PETRA III,
A New High Brilliant Light Source
At
DESY

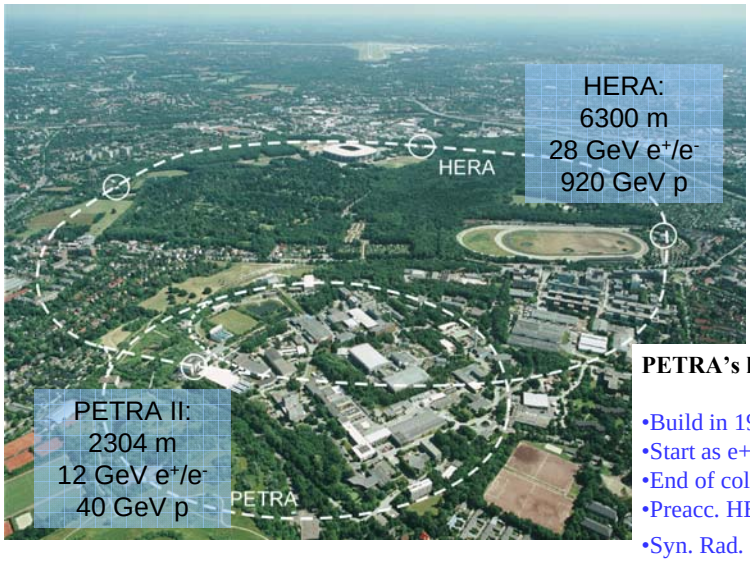
HELMHOLTZ GEMEINSCHAFT

Outline

DESY

- Objectives & Key parameters of PETRA III
- Basic layout of PETRA III
- Commissioning
  1. Linear Dynamics
     - Optics
     - Dispersion
     - Orbit stability
  2. Nonlinear dynamics
     - Aperture
     - Momentum acceptance
  3. Current limitations
     - Single bunch
     - Multi-bunch
  4. Vacuum conditioning
  5. Insertion devices
- Summary & Schedule

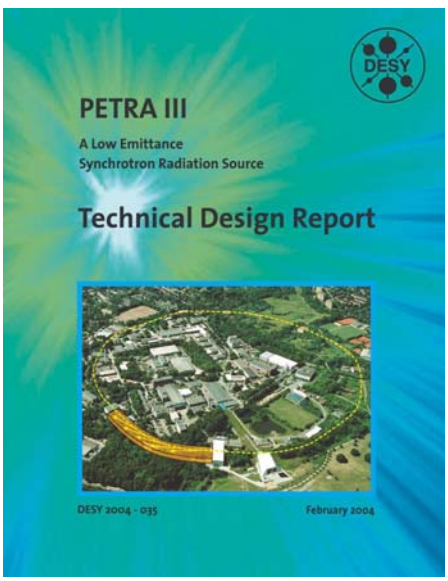
Once upon a time …



PETRA's history

- Build in 1976
- Start as e+e- coll. 1978
- End of coll. 1986
- Preacc. HERA since 1988
- Syn. Rad. Fac. since 1995

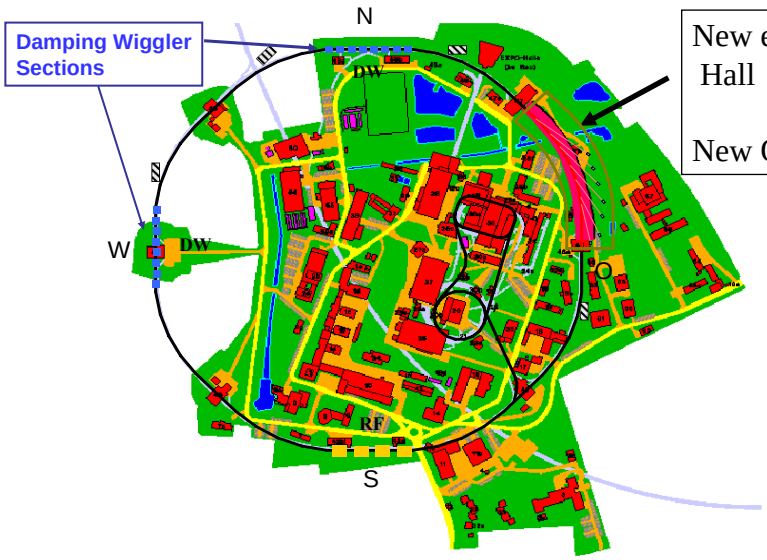
PETRA III



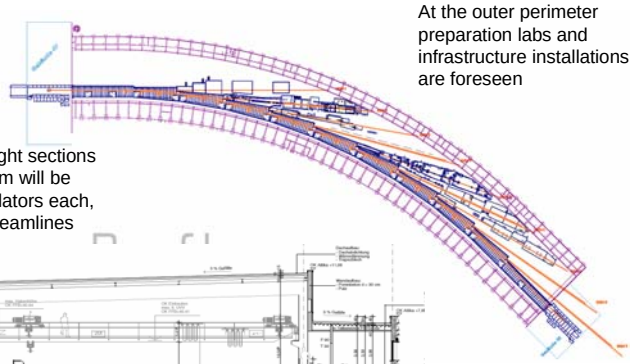
Parameters:

- **circumference: 2304 m**
- **energy: 6 GeV**
- **emittance: 1 nmrad**
- **emittance coup.: 1% (10 pmrad!)**
- **current: 100 (200) mA**
- **# bunches 40 / 960**
- **Limited budget (~ 150 M€)**
- **straight sections: 9**
- **undulators: 14**
- **undulator length: 2, 5, 10 (20) m**

PETRA III

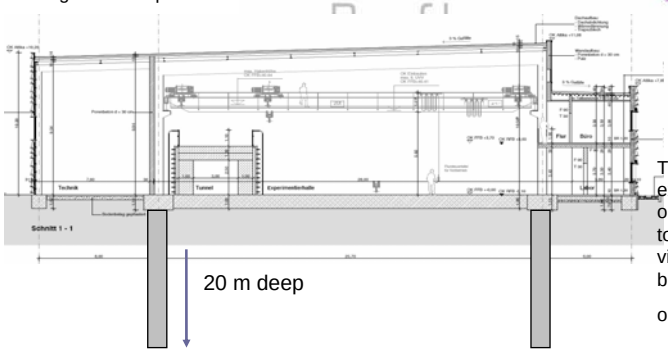


Layout of the new hall



At the outer perimeter preparation labs and infrastructure installations are foreseen

PETRA III will provide 9 straight sections for insertion devices. 5 of them will be equipped with 2 canted undulators each, resulting in 14 independent beamlines

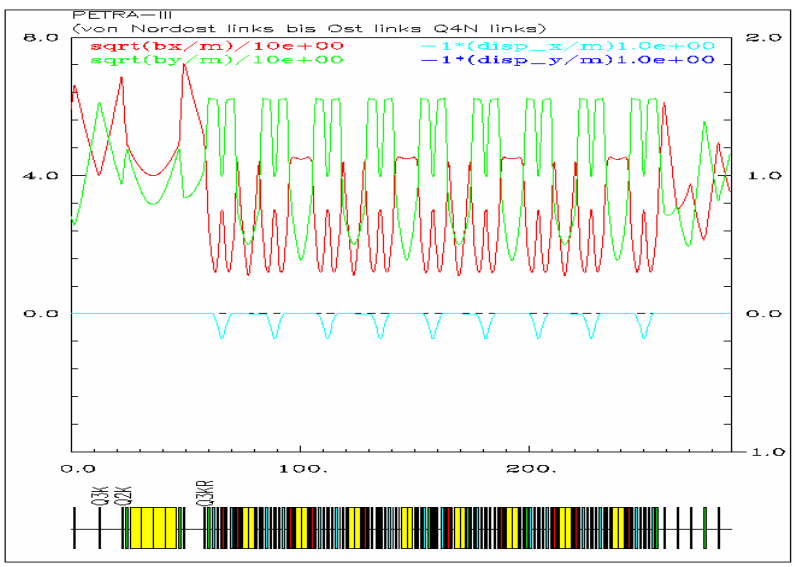


The ring tunnel and the experimental floor are founded on a **1 m thick slab of concrete** to minimize vibrations. For vibrational decoupling, the builiding superstructere rests

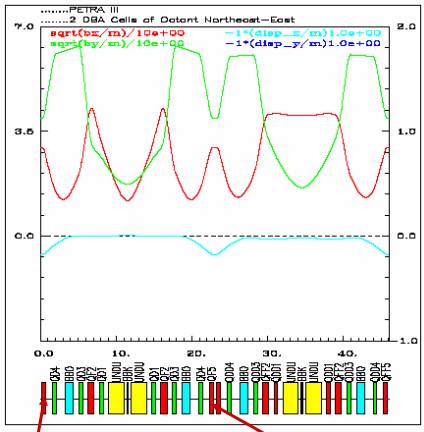
on **20 m long sleeved piles**

New Experimental Hall

PETRA III
Optics of New Octant



Optics New Octant: DBA Cells



Length of DBA cell 23 m

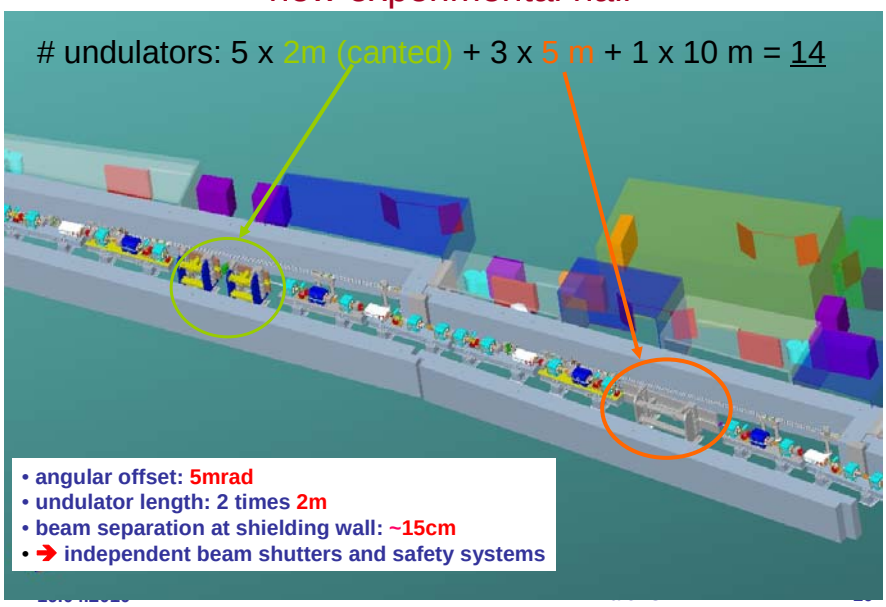
Design requirements (users):
- 5 m long straights
- low and high β_x

Design constrains (machine):
- low ξ, low ε

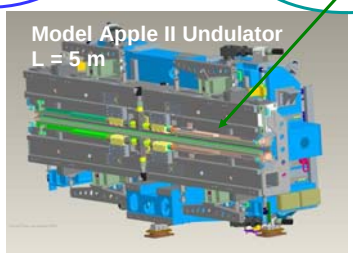
Design consequences:
- D_x small => no sextupoles

Beam sizes at ID positions:
- Horizontal: 35-150 µm
- Vertical: ≈ 5 µm

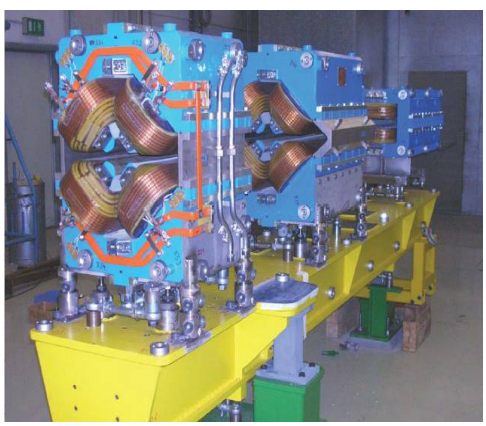
PETRA III
new experimental hall



Aufbau DBA Zelle (# 8)



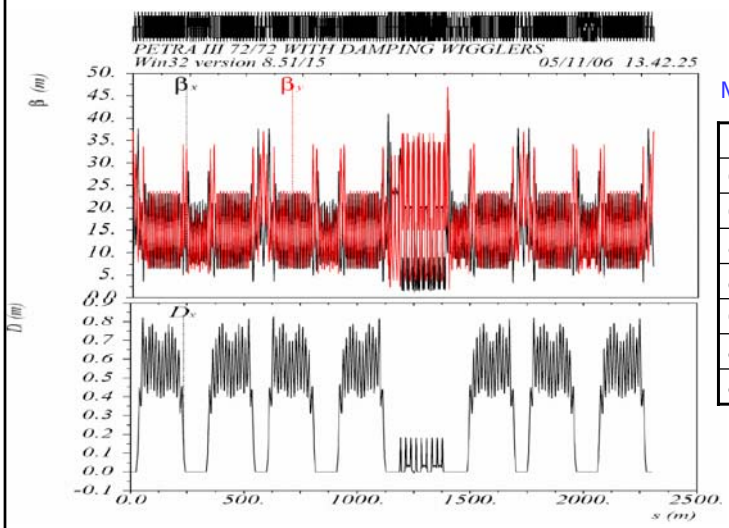
Girder: alignment & fixation



Alignment concept ready and verified:
Alignment within 50 µm

After alignment
Magnets are glued to girder

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	$1.3*10^{-3}$

PETRA III :damping wiggler

ε_x: 4.5 → 1 nmrad

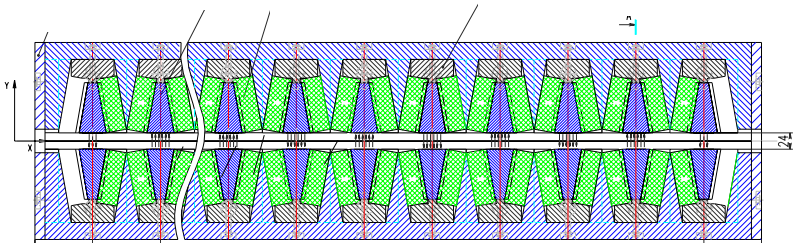
Damping wiggler sections

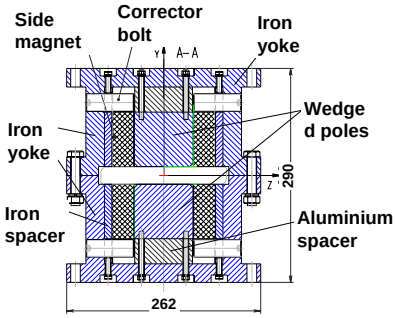
Collaboration with BINP

Damping wigglers

- **B = 1.5 T**
- **λ = 0.2 m**
- **h = 0.025 m**
- **L_{tot} = 80 m (2x40m)**

Damping Wigglers

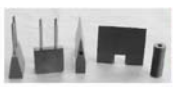




- **Modified hybrid structure**
  poles also powered from aside
- **Iron plates enclose the whole structure**
  act as magnetic yoke on zero magnetic potential
  serve as mech. support for magnetic assembly
- **compact, and mechanically stable design**
  cross section ~ 260 × 290 mm^2
- **easy and cheap**

Wiggler Magnets

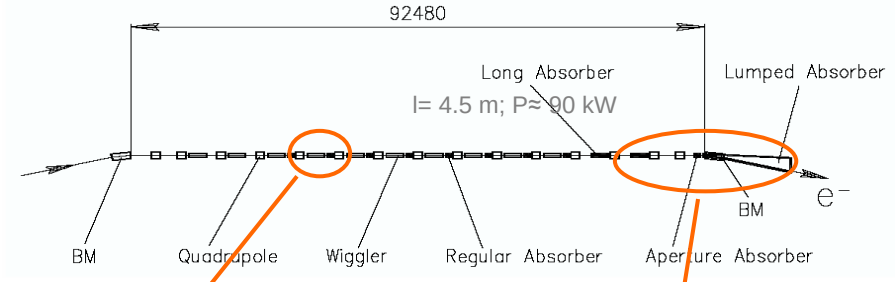
Magic fingers
To adjust field
qualtity

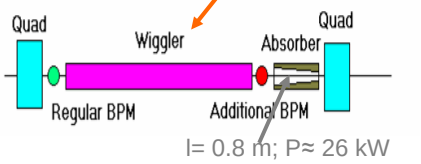


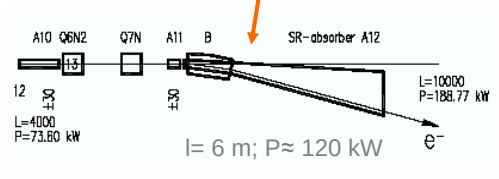
Wigglers can be
Opened and closed
With special tooling

Wiggler Section

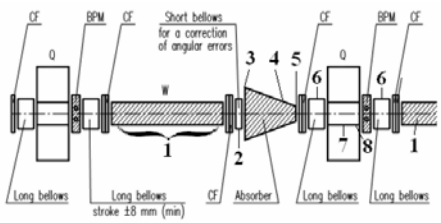
440 kW @ 200 mA, ε_c=36 keV
Opening angle: 5 mrad horizontal, 0.085 mrad vertical

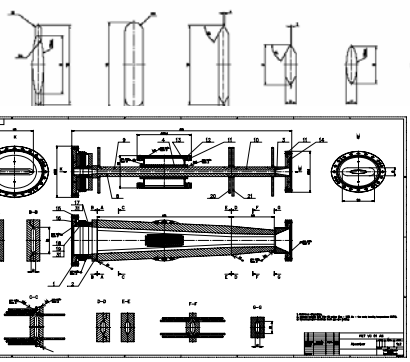


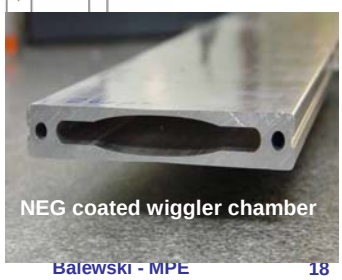




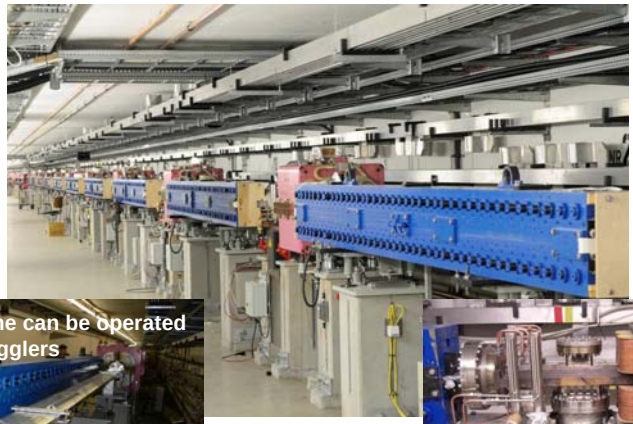
Vacuum: Standard cell





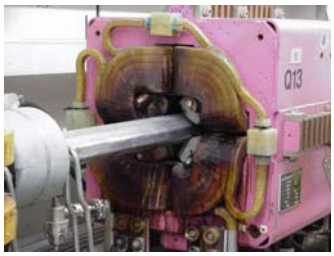


Damping Wiggler Sections
regular cells



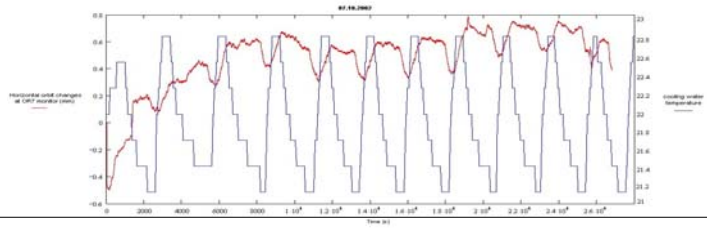
Damping Wiggler Sections

PETRA III
Modernization & refurbishment



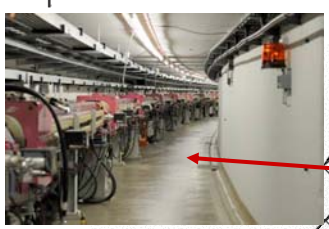
New coils

New cooling

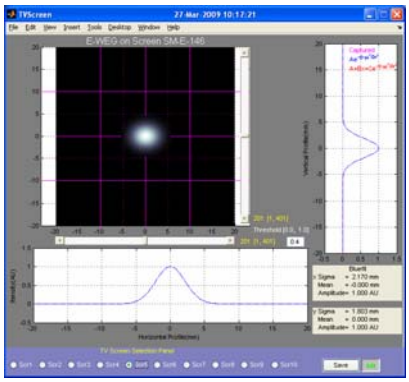


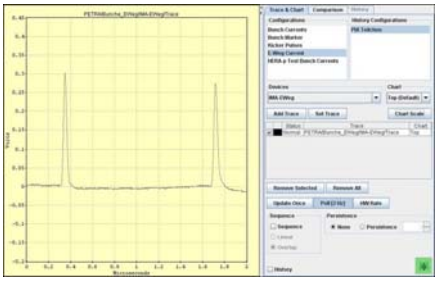
New power supplies, new control system, new vacuum system,...

PETRA III



Start of Commissioning end of March 2009
Transfer line



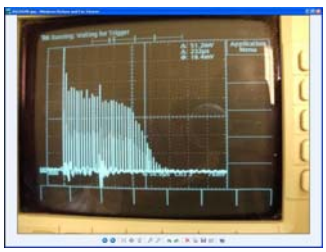


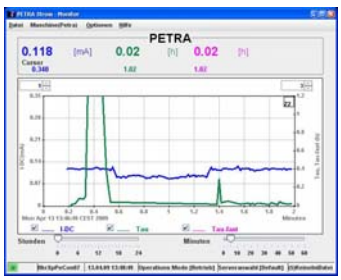
First beam through transferline on 24.03

Optics about correct, i.e. measured profiles agree with theoretical within 10%

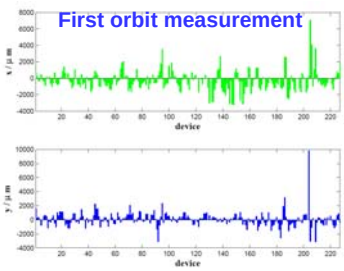
Stored beam

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





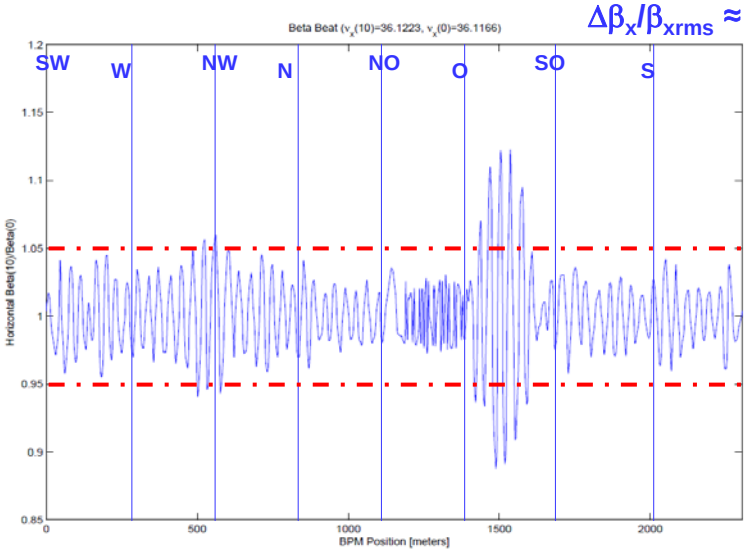
First orbit measurement



Linear Optics

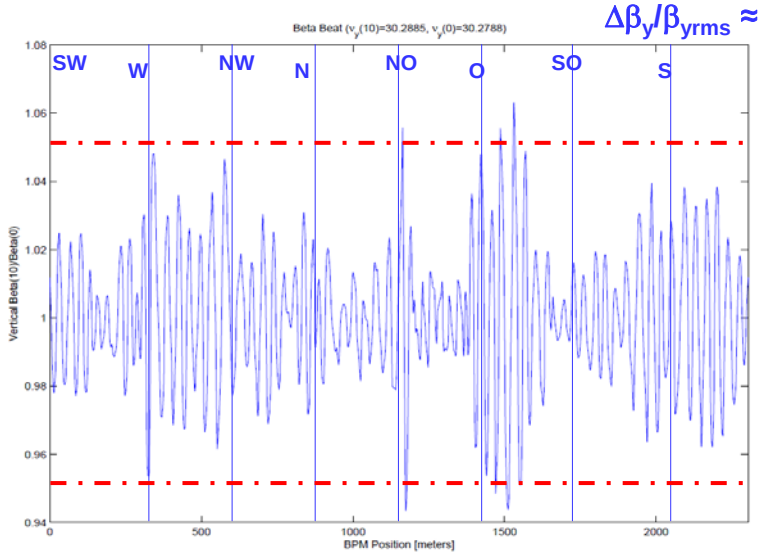
Beta beating horizontal (2nd iter.)

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

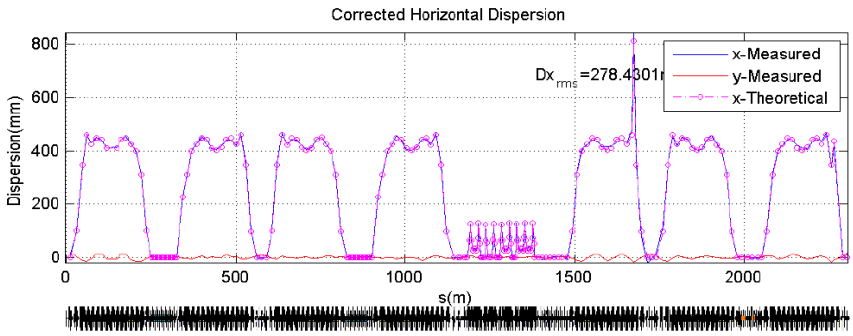


Beta beating vertical (2nd iter.)

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



Dispersion



Spurious vertical dispersion in Damping wiggler sections ≈ 1mm

Emittance

Emittance Measurement

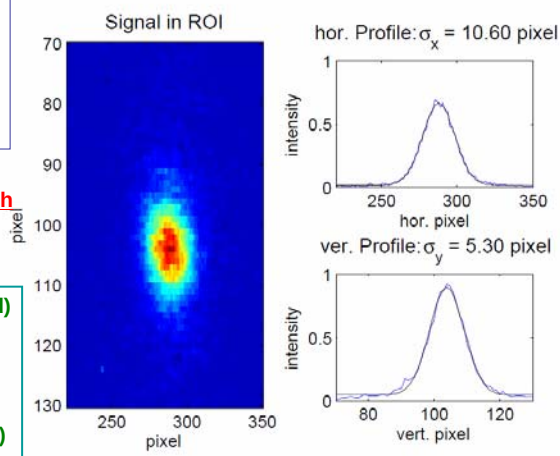
Calculated horizontal width: $\sigma_x \approx 44$ µm

Calculated emittance $\varepsilon_x \approx 0.9$ nm rad

- lousy lifetime
- for I = 1.4 mA => t = 1.5h

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

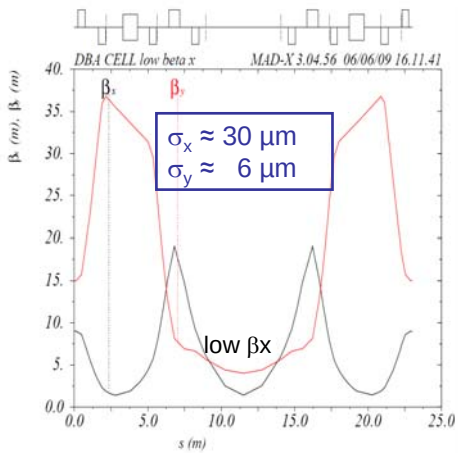
Expected emittance (no ID's)
$\varepsilon_x \approx 1.06$ nm rad

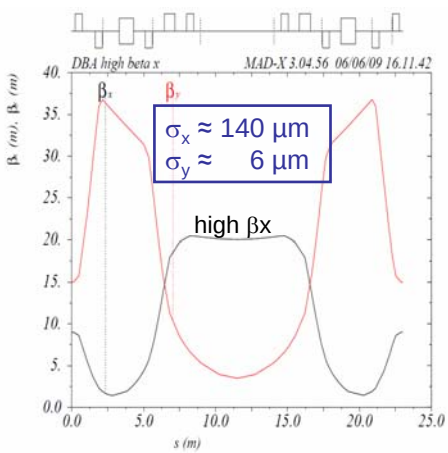


Orbit Stability

Stability Requirements

ε_x = 1 nm rad; κ = 0.01





Stability requirements:

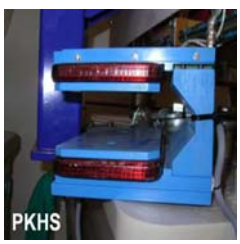
horizontal: 3.0 µm
vertical : 0.6 µm

horizontal:14.0 µm
vertical : 0.6 µm

Orbit Stabilization

- Passive measures
  - Suitable girders
  - Air-conditioning of the new tunnel: ± 0.1° !
  - Foundation of the exp. hall
- Active measures
  - Orbit-Feedback
- Top-up
  - Frequent filling of the machine to assure thermal equilibrium of components

Magnets for Orbit Feedback



Air coils for new Octants
PKHS ca. 37
PKVS ca. 37
Θmax ≈ 35 µrad

Air coils mounted on stainless steel chambers

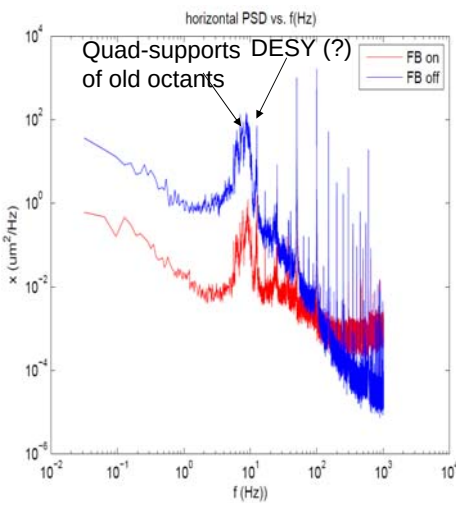
cos – ϕ coils for old octants
ca. 11 per plane
Θmax ≈ 35 µrad

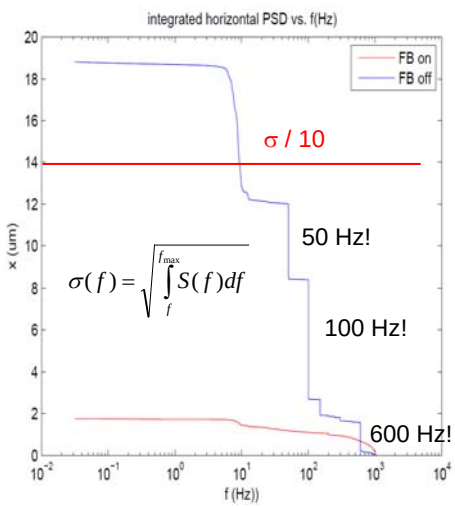
Status orbit feedback

- air coils installed in tunnel
- installation of electronics in climatized huts

- first version of software ready

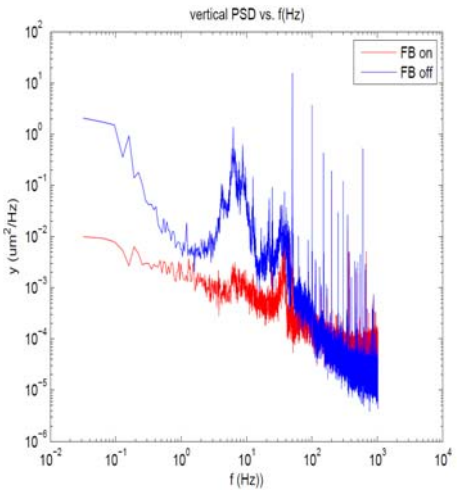
Horizontal Feedback

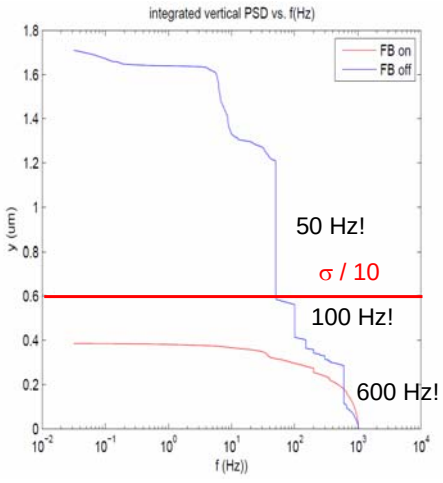




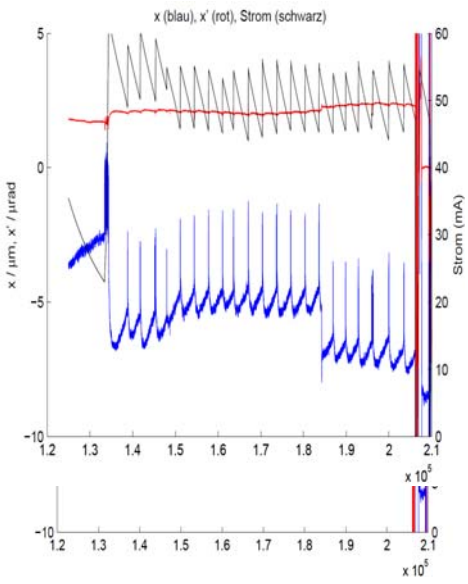
$$\sigma(f) = \sqrt{\int_{f}^{f_{max}} S(f)\,df}$$

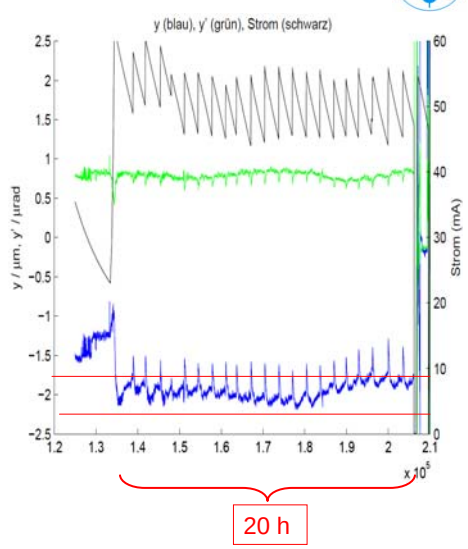
Vertikal Feedback



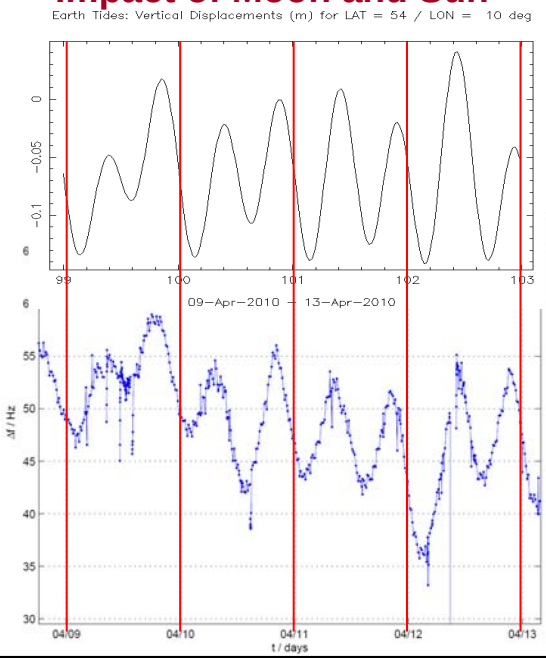


Long term stability





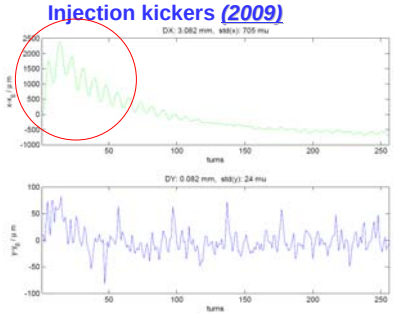
Impact of Moon and Sun



Top-up

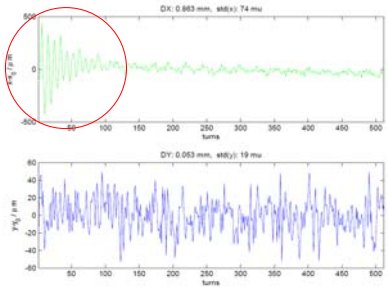
Preparation for top-up
closure of kicker bump & septum stray field

Orbit oscillations (2mm) due
To stray field of septum and
Injection kickers *(2009)*



► Dump of the beam by MPS

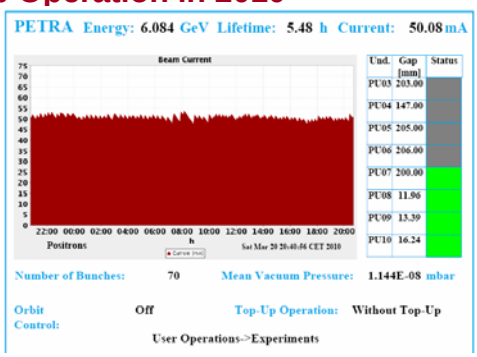
Orbit oscillations (≈0.1 mm) due
To stray field of septum And
injection kickers *(2010)*



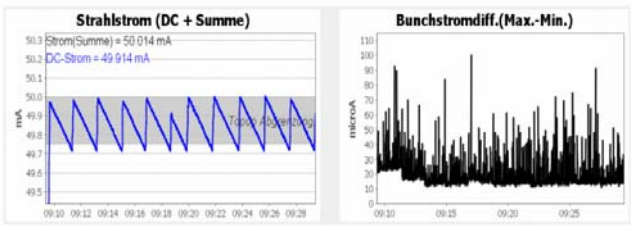
Septum has been replaced during winter shut down

Top-up Operation in 2010

70 bunch filling
Injection with ID's closed
Intensity kept constant manually

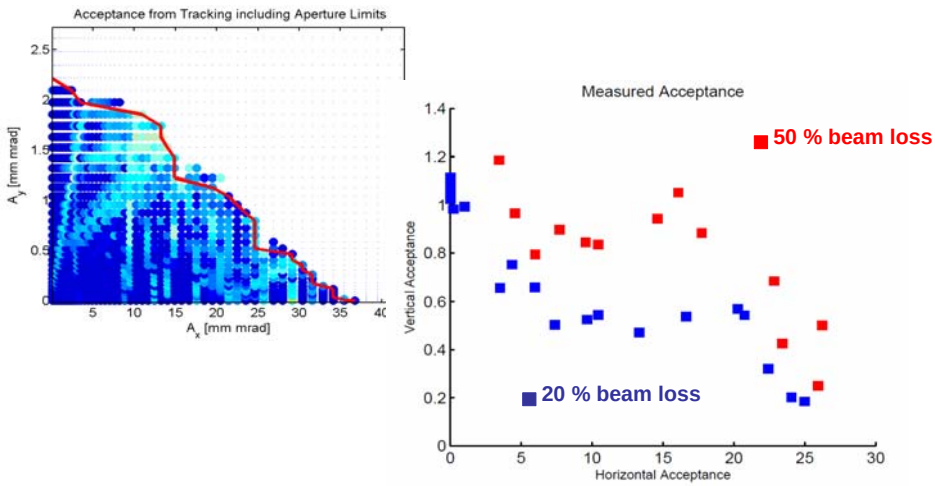


First tests of an automatic
Procedure
70 bunch filling

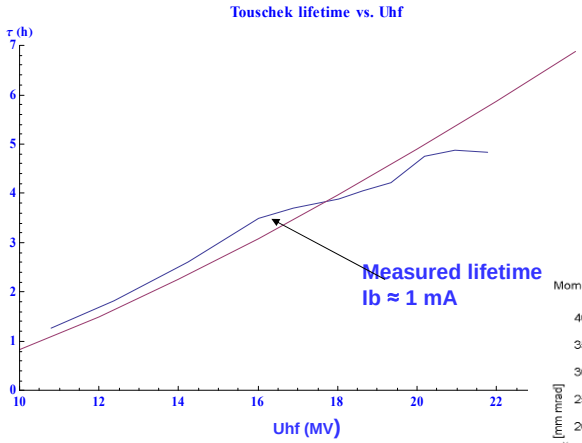


Off- and on-momentum Aperture

Acceptance



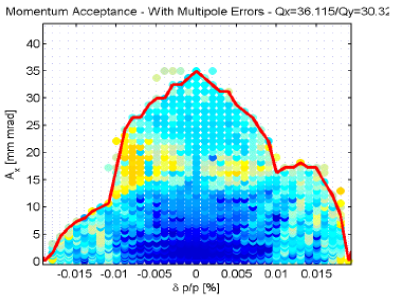
Momentum acceptance



Calculated Touschek Lifetime (MAD)
ε_x = 0.9 nmrad
ε_y = 13 pmrad

Measured lifetime
Ib ≈ 1 mA

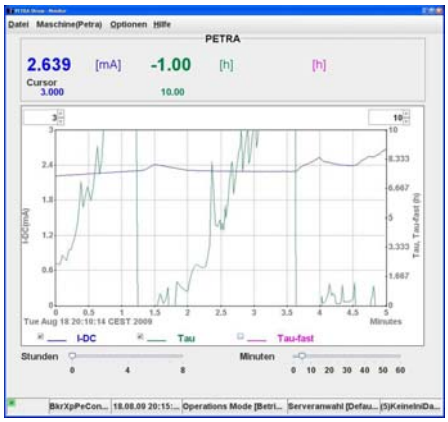
Calculated acceptance
About 1.7 %



Estimated momentum acceptance about 1.6 %

Current limitations

Current limitations single bunch



Measured coherent tune shift

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

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

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

Limit for 2.5 mA : 4800 V/pC/m

Design: 2.5 mA (100 mA in 40 bunches)

PETRA III current limitations

- **Multibunch instabilities in PETRA II:**

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

PETRA III: 12 instead of 16 cav. & larger long. (radiation) damping

→ powerful broadband (BW≥ 60MHz) feedback neccessary

Status
Multibunch Feedback

- Transverse Feedback (BW = 62.5 MHz)
  - 2 horizontal and 2 vertical kickers
  - Total Power: horizontal 1 kW and vertical 1 kW
- Longitudinal Feedback (BW = 62.5 MHz)
  - 8 Daphne like Cavities
  - Total Power: 4 kW
- PETRA II MB-Feedback reinstalled to ease commisioning


Feedback hut Hall east


old Feedback kicker


new Feedback kicker


Cavities for longitudinal feedback

Current limitations
coupled bunch

Design: 100 mA

achieved
70 bunches : 75 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!

Succesful tests with four repaired amplifiers in 2010

ID's

Undulator Installation

Undulator PU 10

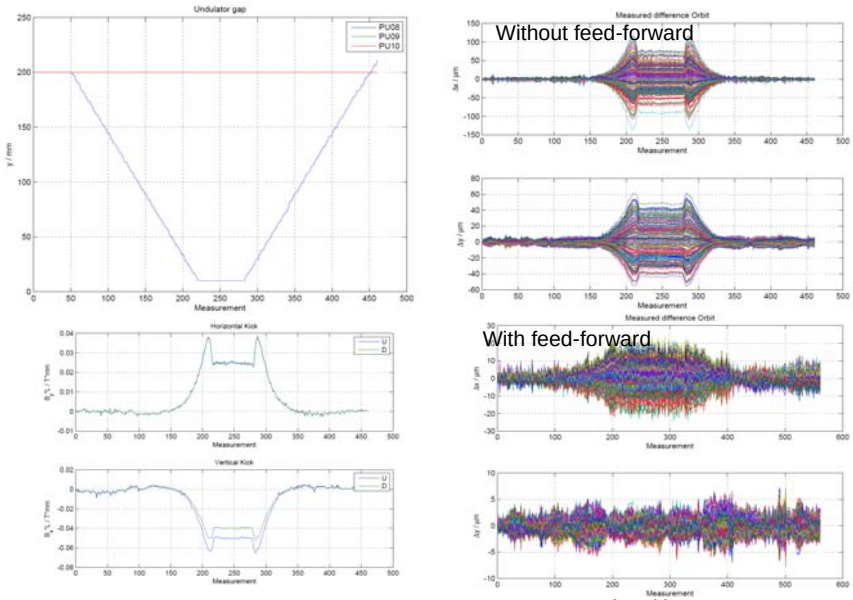
Undulator PU 8 & 9

Undulator PU 4

APPLE II

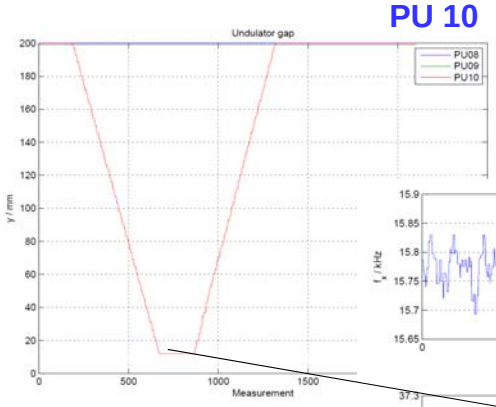
10 of 14 Undulators have been installed

Impact of ID's
PU 8 wo / w feed-forward tables



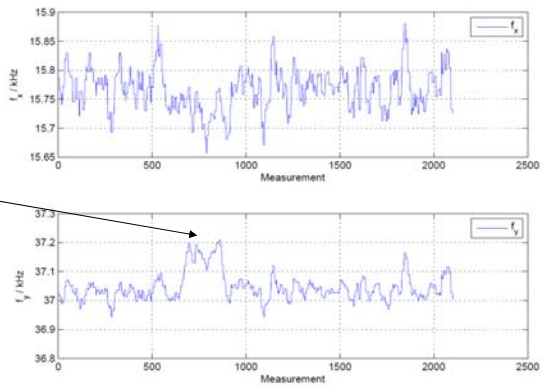
Impact of ID's on tune /optics

PU 10



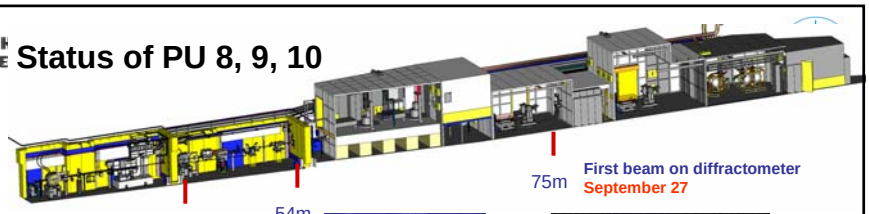
Optics correction for planar Undulators not foreseen!

In case of the Apple II we have to see …

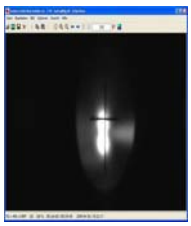


$\Delta Q_y \approx 0.0015$

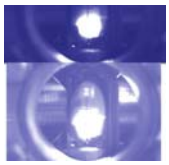
Status of PU 8, 9, 10



47m



54m



Start of beamline commissioning
July 17

75m

First beam on diffractometer
September 27

First Light
April 30

First friendly users
October 5

Operation with currents
Up to 35 mA

Beamlines status March 2010

	Status	first light on optics	first light on sample	beam hours 2009	1st half 2010	2nd half 2010
P01	installation of media	April-10				friendly users
P02	planning	August-10				
P03	commissioning	March 18, 2010				friendly users
P04	installation of hutches	August-10				
P05	installation of experiments	December 17, 2009				friendly users
P06	installation of media	December 17, 2009				friendly users
P07	commissioning	December 1, 2009	March-10			friendly users
P08	commissioning	October 5, 2009	October 20, 2009	1000	friendly users	regular users
P09	commissioning	July 17, 2009	September 27, 2009	1200	friendly users	regular users
P10	commissioning	September 18, 2009	December 11, 2009	200	friendly users	regular users
P11	installation of media	June-10				
P12	installation of media	June-10				
P13	planning	October-10				
P14	planning	September-10				

HELMHOLTZ GEMEINSCHAFT

DESY

Summary

HELMHOLTZ GEMEINSCHAFT

DESY

Summary

Parameter	Design	Achieved
Energy (GeV)	6	6
ε_x (nm rad)	1	1
ε_y (pm rad)	10	< 20
Current (mA)	100	98
Orbit stability	10% of beam size	X okay Y okay
# undulators	14	10

Machine Operation and Maintenance

Commissioning	18.02.10 - 01.03.10	10 days
1. Beamtime	01.03.10 - 22.03.10	22 days
Machine Studies/Maintenance	22.03.10 - 29.03.10	7 days
2. Beamtime	29.03.10 - 03.05.10	35 days
Machine Studies/Maintenance	03.05.10 - 10.05.10	7 days
3. Beamtime	10.05.10 - 14.06.10	35 days
Machine Studies/Maintenance	14.06.10 - 21.06.10	7 days
4. Beamtime	21.06.10 - 26.07.10	35 days

Beamtime: Fr **,**Sa, Su, Mo, Tu early *Hasylab* / Tu late, We, Th *Machine*

Thank you for your attention