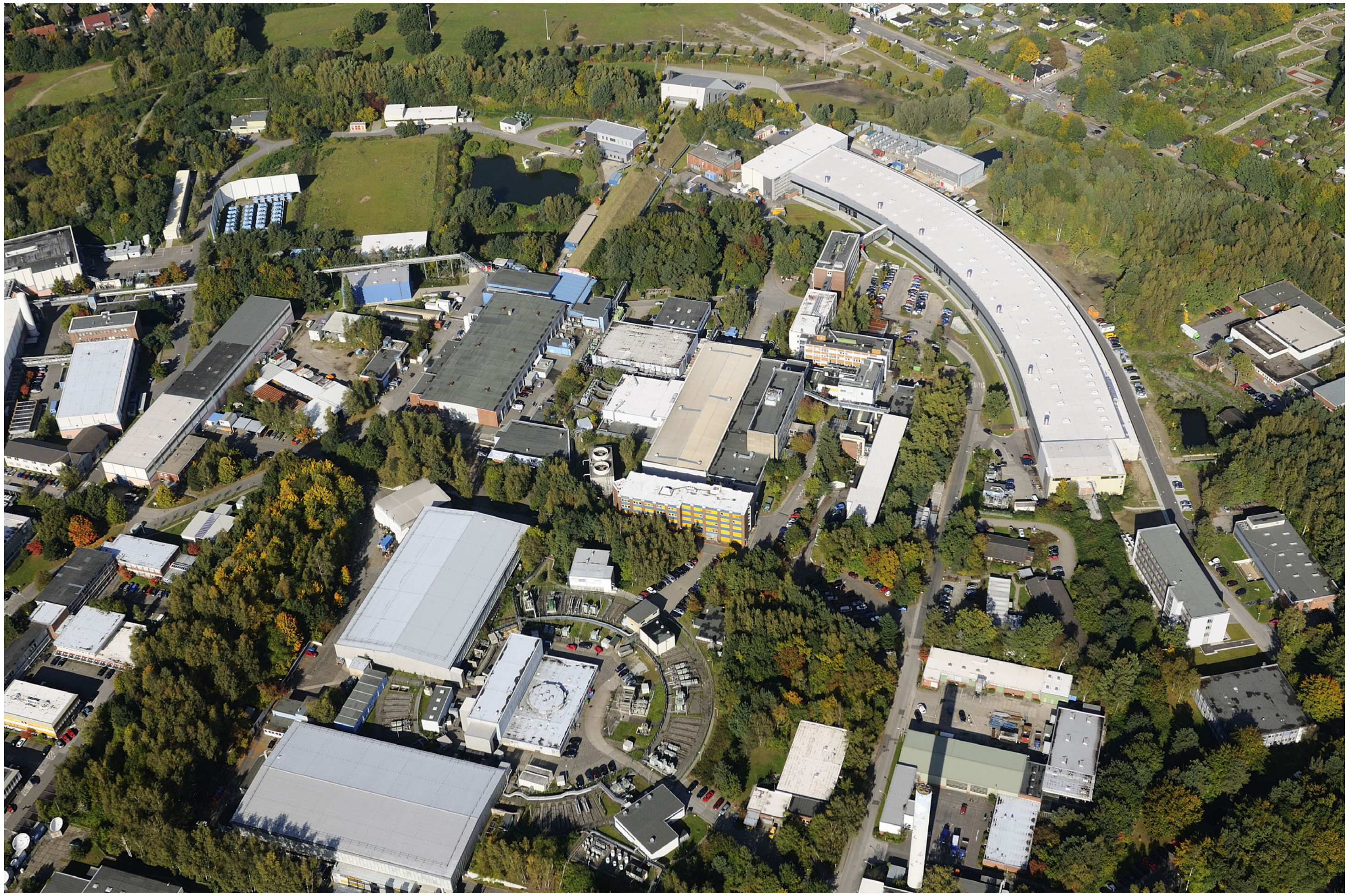
Commissioning of PETRA III



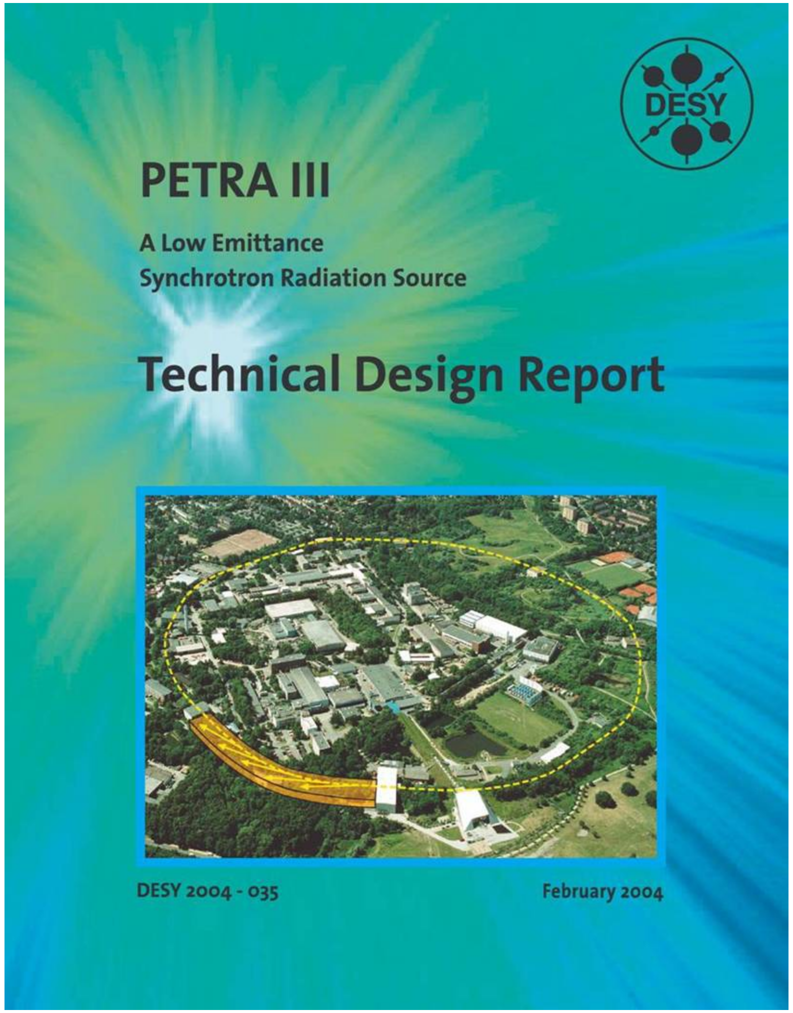
HELMHOLTZ ASSOCIATION

Klaus Balewski on behalf of the PETRA III Team

IPAC 2010, 25 May, 2010

DESY

PETRA III Parameters



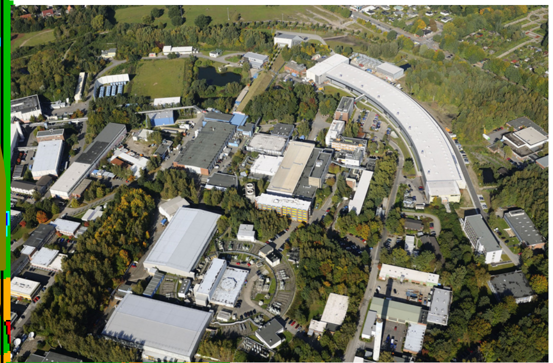
Circumference (m)	2304
Energy (GeV)	6
ε_x (nm rad)	1
ε_y (pm rad)	10
Current (mA)	100 (200)
# bunches	40 / 960
Straight sections (*)	9
Undulators	14
Undulator length (m)	2, 5, 10 (20)

(*) limited budget

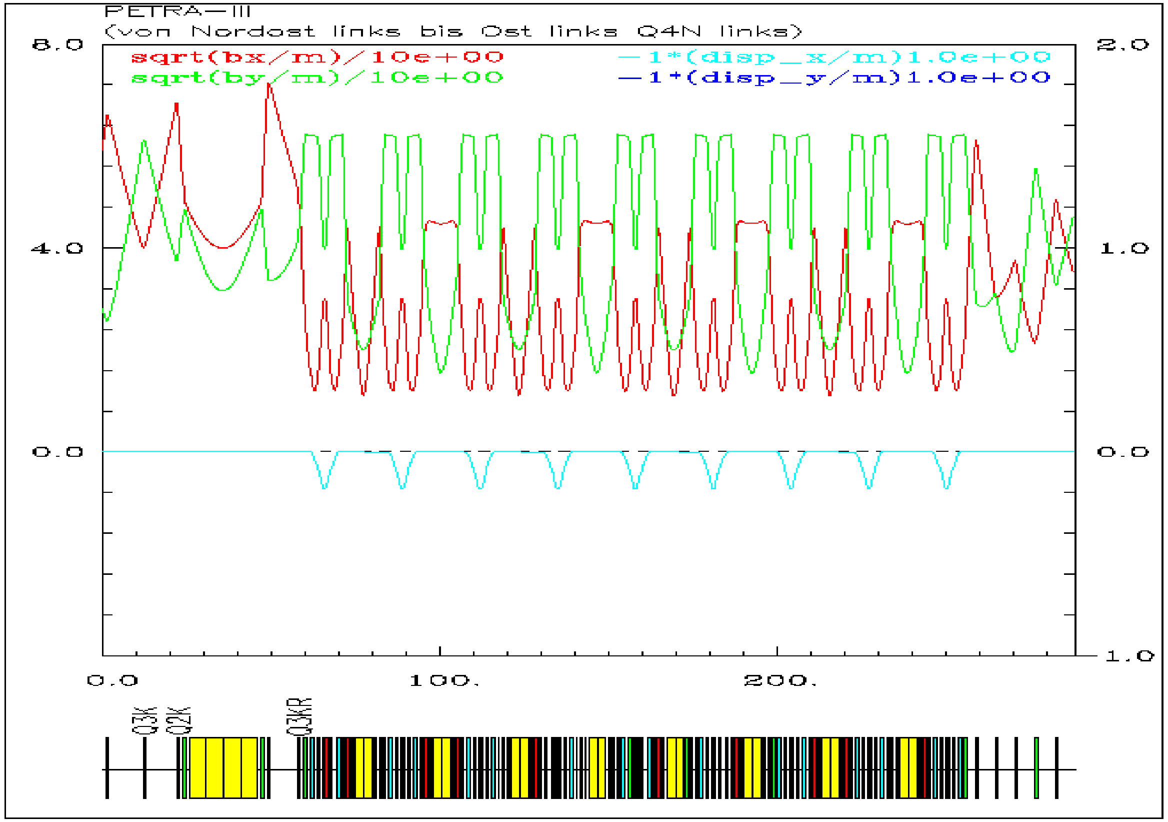
PETRA II → PETRA III

New experimental

Hall



Layout and optics of new octant



8 complete DBA cells
Cell length 23 m
High beta: βx = 20 m βy = 4 m
Low beta : βx = 1.4 m βy = 4 m

No sextupoles in new octant
Because of small Dx!!!

Straights can house
either
  5m long IDs
or
  2 2m long IDs (canted undulators)
  angle between canted IDs: 5mrad

Number of 2m IDs: 10
Number of 5m IDs: 3
Number of 10m ID: 1
Total : 14

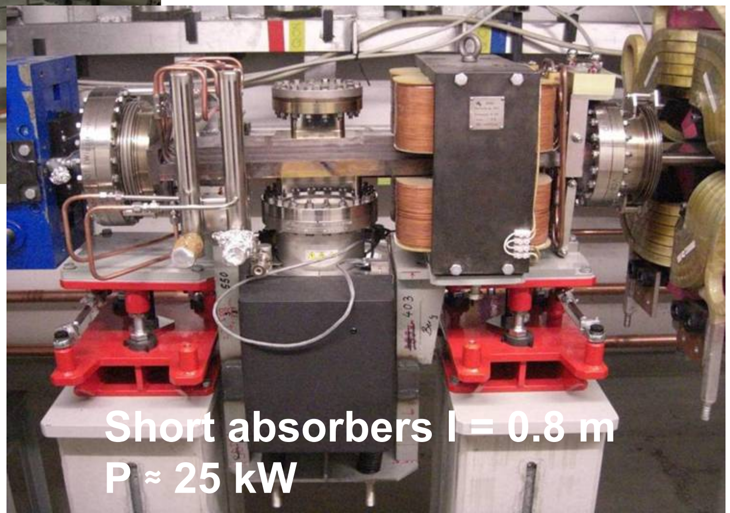
Damping Wiggler Sections

Collaboration with BINP

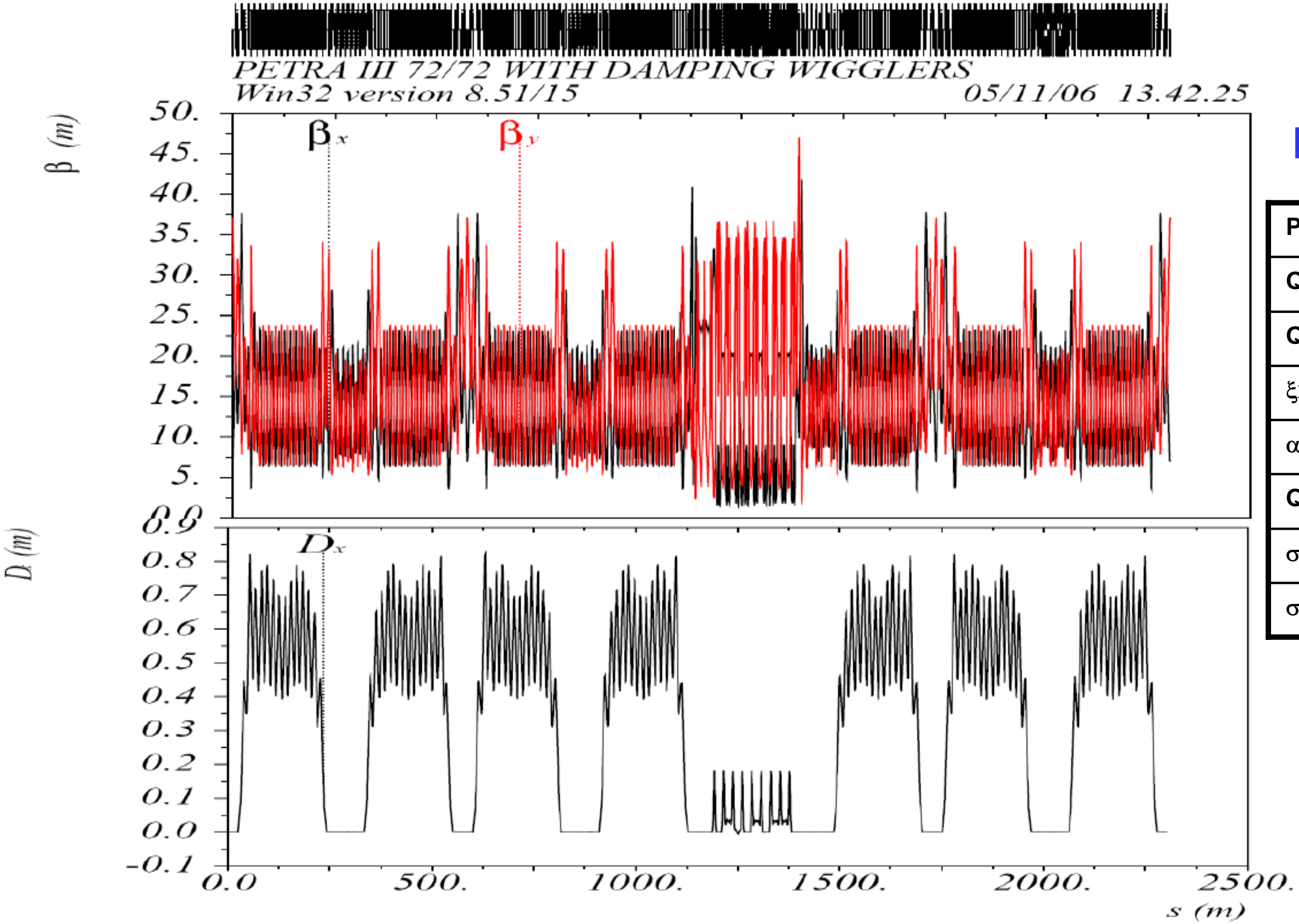
ε_x: 4.5 → 1 nmrad

Damping wigglers

- Number 20
- $L_{wiggler}$ = 4 m
- B = 1.5 T
- λ = 0.2 m
- h = 0.025 m
- Prad@200 mA = 2*440kW
- critical energy 36 keV



Complete Optics

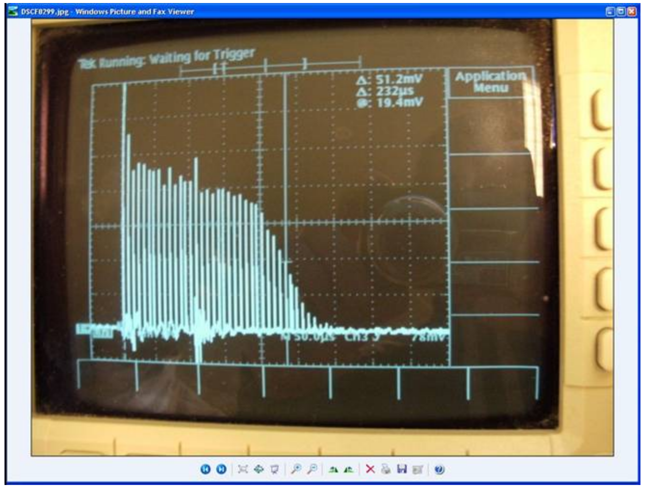


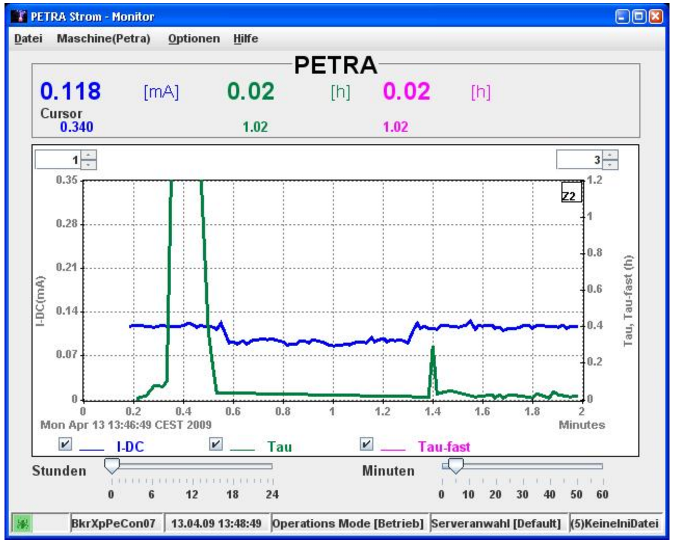
Machine Parameters

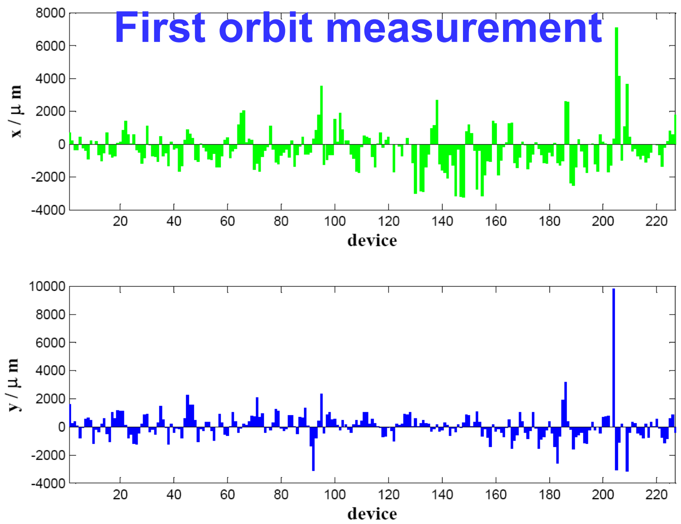
Parameter	Value
Qx	37.1
Qy	33.26
ξx / ξy	-41 / -40
α	$1.2 * 10^{-3}$
Qs	0.05
σs	13 mm
σE	$1.3*10^{-3}$

Stored beam

Beam was stored on April 13 (one bunch with 20 µA i.e. about 10^9 e+)
RF – phase right and orbit empirically corrected in the new octant





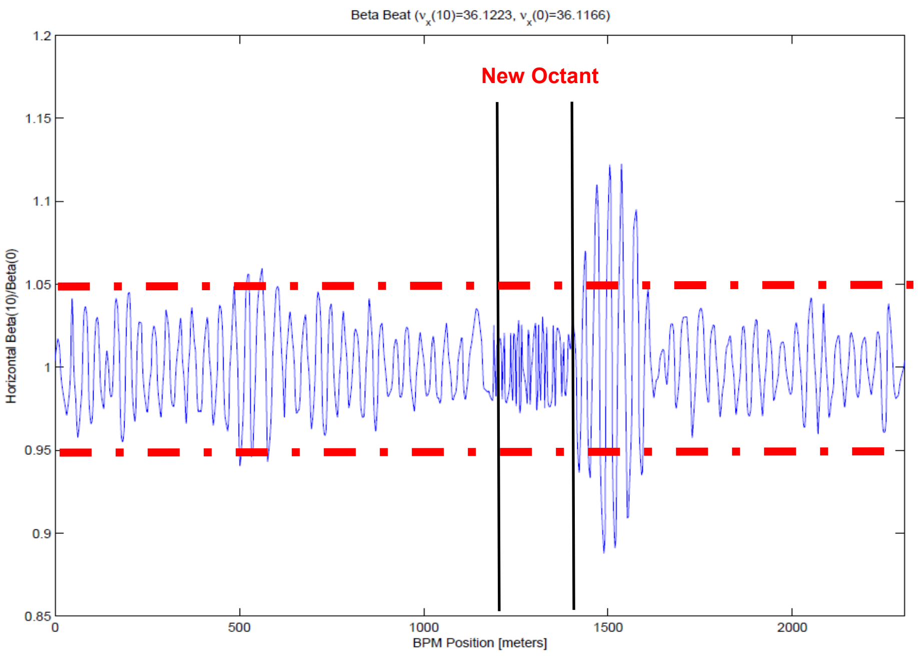


Summary of Commissioning Results with all wigglers installed

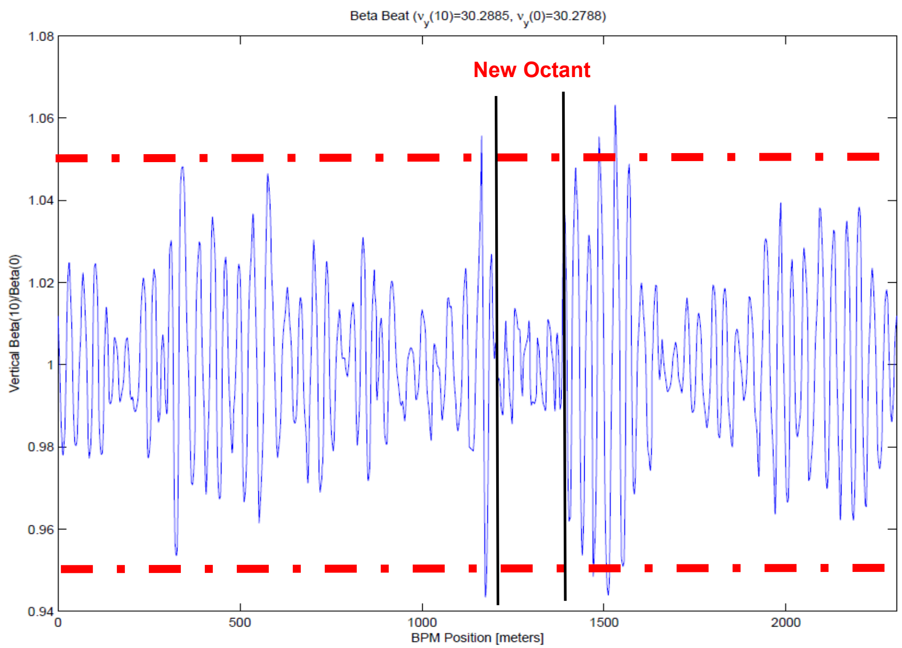
Optics correction

Result after 2 Iterations $(\Delta k/k)_{max} \approx 2\%$

Horizontal $\Delta\beta_x/\beta_{xrms} \approx 3\%$

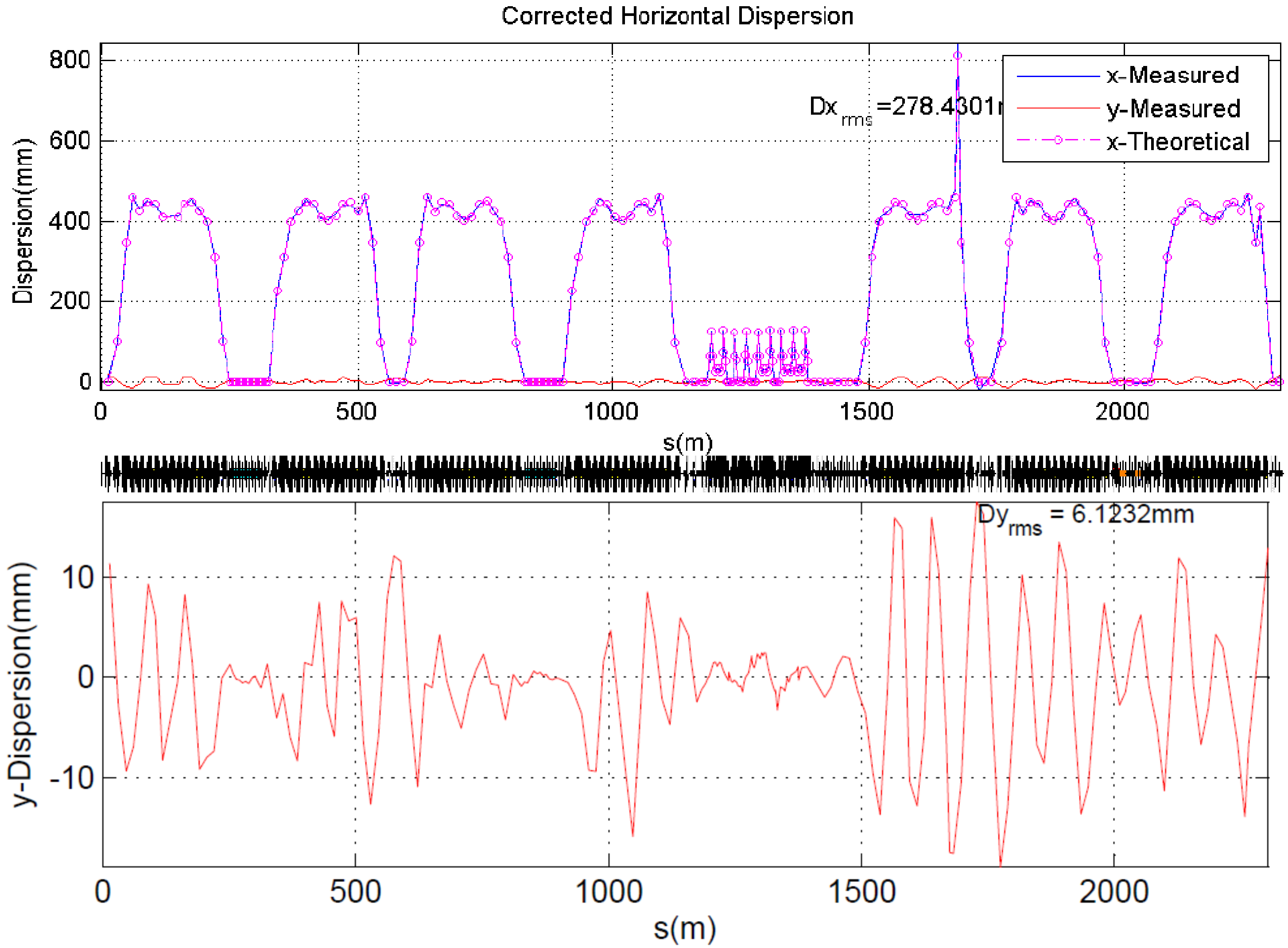


Vertical $\Delta\beta_y/\beta_{yrms} \approx 2\%$



Details see THPD085

Dispersion

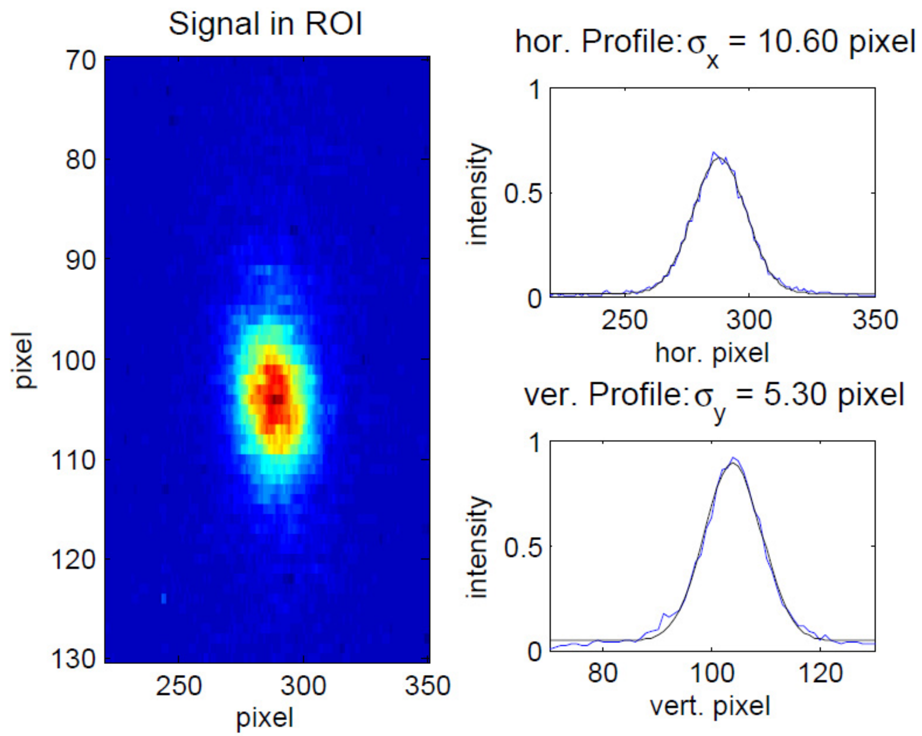


Spurious vertical dispersion in Damping wiggler sections ≈ 1mm

Details see THPD086

Emittance Measurement

Emittance measured with dedicated beam line
Details see MOPD089



Calculated horizontal width: $\sigma_x \approx 44\ \mu m$

Calculated emittance $\varepsilon_x \approx 0.9$ nm rad

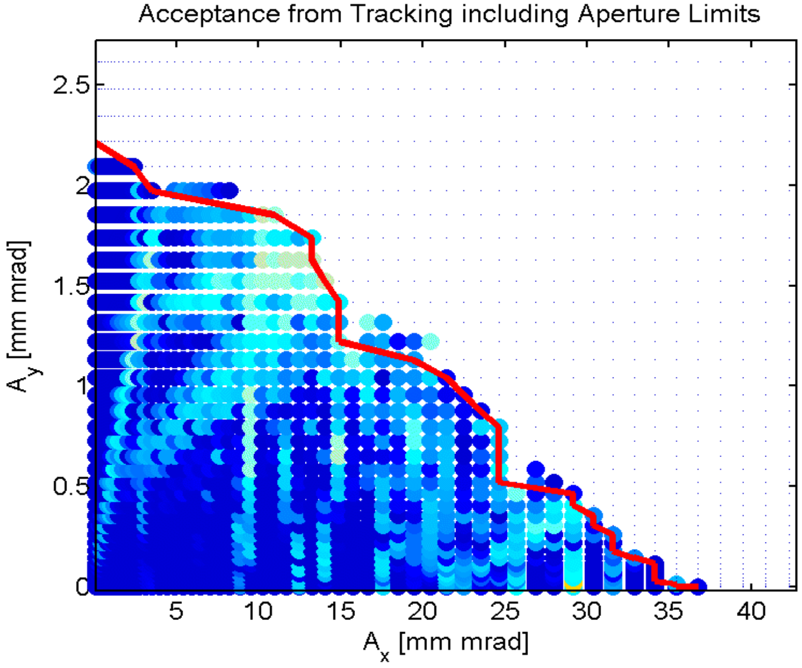
Summary

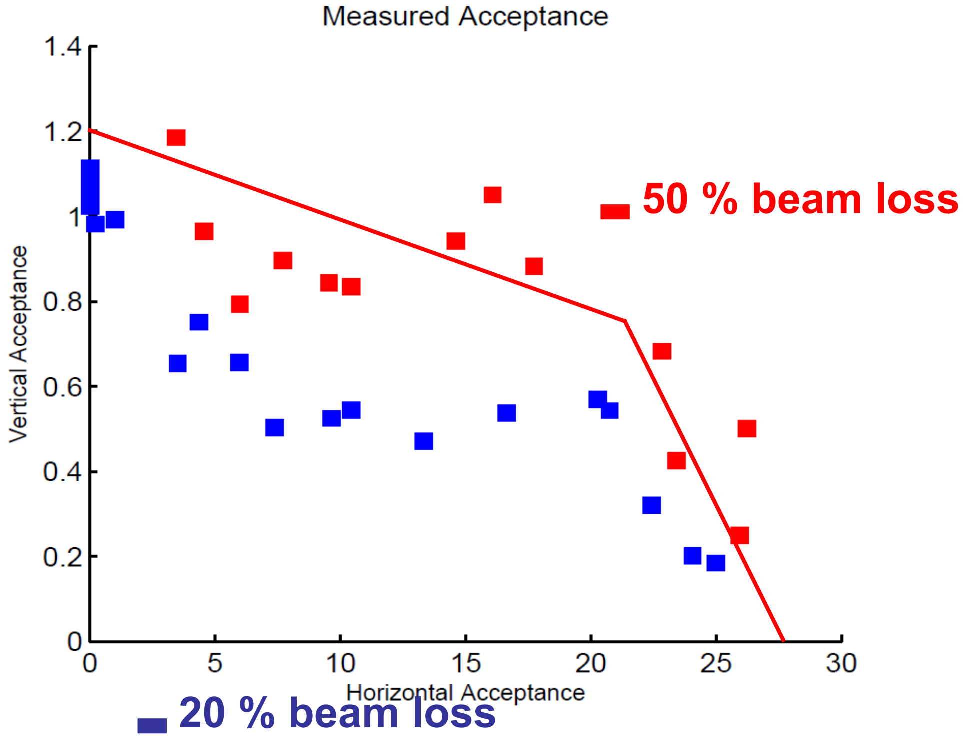
Measured emittances (nmrad)
$0.9 \leq \varepsilon_x \leq 1.1$
$\varepsilon_y \leq 0.02$

Expected emittance (no ID's)
$\varepsilon_x \approx 1.06$ nm rad

Off- and on-momentum Aperture

Acceptance





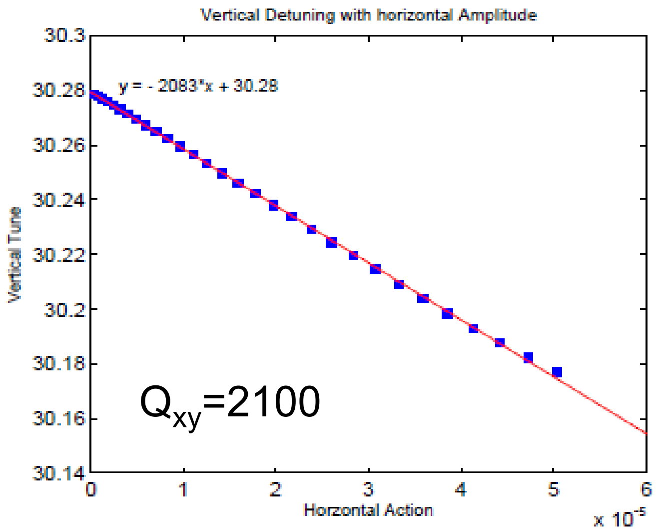
Calculated Acceptance:
Ax = 35.0 mm mrad
Ay = 2.2 mm mrad

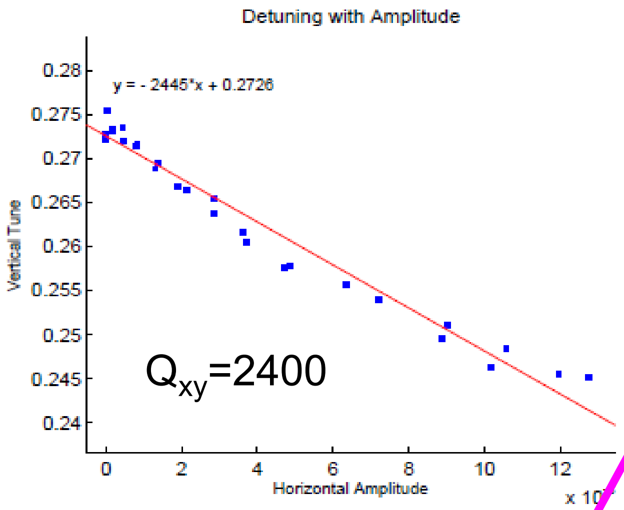
Measured Acceptance:
Ax = 27.0 mm mrad
Ay = 1.2 mm mrad

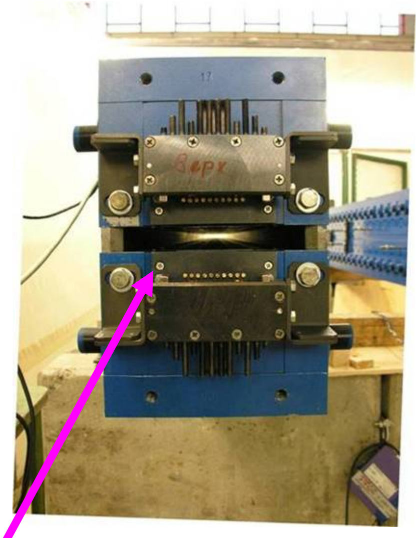
Close to 100 % Injektion efficiency requires Ax = 20 mm mrad and Ay= 0.8 mm mrad

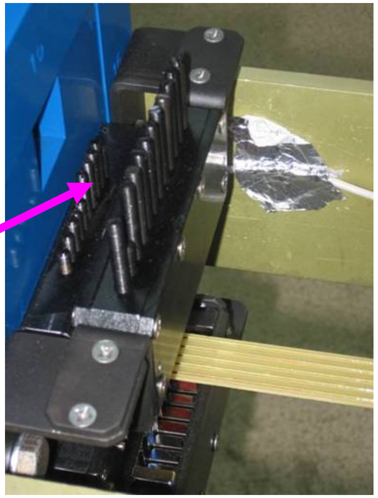
Detuning with Amplitude

$$Q_y = Q_{yy} \cdot J_y + Q_{yx} \cdot J_x$$









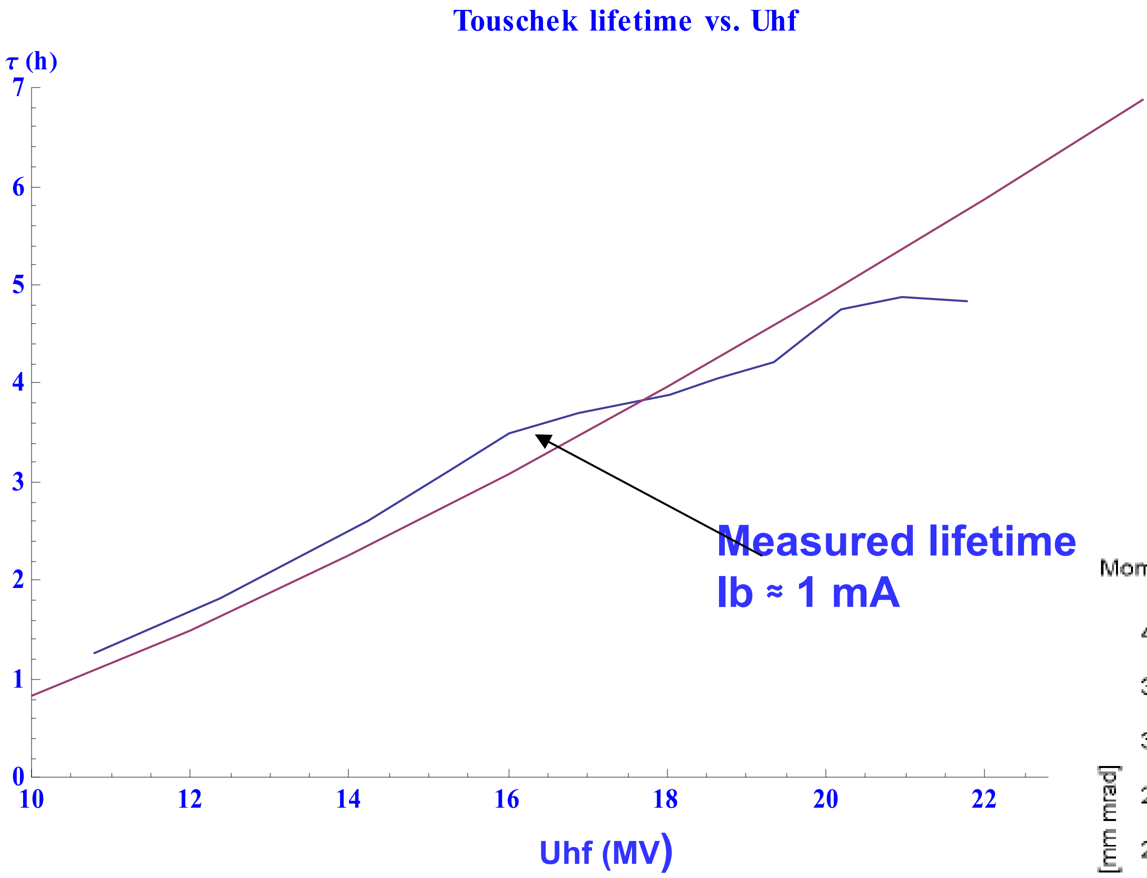
Calculated detuning;
basically dominated by Sextupoles
(wigglers included!)

Measured detuning

Adjustment of wiggler
Field quality with magic fingers

Details see WEPEA016,
WEPEA017

Momentum acceptance

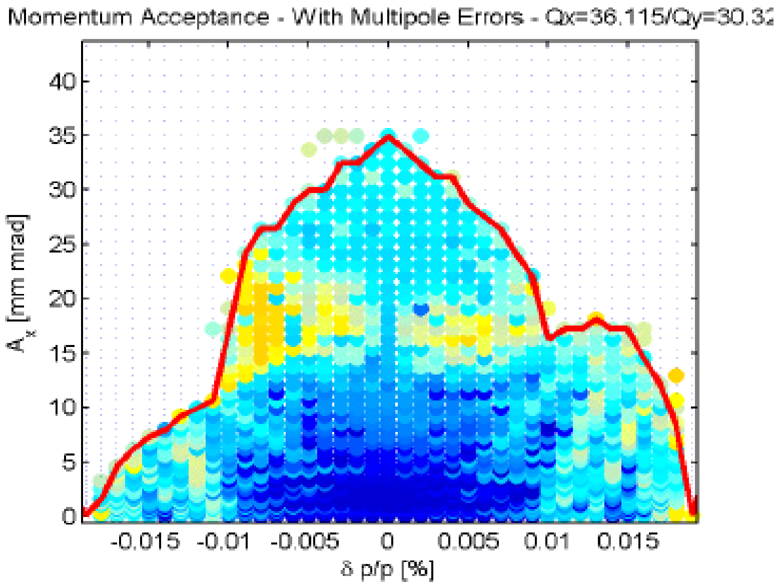


Calculated Touschek Lifetime (MAD)

ε_x = 0.9 nmrad

ε_y = 13 pmrad

Calculated acceptance
About 1.7 %

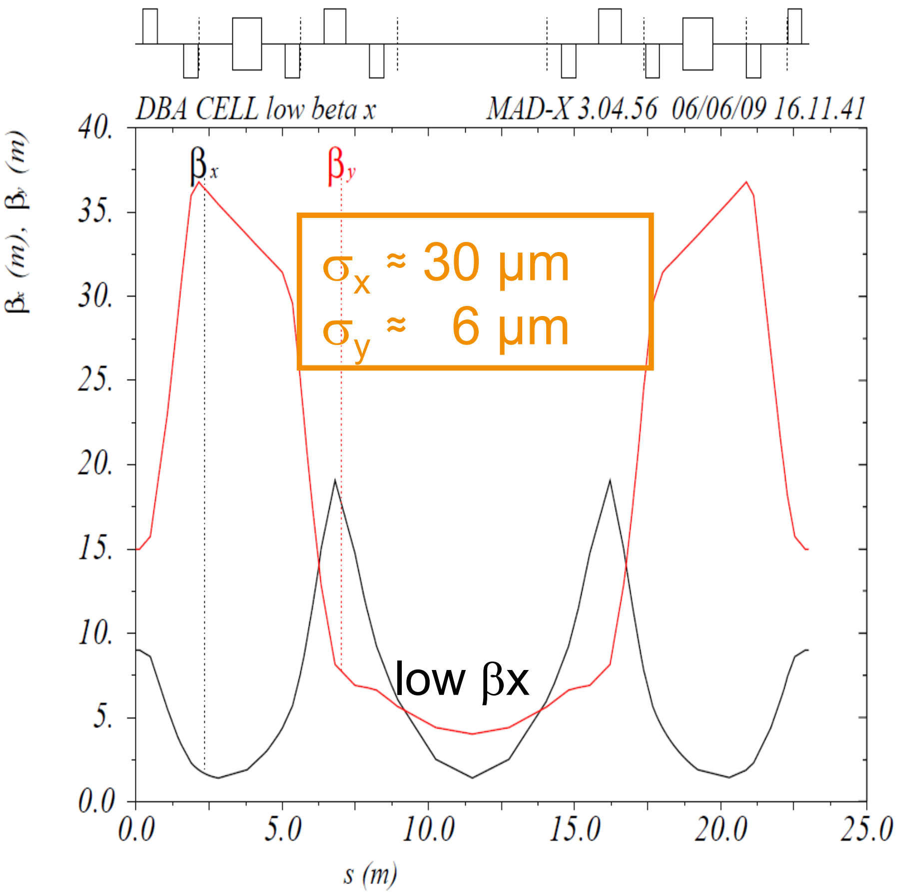


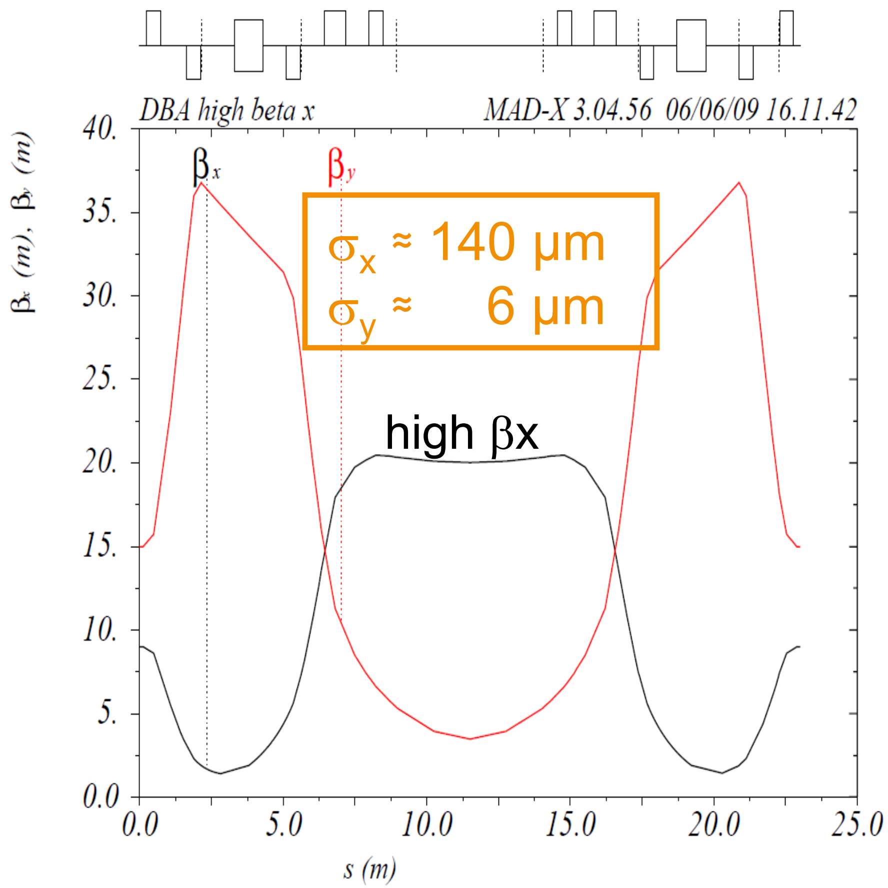
Estimated momentum acceptance about 1.6 %

Orbit Stability

Stability Requirements

ε_x = 1 nm rad; κ = 0.01





Stability requirements:

horizontal: 3.0 µm
vertical : 0.6 µm

horizontal:14.0 µm
vertical : 0.6 µm

Orbit Stabilization

> Passive measures
- Foundation of the exp. hall
- Careful design of girders
- Air-conditioning of the new tunnel: ± 0.1° !
- …

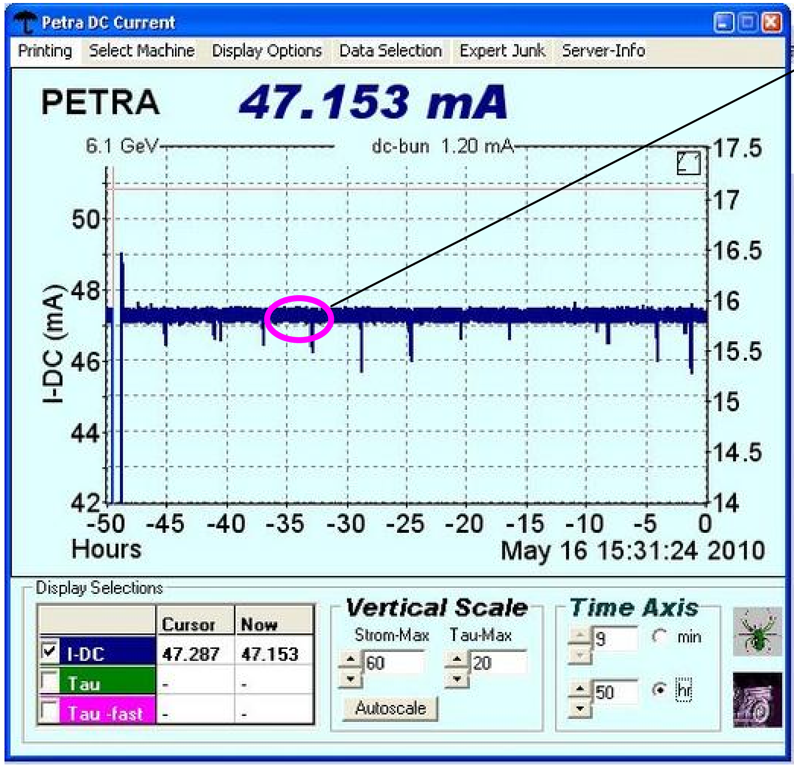
> Top-up
- Frequent filling of the machine to assure thermal equilibrium of components

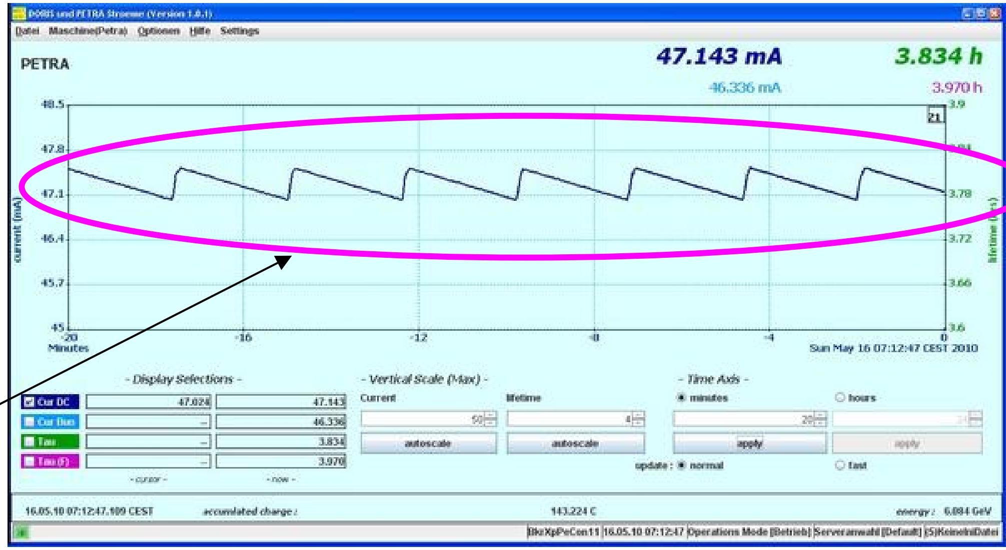
> Active measures
- Orbit-Feedback

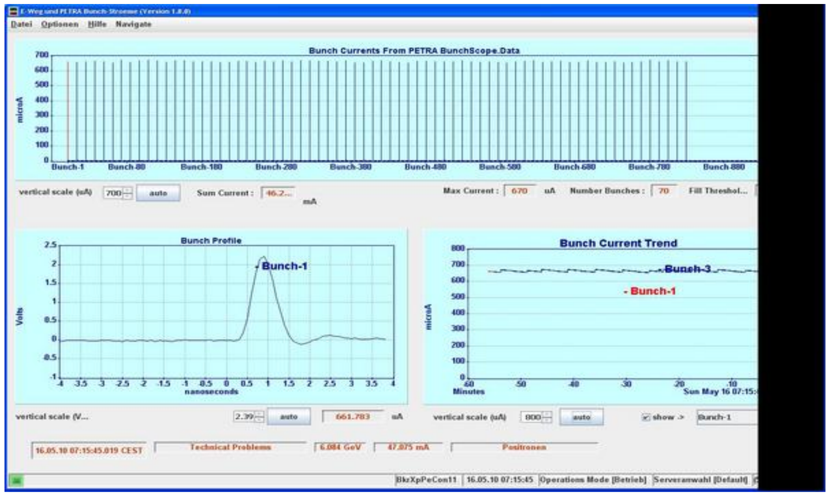
Top-up Operation

Automatic procedure
Keeps current constant on a
0.1 % - 1.0 % level

For example:
70 bunch filling
(At present standard filling for users)

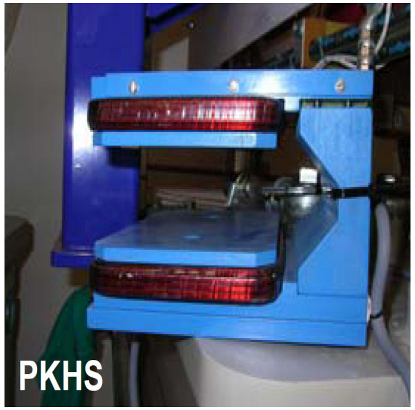






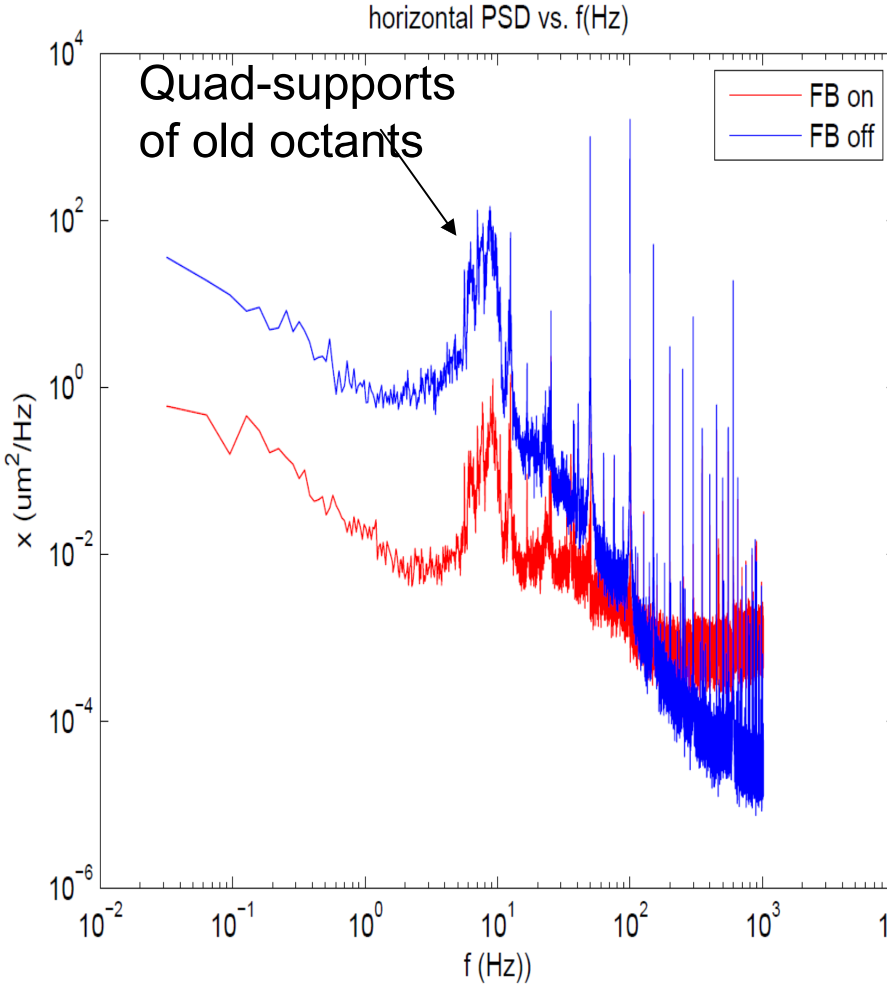
Orbit Feedback

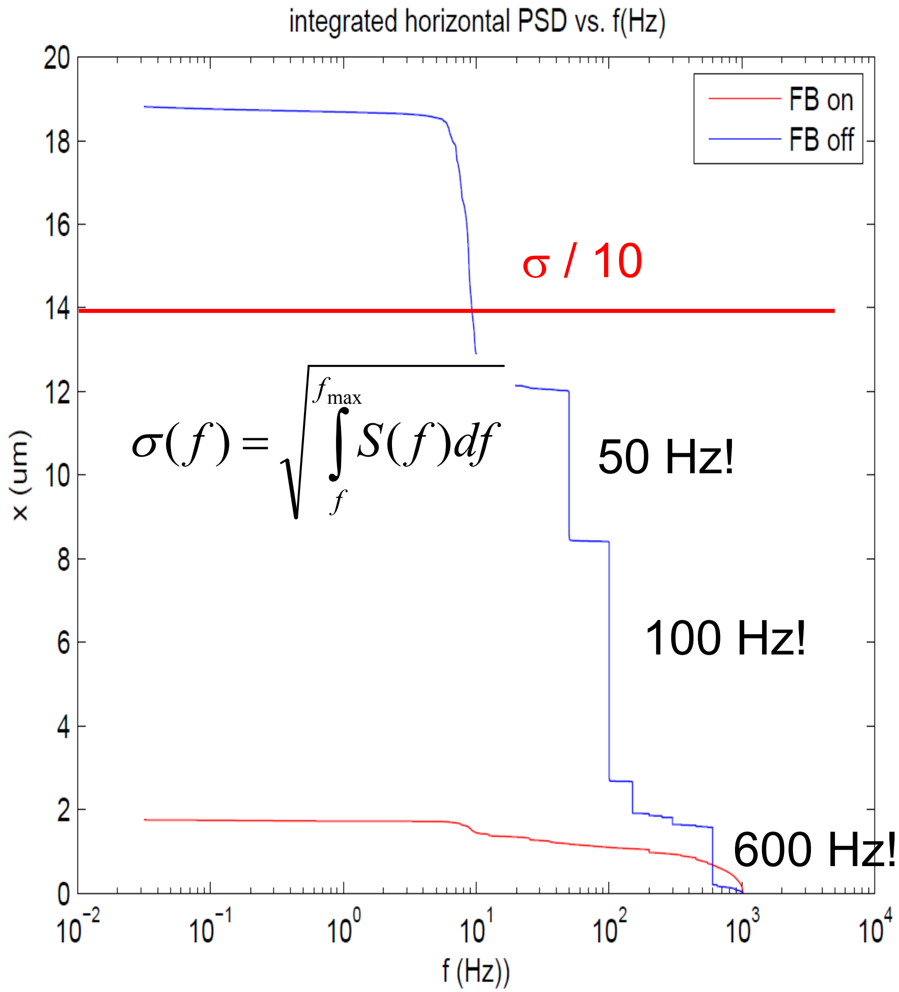
- PI controller & suppression n * 50 Hz
- Standard BPM electronics
  but special output port with higher data rate
- central processing via star structure
  positive feedback effect from DC up to 600 Hz



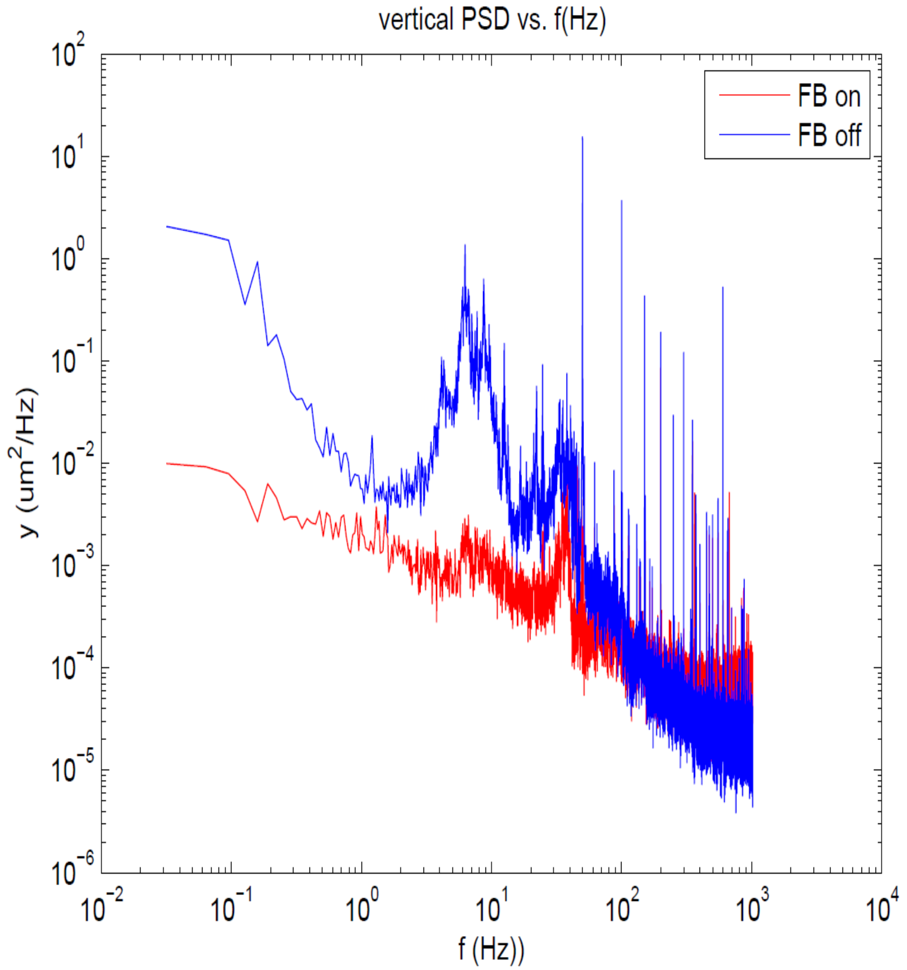
- Air coils
  Θmax ≈ 35 µrad
  # new part: 30 hor. & ver.
  # old part : 11 hor. & ver.
  mounted on stainless steel chambers

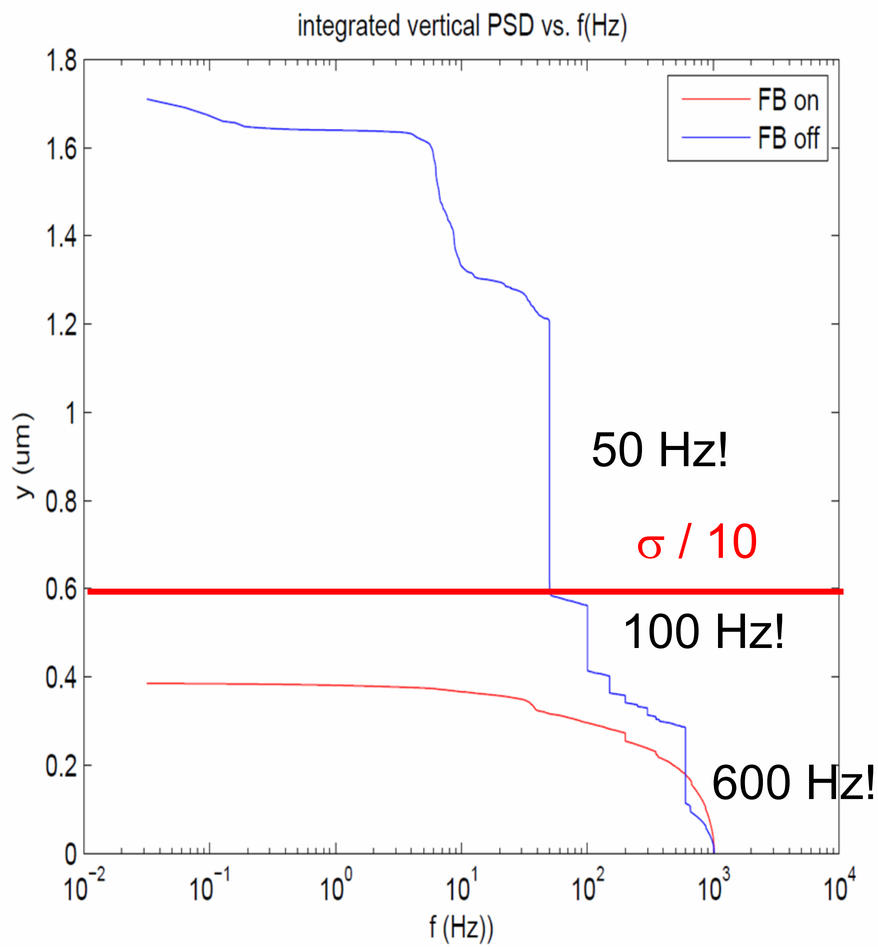
Horizontal Feedback (short term stability)





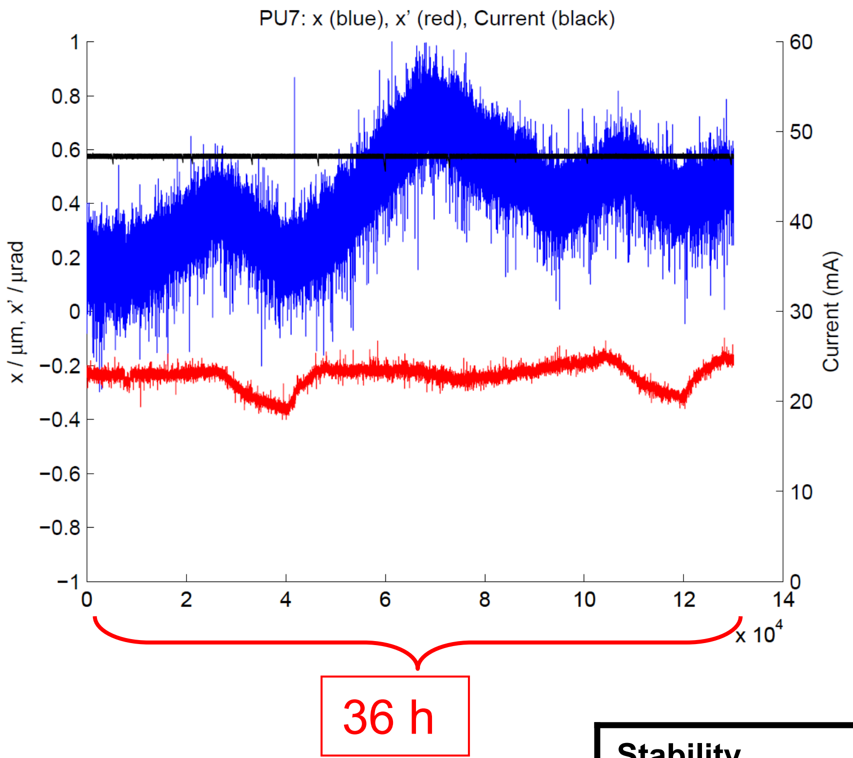
Vertikal Feedback (short term stability)

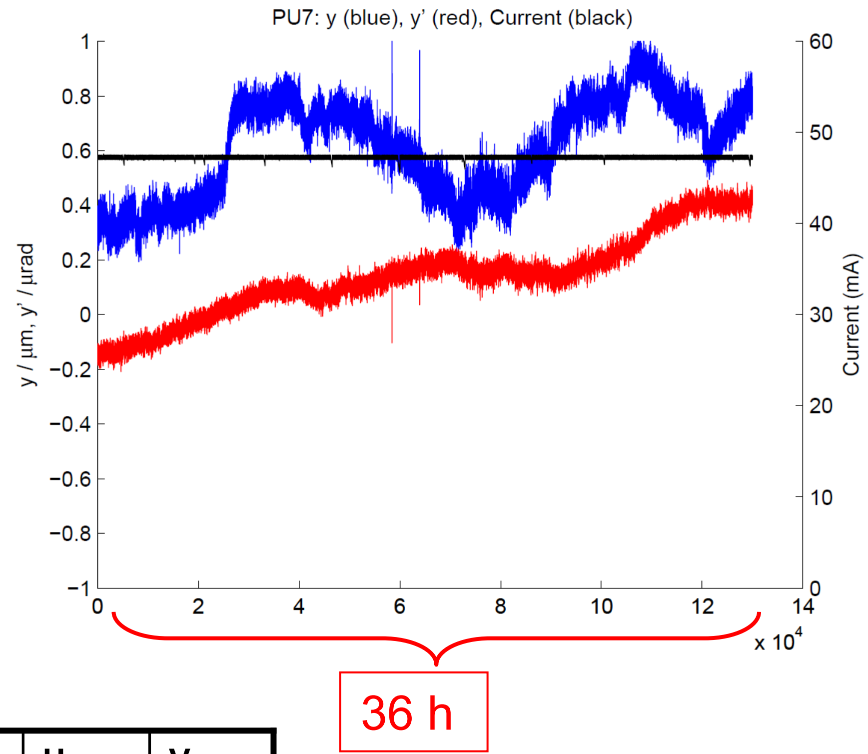




Long term stability

Stability of position and angle at PU7 (high beta cell)



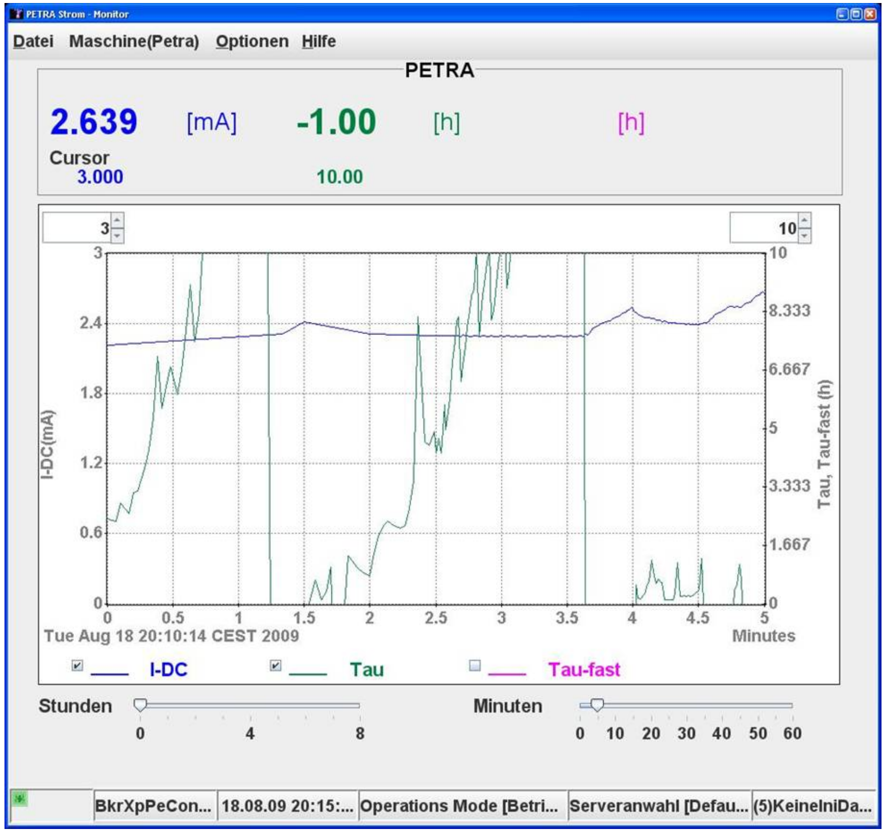


Stability requirements	Hor.	Ver.
Position (µm)	14	0.60
Angle (µrad)	6	0.24

Current limitations

Current limitations
single bunch (TMCI)

Design: 2.5 mA (100 mA in 40 bunches)



Measured coherent tune shift vs, current

$$\frac{\Delta f_x}{\Delta I} \approx -0.15 \frac{\text{kHz}}{\text{mA}} \qquad \frac{\Delta f_y}{\Delta I} \approx -1 \frac{\text{kHz}}{\text{mA}}$$

Determine kick parameters:

$$\frac{d}{d\,I} f = \frac{\langle \beta \rangle}{4\pi \; E/e} \; k_\perp$$

Kick parameter (V/pC/m)	horizontal	vertical
measured :	490	3420
calculated :	750	2600

Limit for 2.5 mA : 4800 V/pC/m

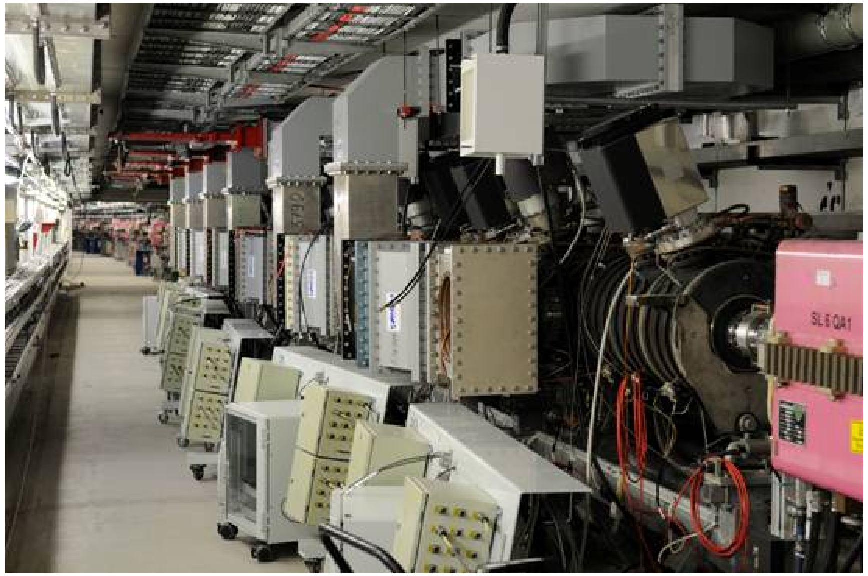
Single bunch intensities of up to 2.9 mA could be stored;
Deliberately limited at this current
In ordner not to damage BPM electronics

Details see WEPEA018

Current limitations
coupled bunch instabilities

> **Coupled bunch instabilities in PETRA II:**

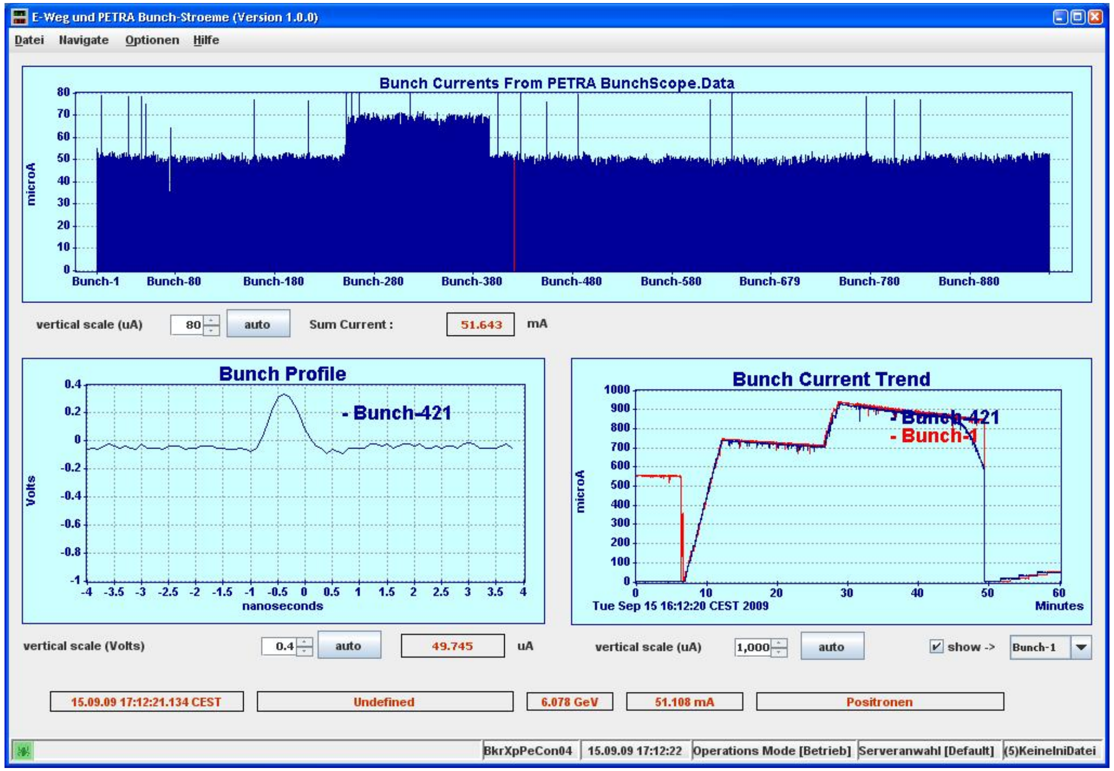
	longitudinal	horizontal	vertical
I_{thres} (mA)	7	6	6
$1/\tau$ (Hz)	35	50	60
Z_{eff}	3.6 MΩ	45 MΩ/m	54 MΩ/m



PETRA III: 12 seven cell cavities which large par. shunt impedance

→ powerful broadband (BW≥ 60MHz) feedback neccessary

Current limitations
coupled bunch



Design: 100 mA

achieved
70 bunches : 96 mA
240 bunches: 98 mA
960 bunches: 89 mA

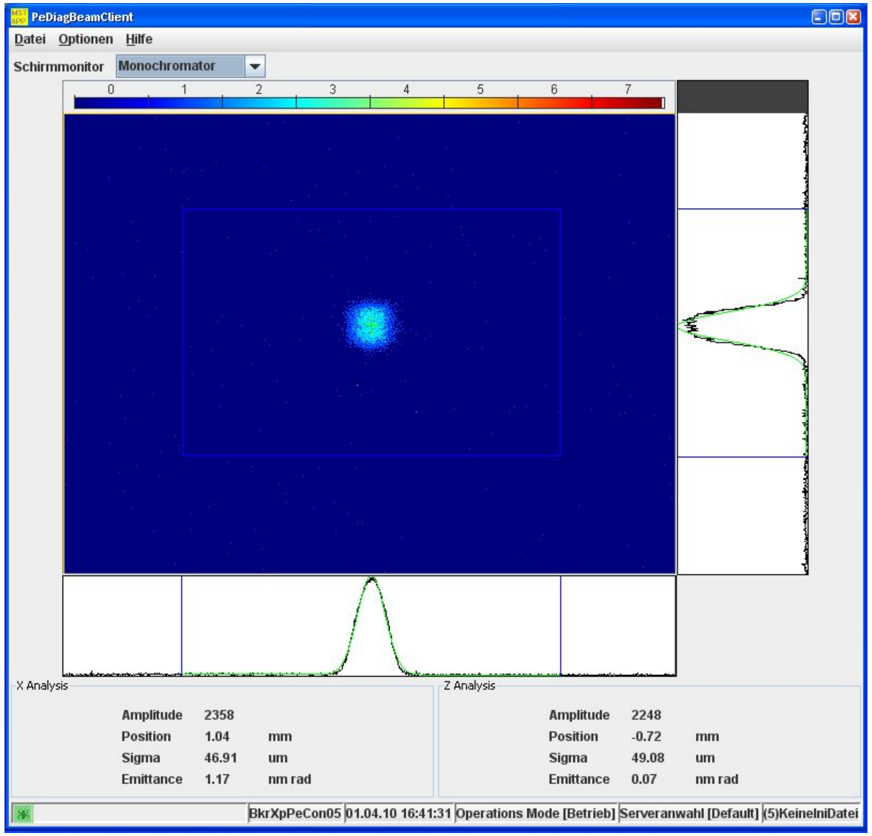
Transverse broadband FB is working well

Longitudinal FB: at least 5 out of 8 broadband amplifiers damaged October ‘09!
Probably amplifiers were destroyed during switch on!

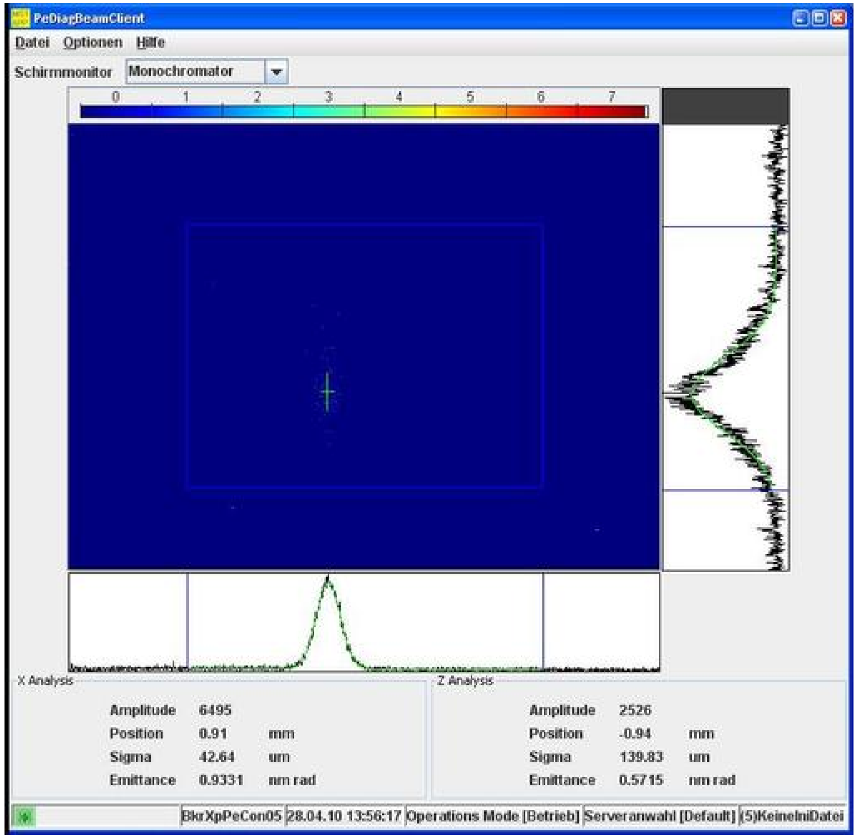
Successful tests with four repaired amplifiers in 2010

Vertical blow up (Operation with e+!)

50 mA in 70 bunches

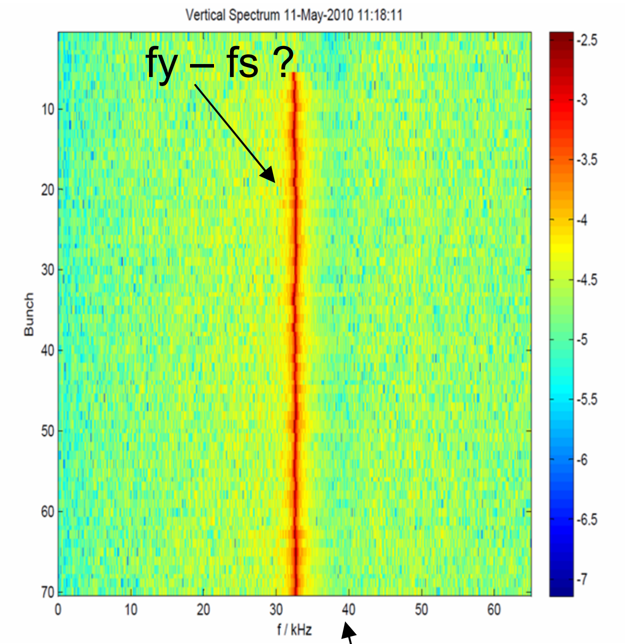


63 mA in 70 bunches



Vertical blow up (Operation with e+!)

70 bunche (Δt_B=96ns)
I = 55 mA

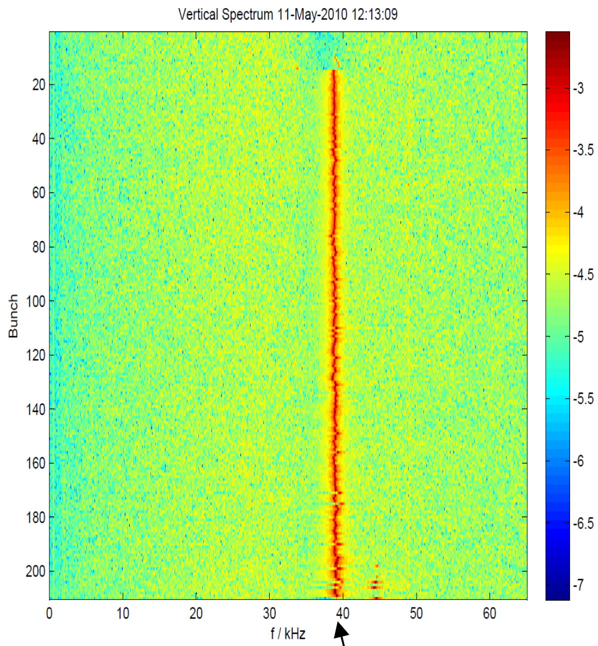


fy = 39 kHz

Remedy for 70 bunches:

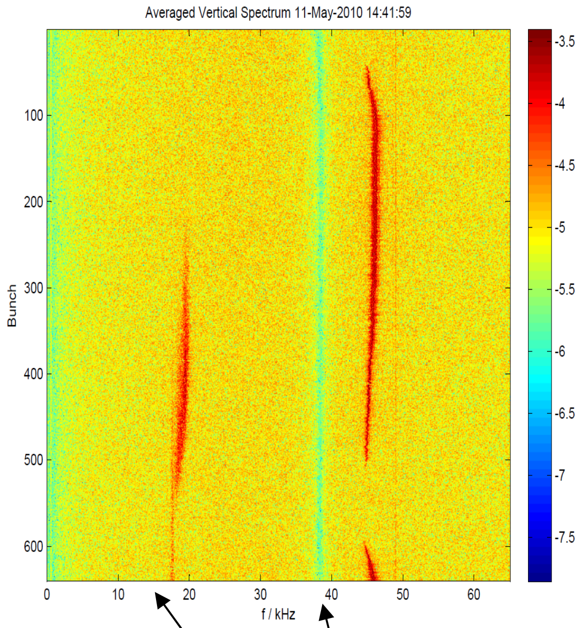
- $\xi \rightarrow +5$
- Increase Gain of vertical feedback by a factor of 4

210 bunche (Δt_B=32ns)
I = 74 mA



fy = 39 kHz

640 bunche (Δt_B= 8ns)
I = 64 mA



fx = 15 kHz

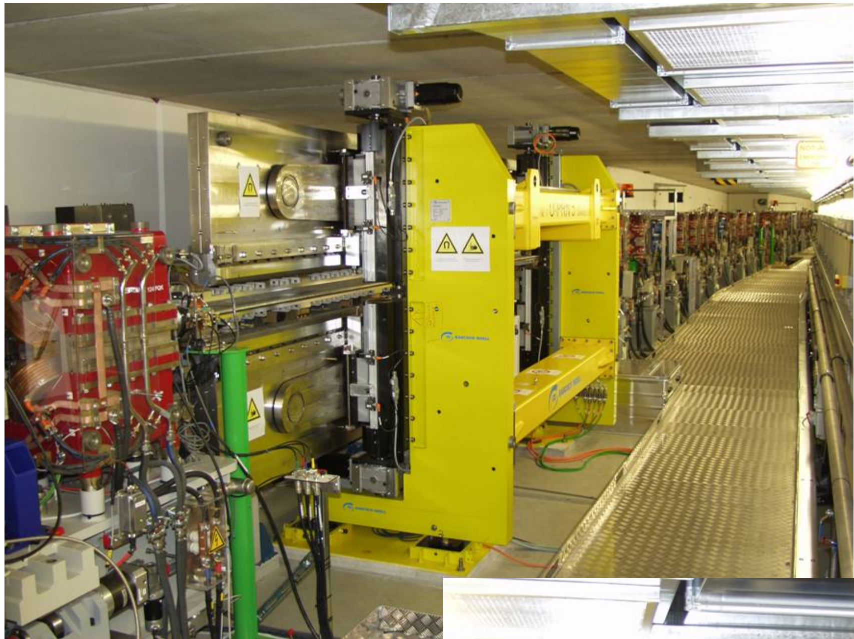
fy = 39 kHz

e – cloud ?

ID’s

Undulator Installation

Undulator PU 10



Undulator PU 8 & 9

Undulator PU 4

APPLE II

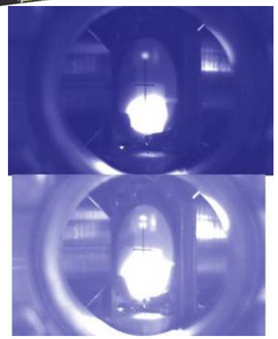
10 of 14 Undulators have been installed

ID types

	U29_5m	U29	U32	U23	UE65 *	U19	U32_10m
Minimum magnetic gap [mm]	9.5	9.5	9.5	9.5	11.0	7.0	12.5
Period length λ_U [mm]	29	29	31.4	23	65.6	19	31.4
Length L [m]	5	2	2	2	5	4	10
Periods	169	66	60	84	72	204	2x 156
Peak field B_0 [T]	0.81	0.81	0.91	0.61	1.03	0.7	0.68
Deflection parameter K_{max}	2.2	2.2	2.7	1.3	6.3	1.24	2.0
1st Harmonic E_1 [keV]	3.5	3.5	2.4	8.0	0.3	10.2	3.6
Total power P_{tot} [kW]	7.5	3.0	3.8	1.7	11.8	4.5	10.7
On-axis power density [kW/mrad^2]	190	76	80	71	0.17	200	300
Power in 1x1mm^2 at 40m [W]	119	47	49	44	0.1	122	185
High-β source (10keV)	size : 140 x 5.6 µm^2 divergence : 7.9 x 4.1 µrad^2						
Low-β source (10keV)	size : 36 x 6.1 µm^2 divergence : 28 x 4.0 µrad^2						

Beam-line Status 2009


First Light April 30



Start of beamline commissioning
July 17


First beam on diffractometer
September 27

First friendly users
October 5

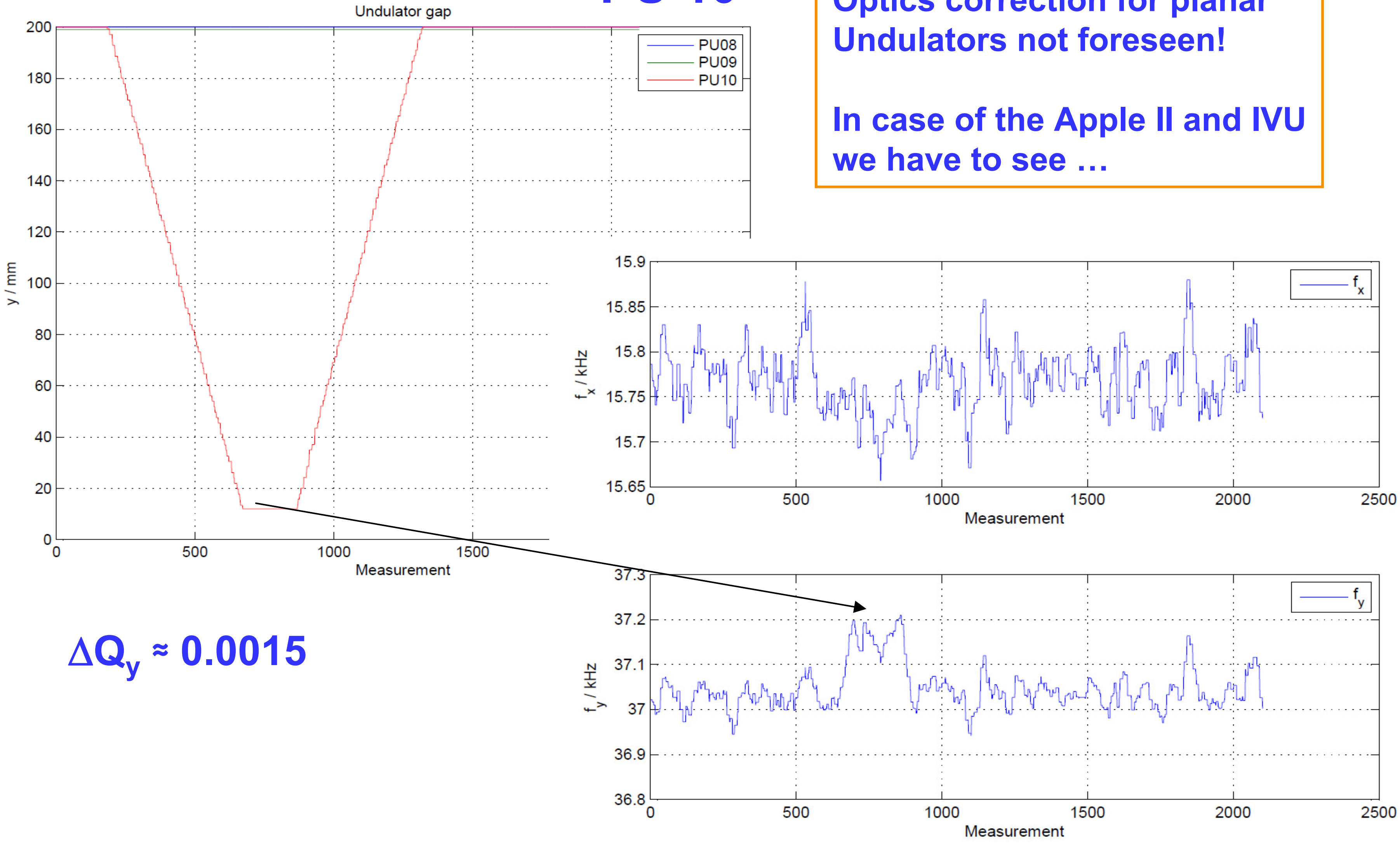
Beam - line	Beam hours ‘09
P08	1000
P09	1200
P10	200

Impact of IDs on tune /optics

PU 10

Optics correction for planar Undulators not foreseen!

In case of the Apple II and IVU we have to see …



$\Delta Q_y \approx 0.0015$

Beam-line status March 2010

Number	ID Type	Energy range (keV)	Status 2010	
			First half	Second half
P01	10 m U32 (pres. 2m)	5 – 40	commissioning	Friendly users
P02	2 m U23	20 – 100		commissioning
P03	2 m U29	8 – 25	commissioning	Friendly users
P04	5 m UE65 (APPLE)	0.2 – 3.0		commissioning
P05	2 m U29	8 – 50	commissioning	Friendly users
P06	2 m U32	2.4 – 50	commissioning	Friendly users
P07	4 m U19 (IV) (pres. 2m)	50 – 300	commissioning	Friendly users
P08	2 m U29	5.4 – 30	Friendly users	**Regular users**
P09	2 m U32	2.4 – 50	Friendly users	**Regular users**
P10	5 m U29	4 – 25	Friendly users	**Regular users**
P11	2 m U32	8 – 35		commissioning
P12	2 m U29	4 - 20		commissioning
P13	2 m U29	5 – 35		commissioning
P14	2 m U29	5 - 35		commissioning

High β_x
Low β_x

Summary

Parameter	Design	Achieved
Energy (GeV)	6	6
ε_x (nm rad)	1	1
ε_y (pm rad)	10	< 20
Current (mA)	100	98
# undulators	14	10

Regular user operation (4.5 d / week) with up to 60 mA works fine

Orbit stability:

short term stability okay

long term stability looks promising but more work required

Current:

more work required to raise current

and in particular to understand the vertical blow-up

Thank you
for your attention