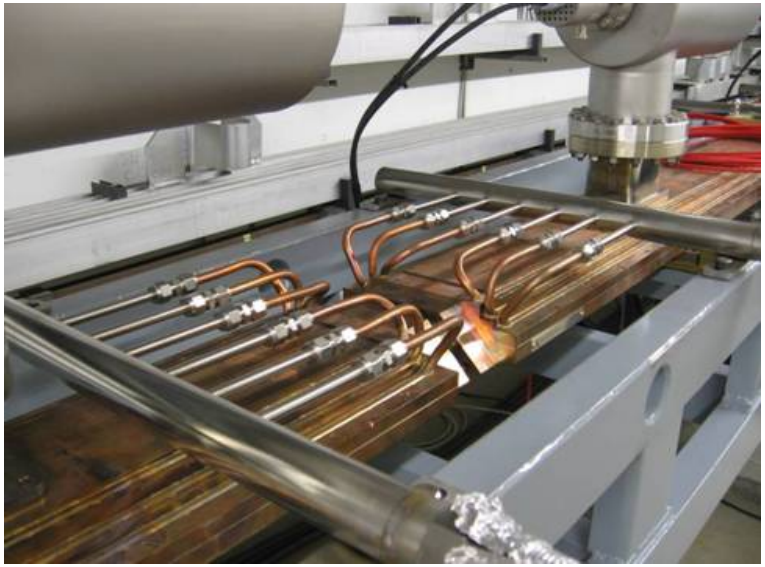
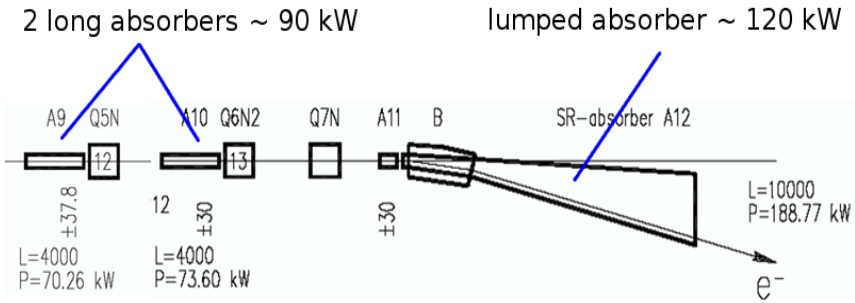


FIGURE: Regular absorber.

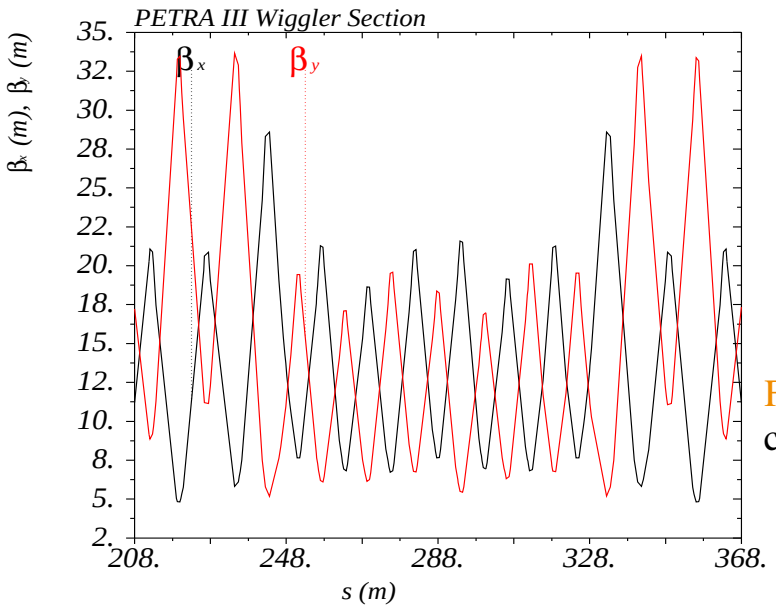
VACUUM SYSTEM AND ABSORBER DESIGN.





INFLUENCE ON OPTICS.

- Regular FODO structure in long straight sections
- Main influence on linear optics from additional vertical focusing
- Optics model from tracking implemented as matrix im MadX
- Vertically focusing quads single powered to compensate wigglers



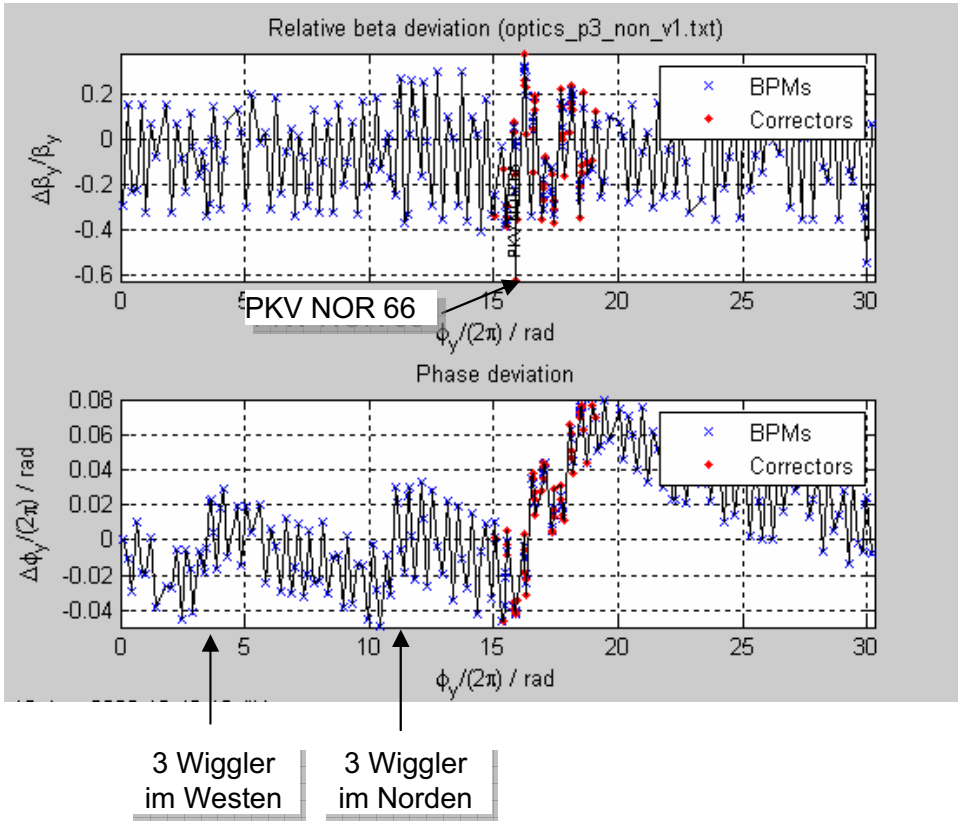
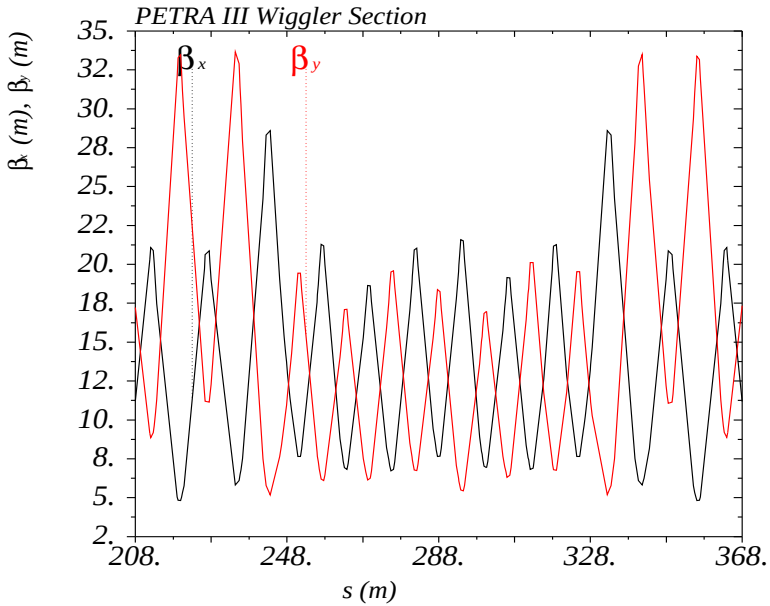


FIGURE: Measured beta and phase beating with 3+3 wigglers installed compared to the optics for the bare machine.

- Gradually installed wigglers during commissioning.
- ORM measurements used to verify optics.

INFLUENCE ON OPTICS.



- Marginal effect on horizontal optics
- Horizontally focusing quads powered in series

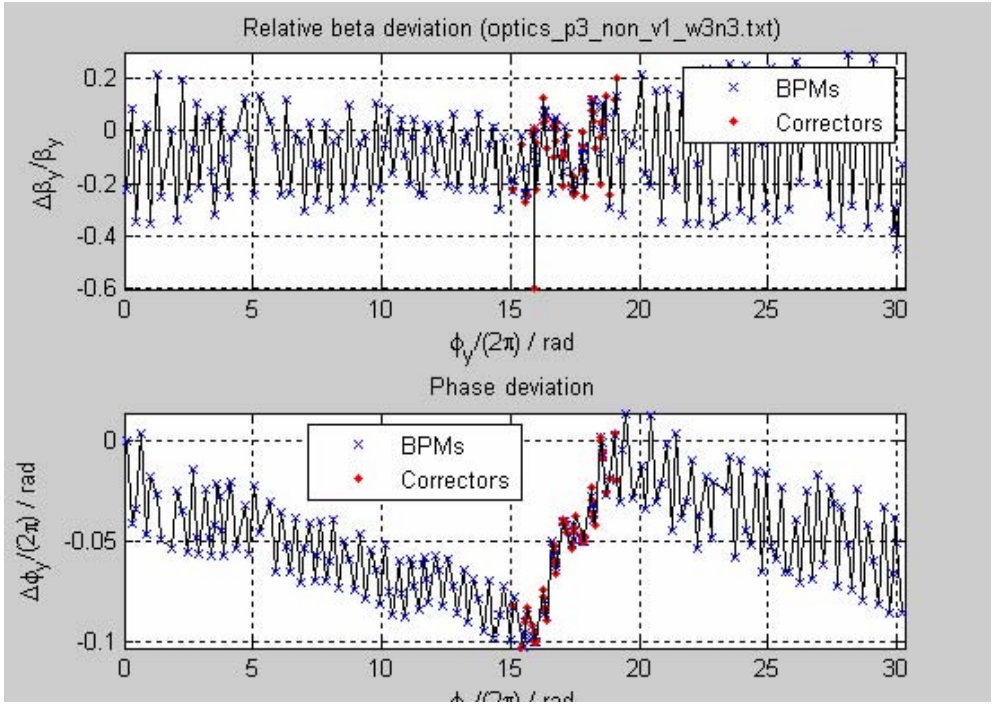
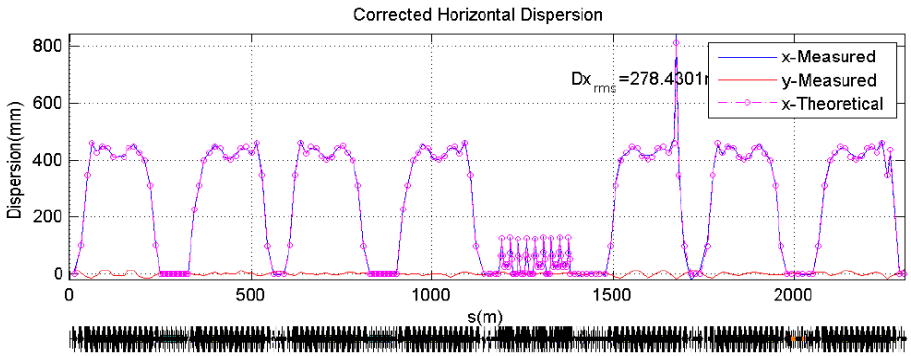
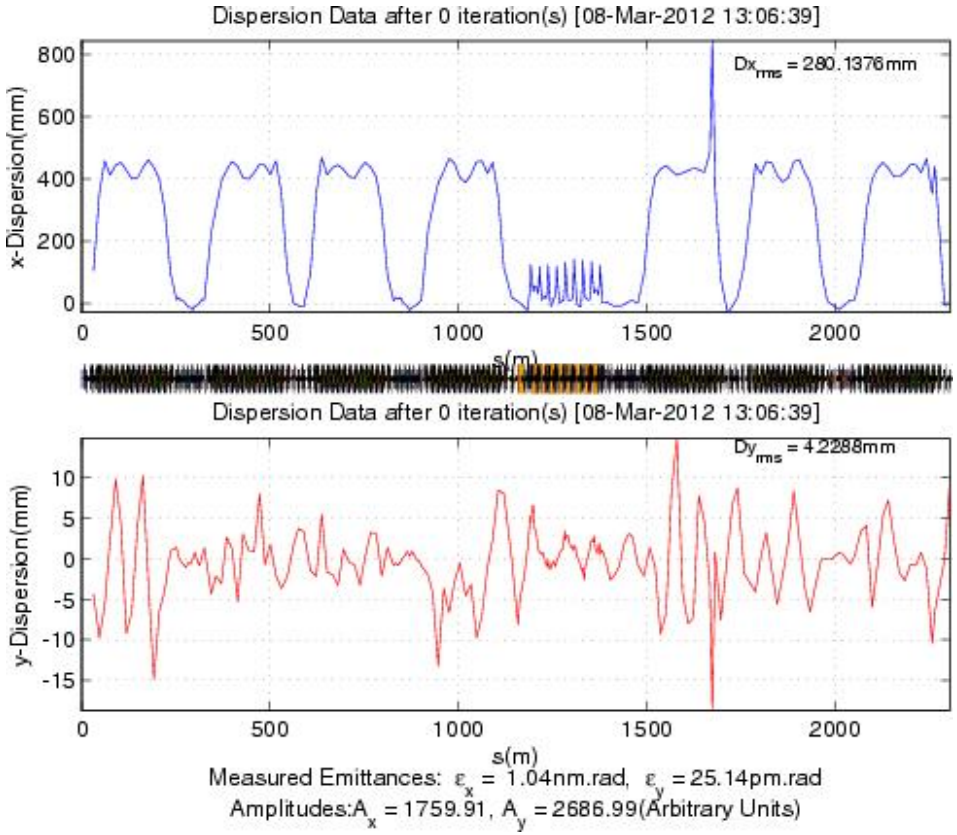


FIGURE: Measured beta and phase beating with 3+3 wigglers installed compared to the optics including wiggler matrix descriptions.

Matrix description works well!

DISPERSION CONTROL.

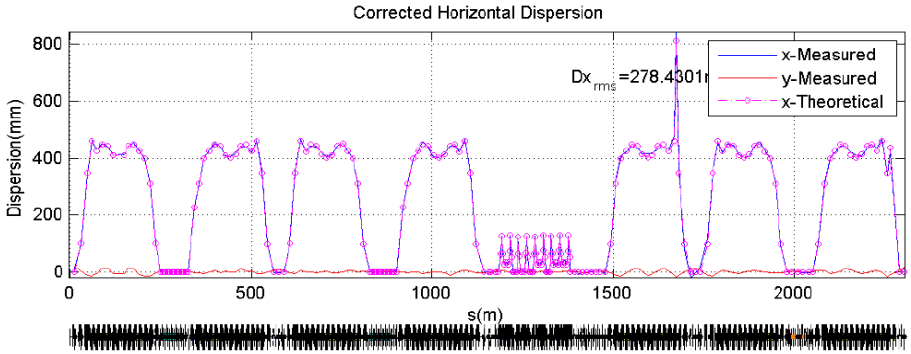




- Constraints on residual dispersion in wiggler sections:
  $D_x < 18$ mm,
  $D_y < 5$ mm
- Careful combined orbit and dispersion correction necessary (ORM,DRM,SVD).
- Control of vertical dispersion using skew quads.

FIGURE: Measured dispersion after orbit correction to BBA values.

DISPERSION CONTROL.



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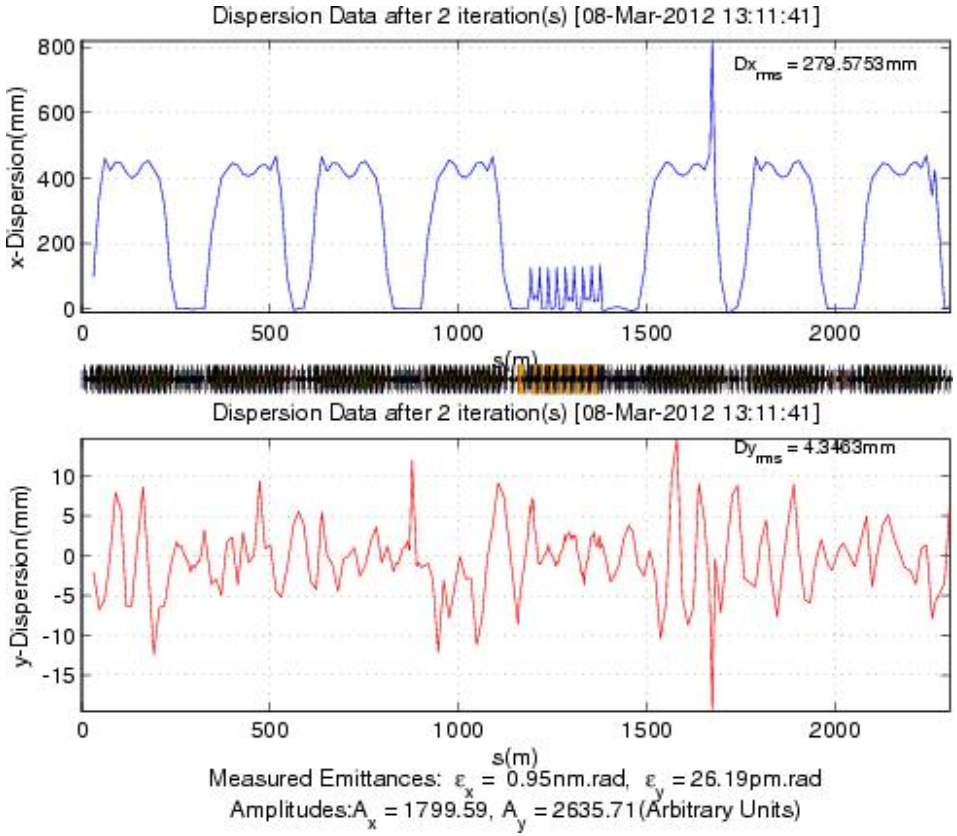

FIGURE: Measured dispersion after combined orbit and dispersion correction.

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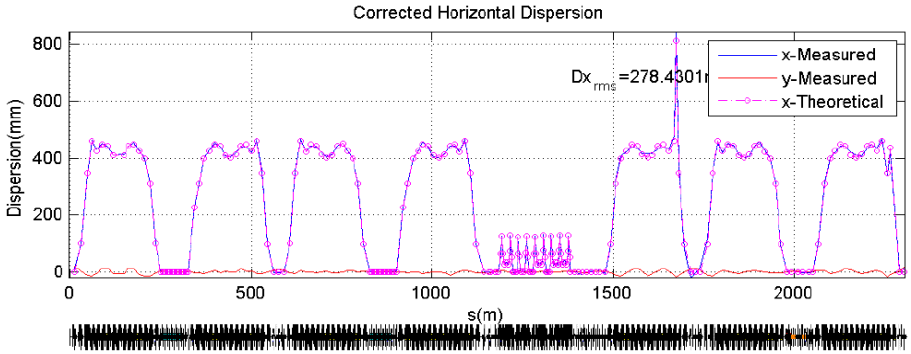

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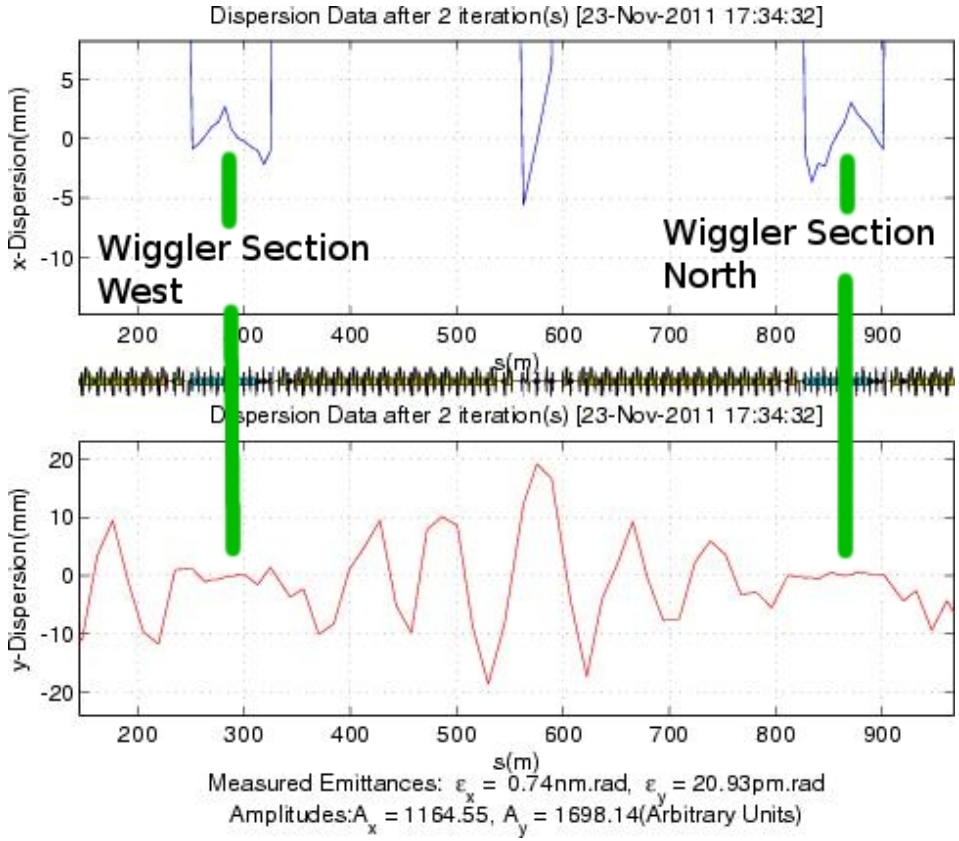
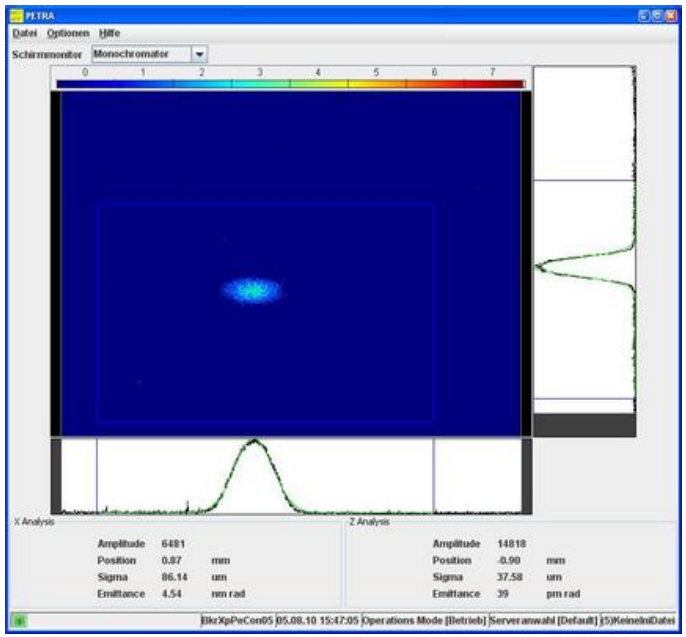


FIGURE: Measured dispersion in the wiggler sections after combined orbit and dispersion correction.

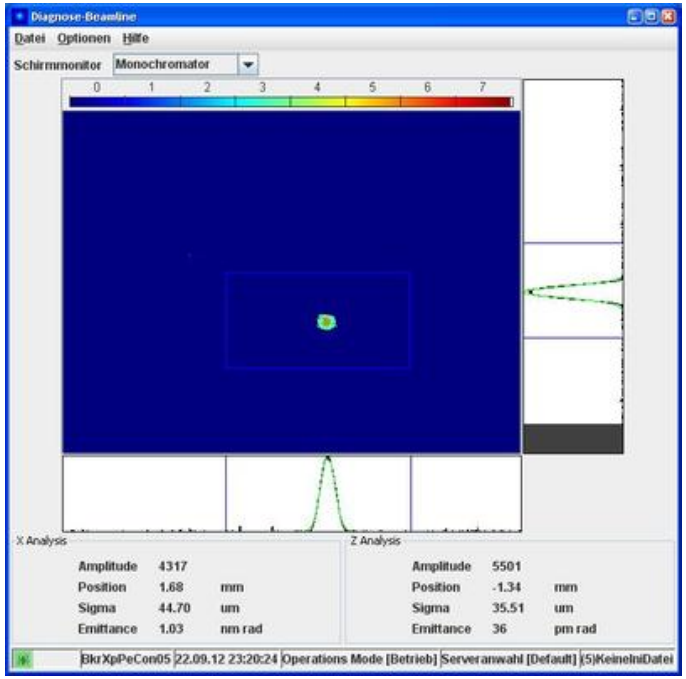
Measured Emittance.



Machine without Damping Wigglers

Measured horizontal width:
$\sigma_x = 86\ \mu m$,
Calculated emittance:
$\varepsilon_x = 4.54$ nm rad

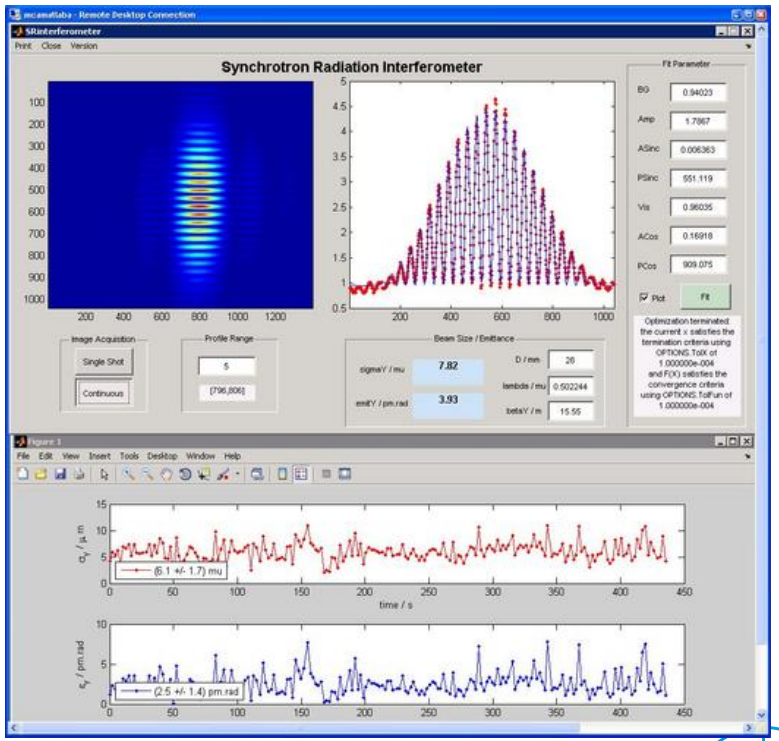
MEASURED EMITTANCE.



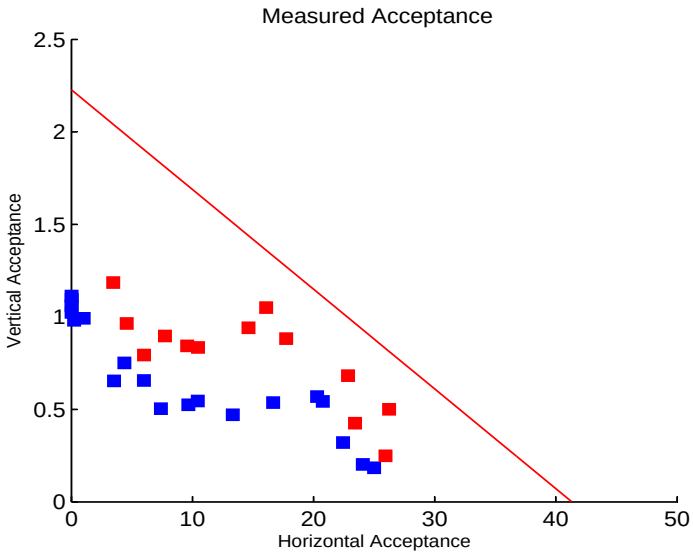
- Vertical emittance:
  $\varepsilon_y \sim 10$ pm rad
- Clear decrease in lifetime after dispersion tuning.
- Touschek lifetime 1.6h @ 2.0 mA

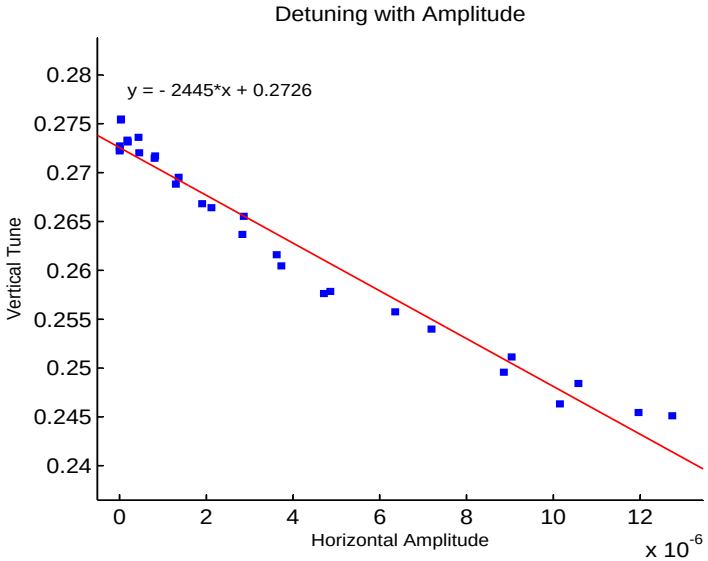
DAMPING WIGGLERS INSTALLED

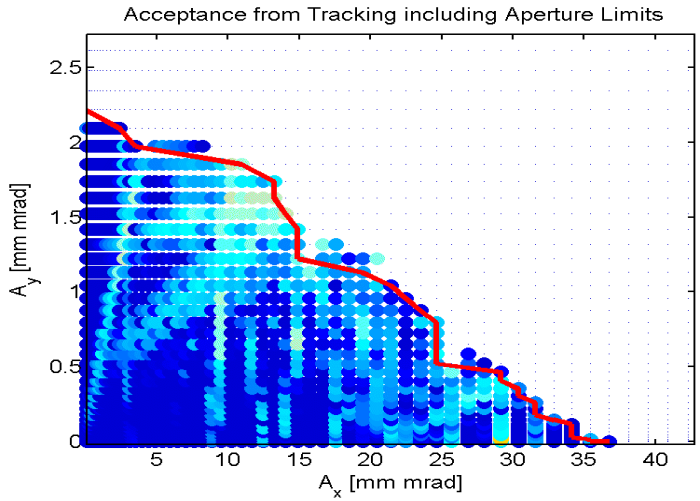
Measured horizontal width:
$\sigma_x = 44\ \mu m$,
Calculated emittance:
$\varepsilon_x = 1.03$ nm rad



NONLINEAR DYNAMICS.



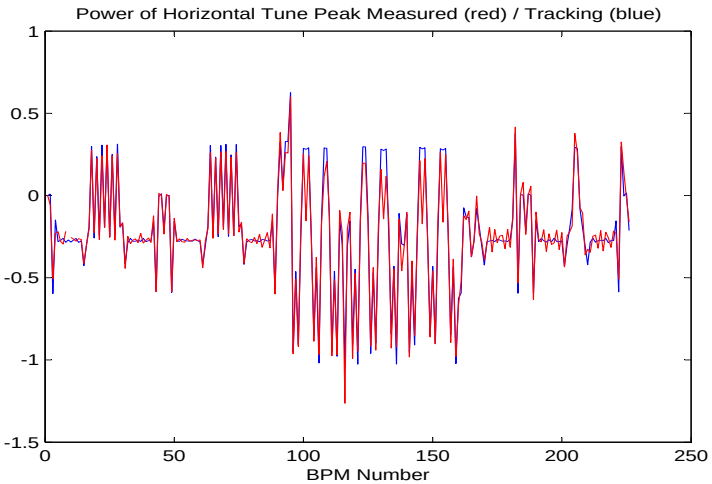


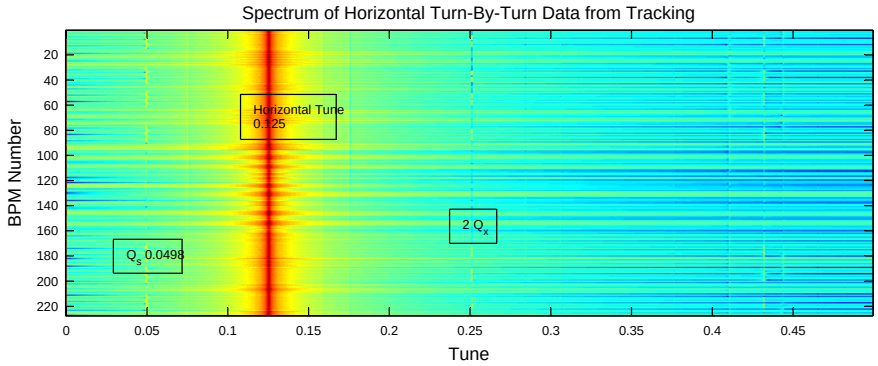


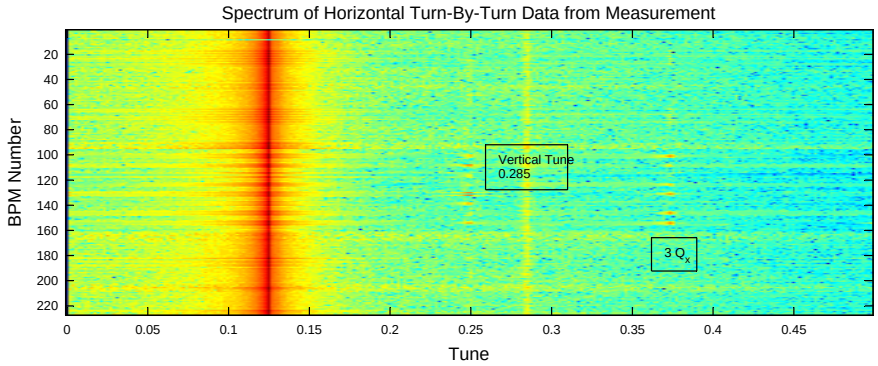
- Injected beam size: 350 nm rad, 10% coupling.
- Required acceptance for injection:
  $\sim$ 18 mm mrad (aiming at 30)
- Vertical: $\sim$ 1 mm mrad
- Detuning with amplitude:
  dominant cross term $\partial Q_y / \partial J_x$
- MadX (pure sextupole): $\sim$ -2400,
  SixTrack with wigglers: $\sim$ -2100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

NONLINEAR DYNAMICS.

- Multiturn measurements with all Bpms (with R. Bartolini).
- Good agreement with tracking results.
- Also confirms good control of linear optics.

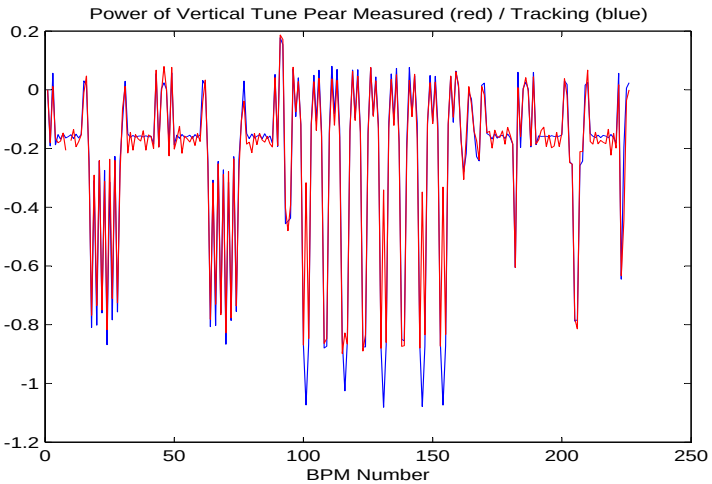


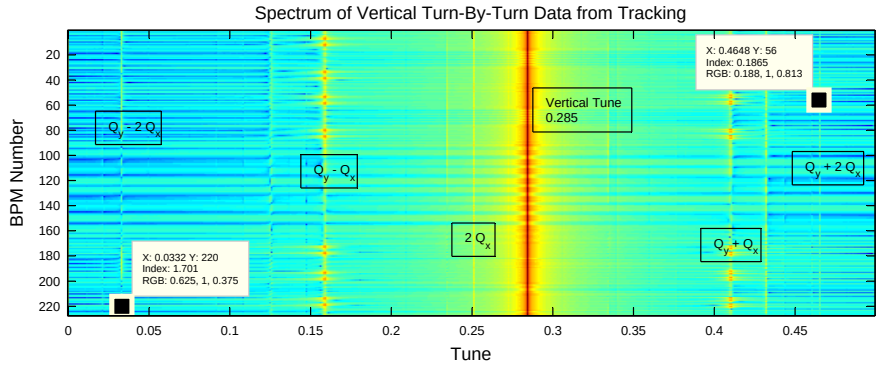


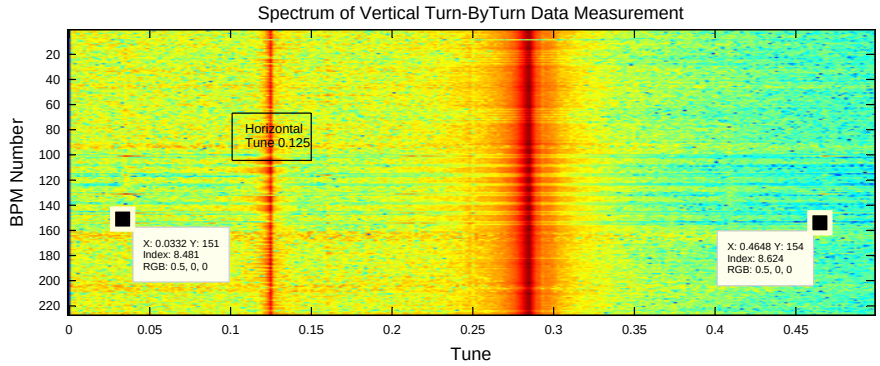


NONLINEAR DYNAMICS.

- Some more lines appear in the vertical spectrum.
- Machine model has still to be improved.
- Careful compensation of bpm nonlinearities required.







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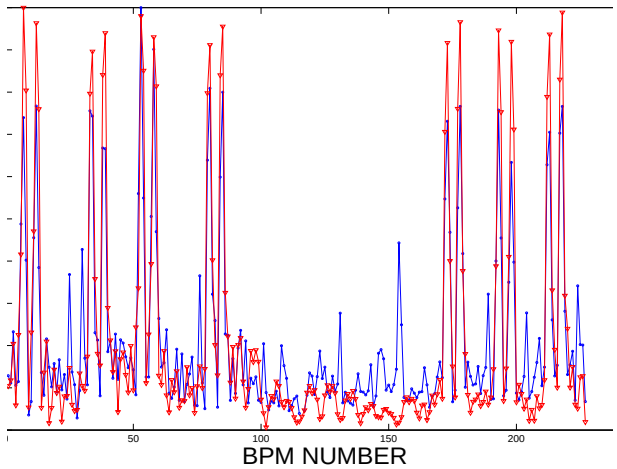
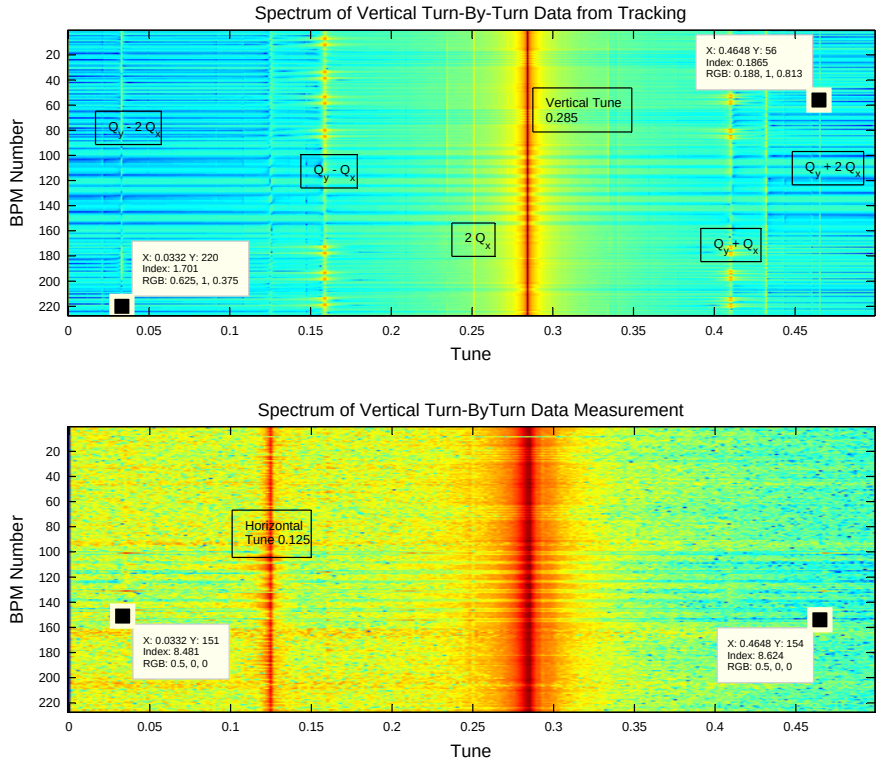
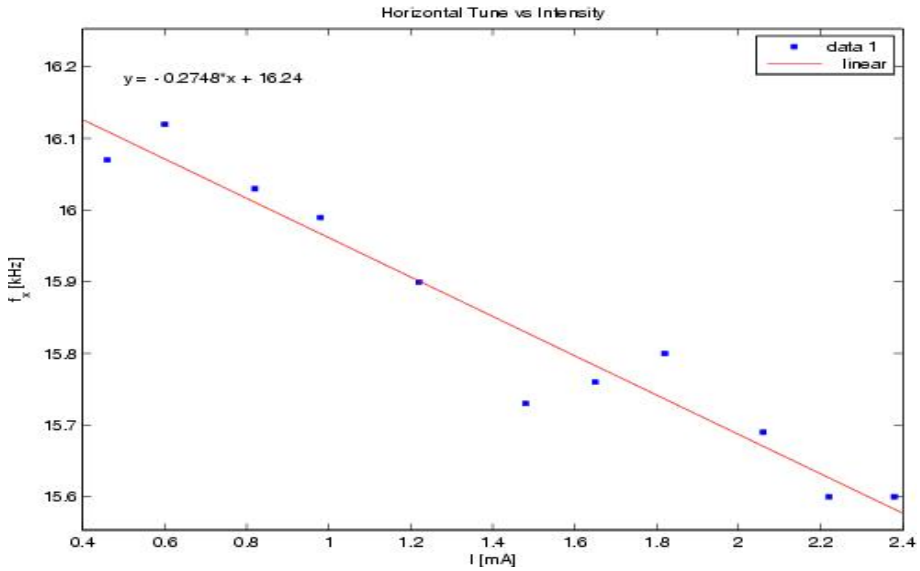


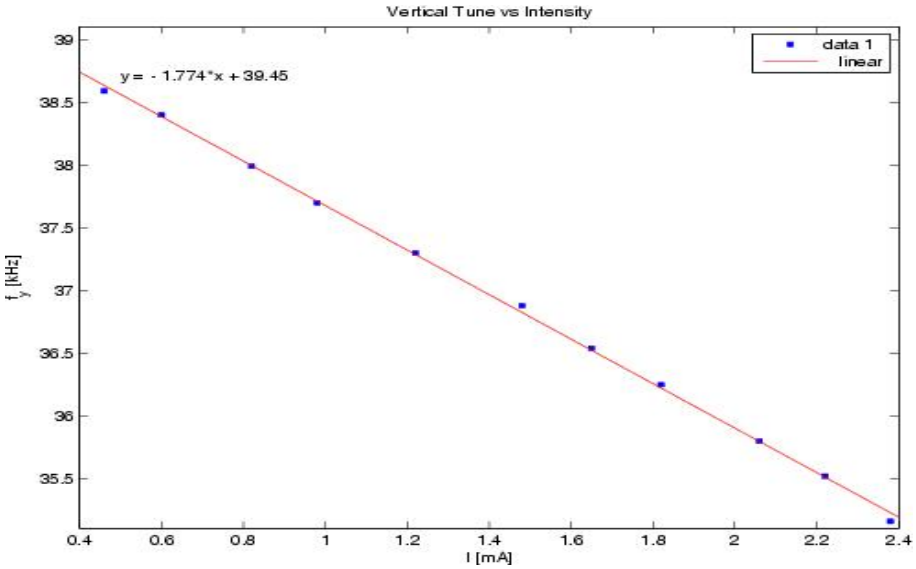
FIGURE: Nonlinear resonance line $Q_y \pm Q_x$ determined by the sextupoles.



TUNE SHIFT WITH INTENSITY.

- Without damping Wigglers:
  $\Delta Q_x / \Delta I = -0.0021$

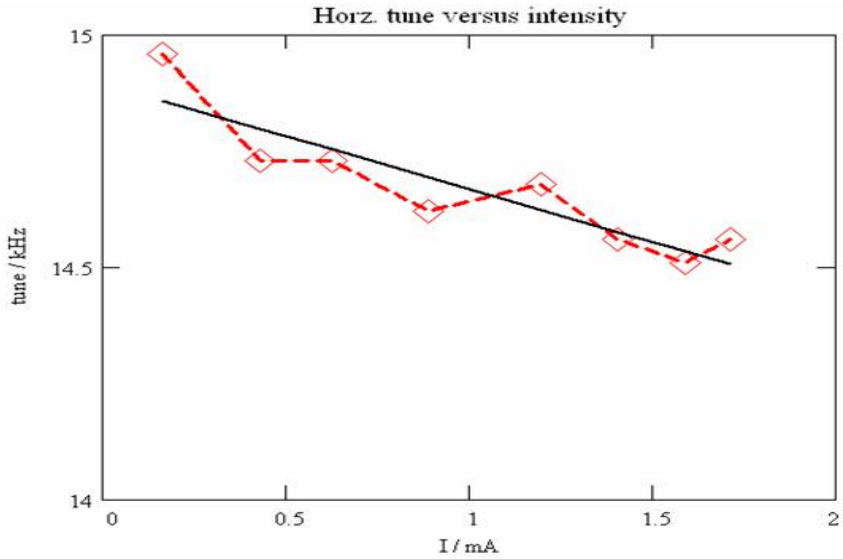


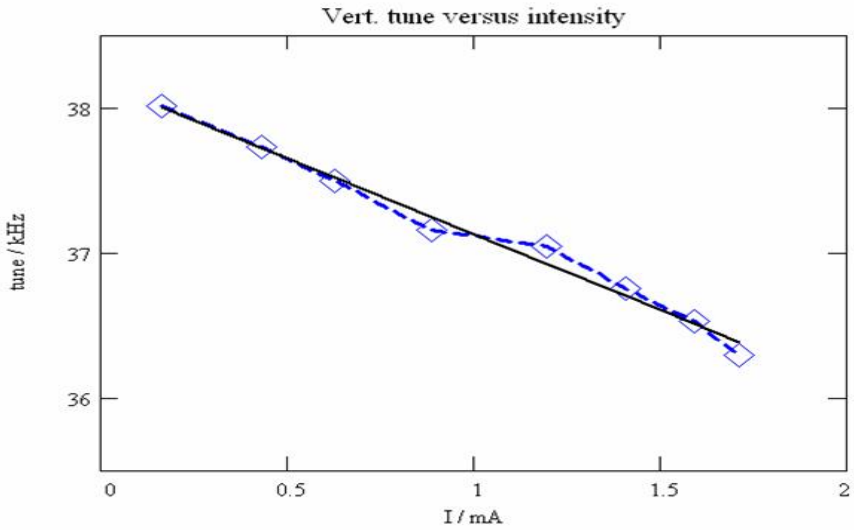


- Without damping wigglers:
  $\Delta Q_y / \Delta I = -0.0136$
- Both values larger than with damping wigglers installed!

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.

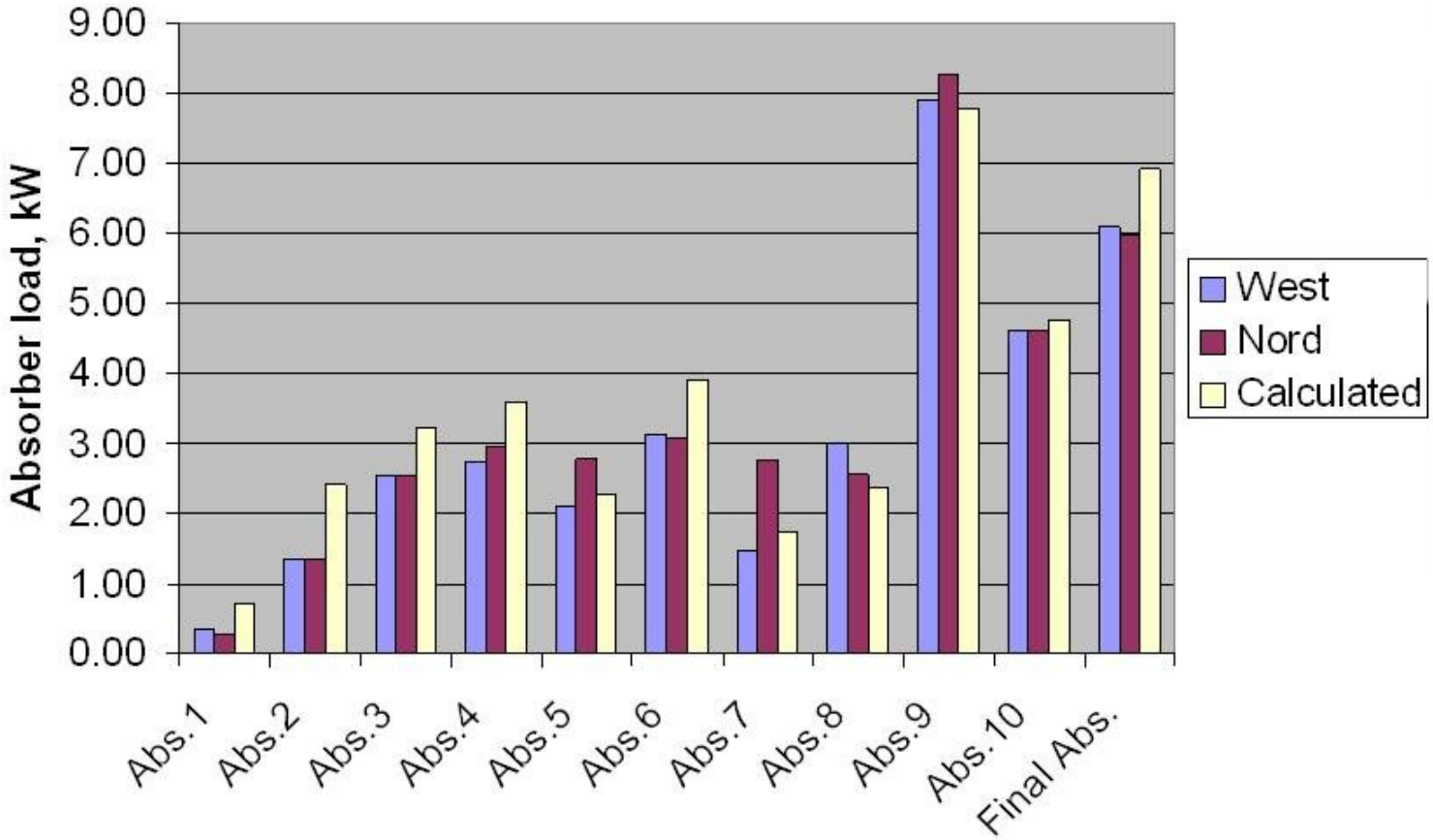
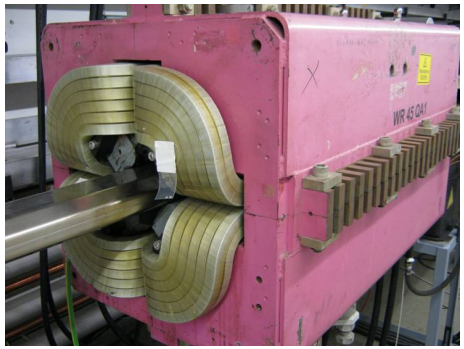
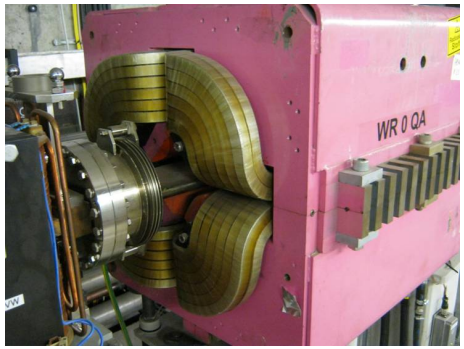
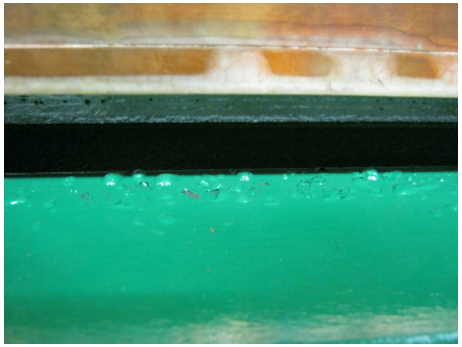


FIGURE: First measurements of power load on absorbers with 6+6 wigglers installed. Good agreement with theory (Mind however Abs. 7!). Measurements with all wigglers not yet evaluated.

Radiation Issues.





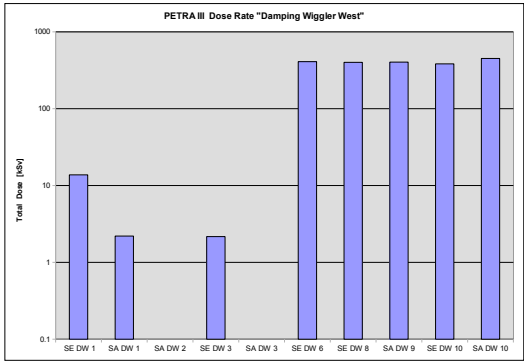


- Cisco switches died
- Radiation damage can be seen on magnet coils, paintings, cables, etc.
- PETRA Hall West temporarily declared radiation controlled area

Radiation Issues.

- Measured radiation during 3 weeks standard user operation:
  20-30 kSv @ integrated current of 43 Ah
- Highest value Absorber WR 28m: 50 kSv
- Radiation shielding delicate because of temperature at absobers!
- Consequences for lifetime of wiggler magnets?

RADIATION ISSUES.



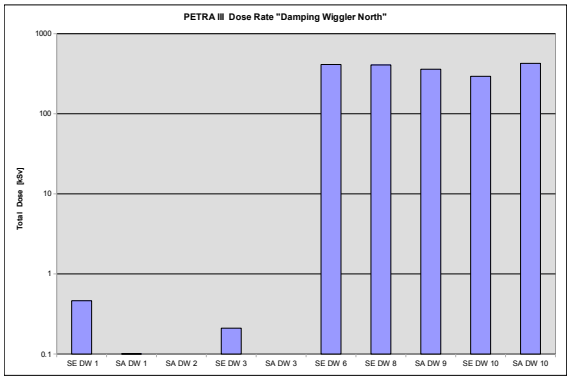


FIGURE: Integrated Dose Rate measured in wiggler sections.

- Measured radiation during 3 weeks standard user operation:
  20-30 kSv @ integrated current of 43 Ah
- Highest value Absorber WR 28m: 50 kSv
- Radiation shielding delicate because of temperature at absobers!
- Consequences for lifetime of wiggler magnets?

RADIATION ISSUES.

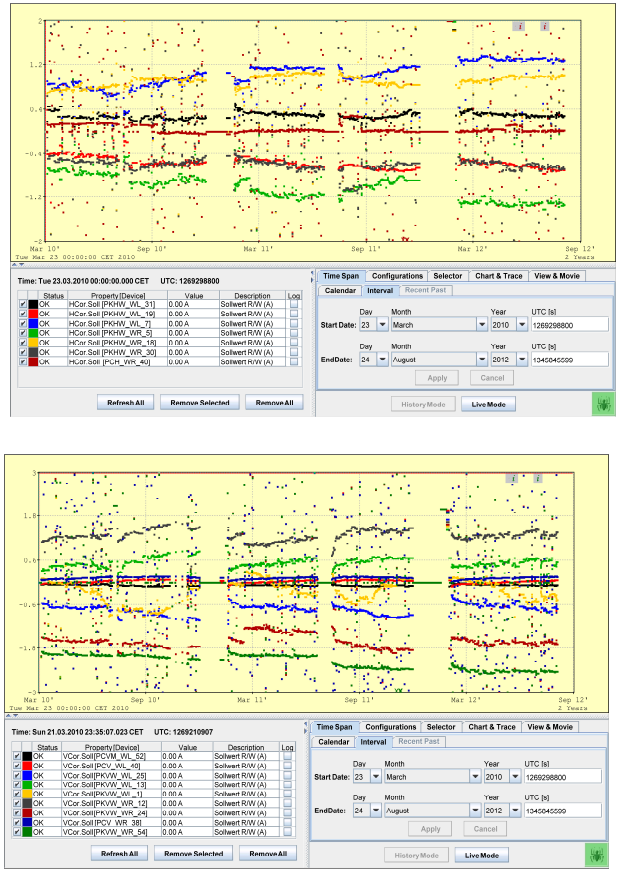


FIGURE: Variation of corrector strenghts from 2010 to 2012.

- Measured radiation during 3 weeks standard user operation:
  20-30 kSv @ integrated current of 43 Ah
- Highest value Absorber WR 28m: 50 kSv
- Radiation shielding delicate because of temperture at absobers!
- Consequences for lifetime of wiggler magnets?

CONCLUSIONS.

- Petra III strongly relies on damping wiggler performance
- Linear optics well understood
- Dispersion control (long term) essential
- Wiggler nonlinearities not a problem
- Radiation issues to be considered

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Thank you!