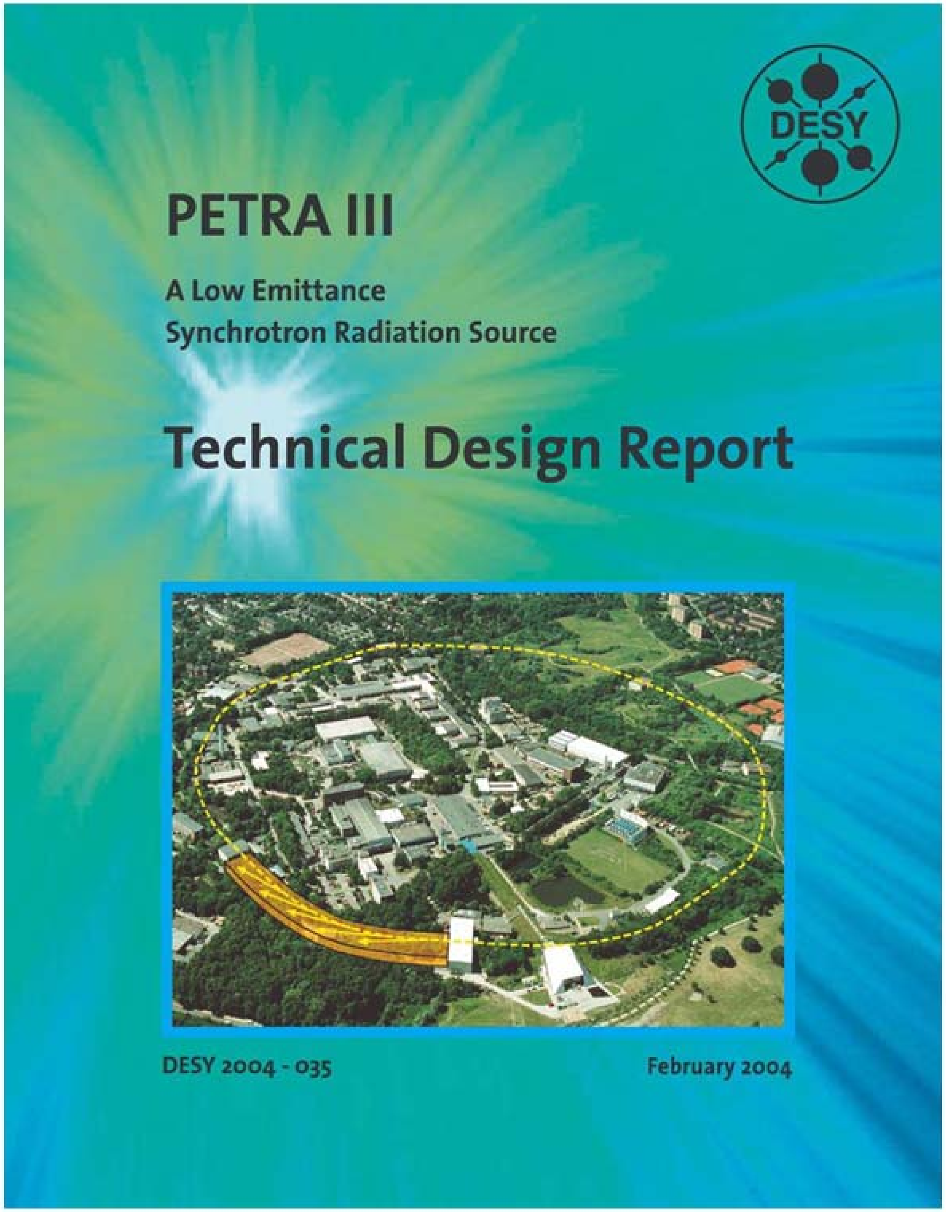
Commissioning Results of Beam Diagnostics for the PETRA III Light Source

K. Balewski et al.

Outline

- PETRA III – Introduction
- Commissioning
  - Transfer line
  - Storage ring
- Commissioning of
  - Monitoring the position of BPMs
  - Temperature sensors
- Outlook
  - Emittance measurement

PETRA III



Parameters:

- circumference: 2304 m
- energy: 6 GeV

- emittance: 1 nmrad
- emittance coup.: 1% (10 pmrad!)

- current: 100 (200) mA
- # bunches 40 / 960

- straight sections: 9
- undulators: 14
- undulator length: 2, 5, 10 (20) m

- supplement to X-FEL
- → cost effective!

PETRA III Introduction

Damping wiggler sections

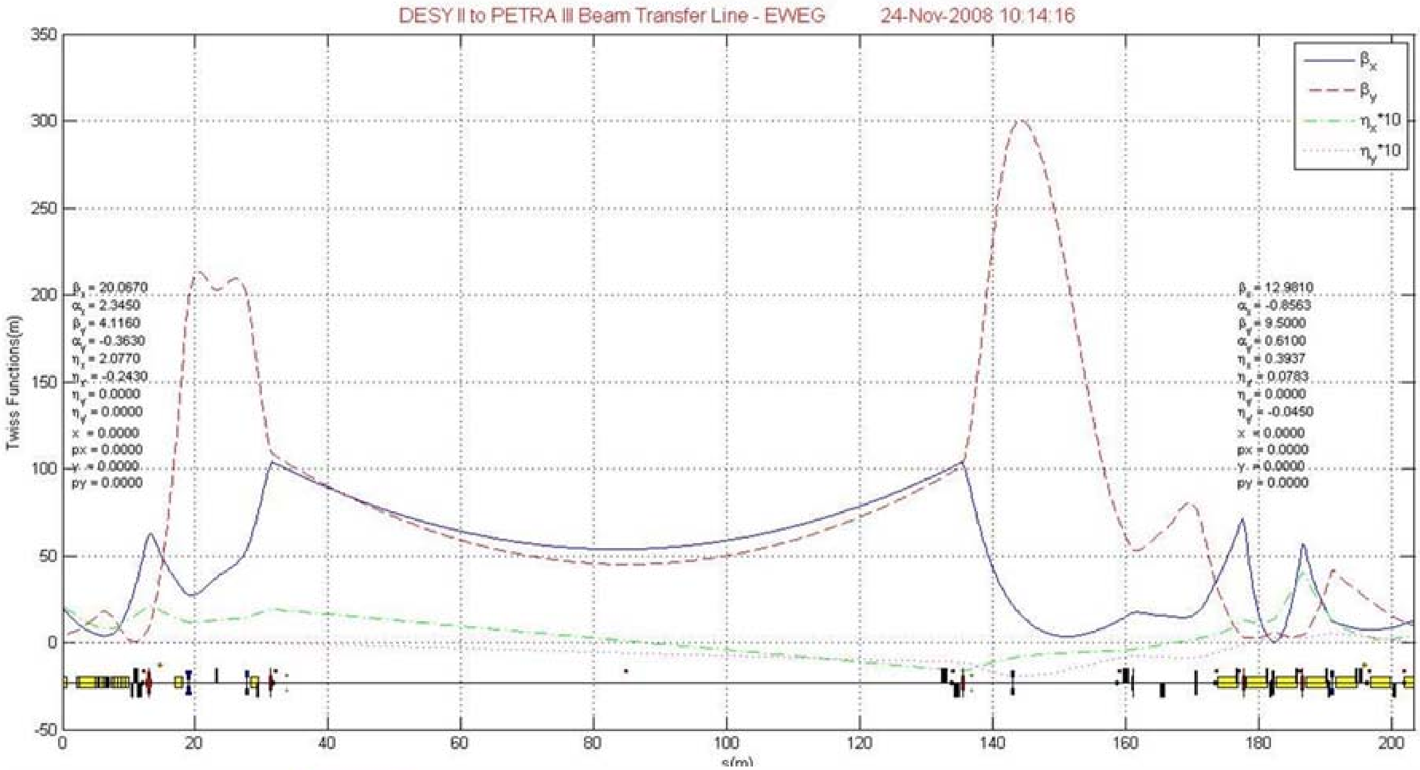
New experimental hall

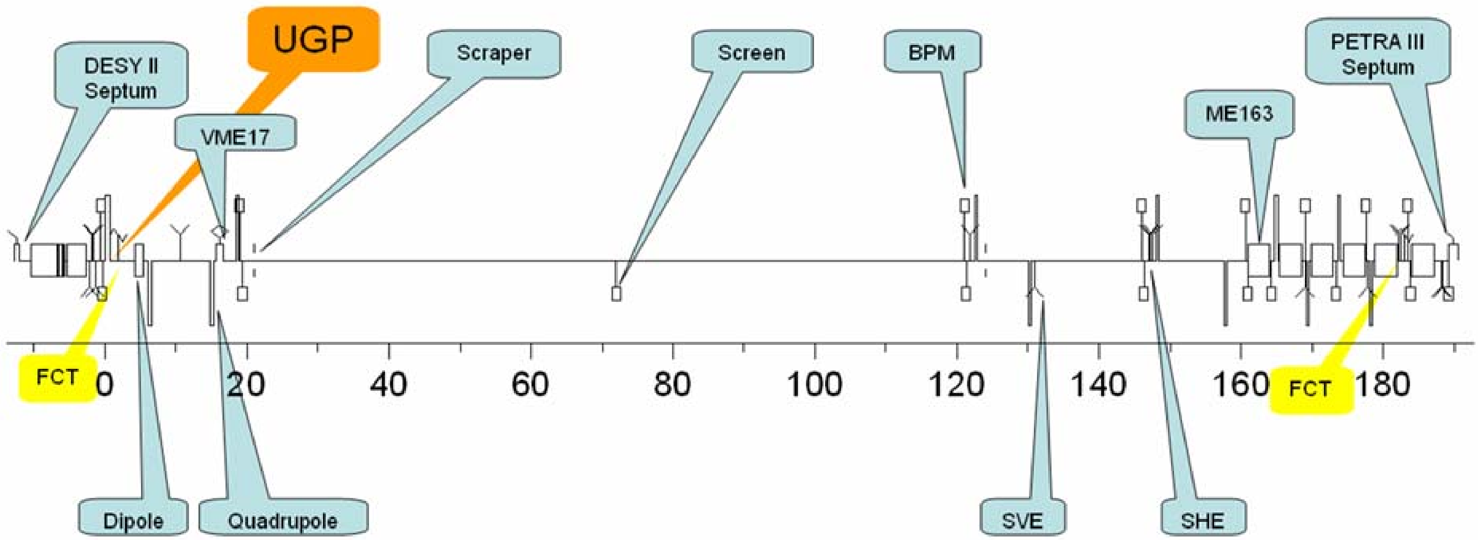
PETRA III:

Conversion of the former storage ring PETRA II into a light source

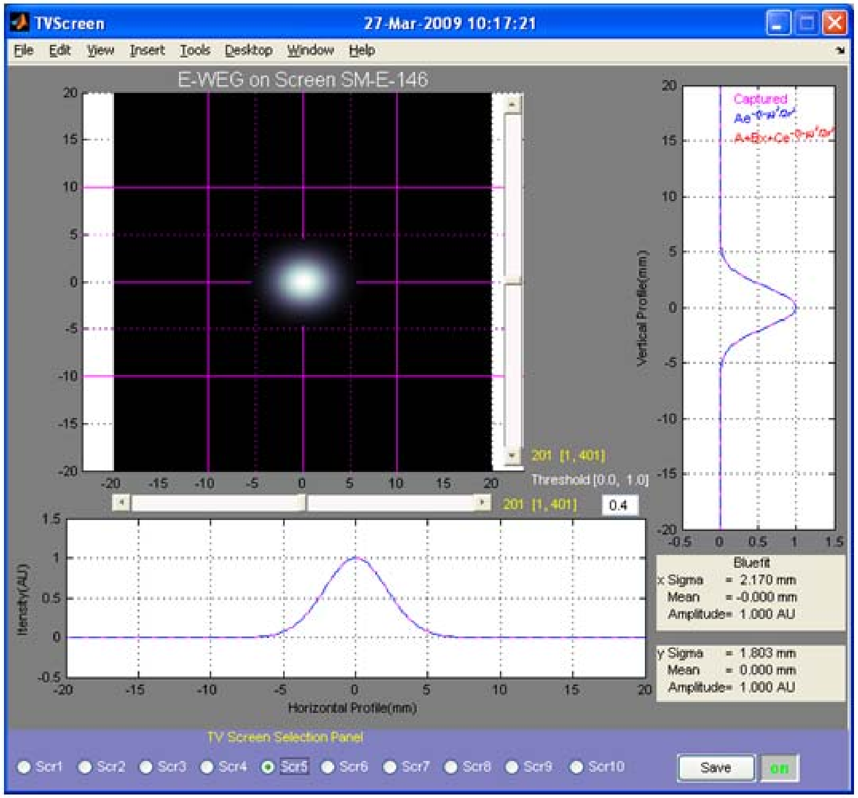
C=2304m !!!

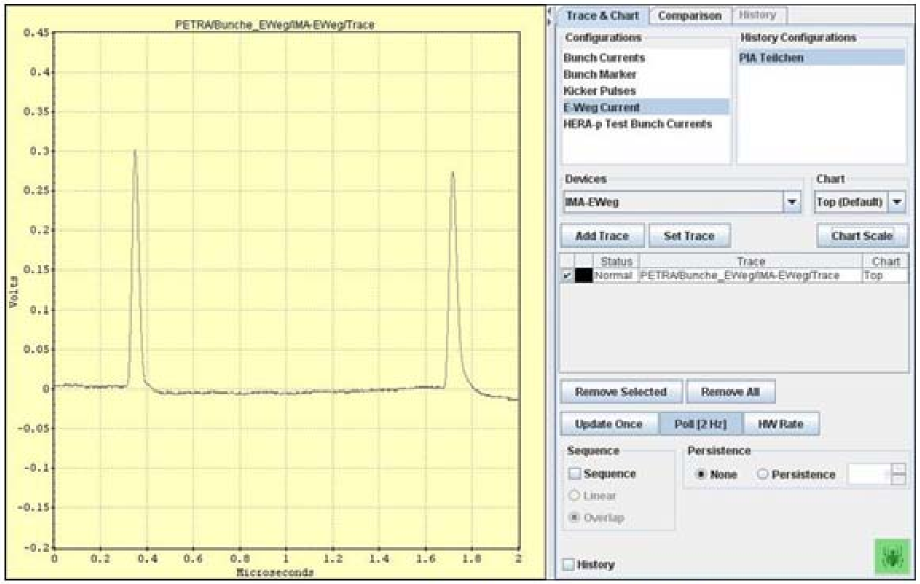
Transferline - Diagnostics





Transferline

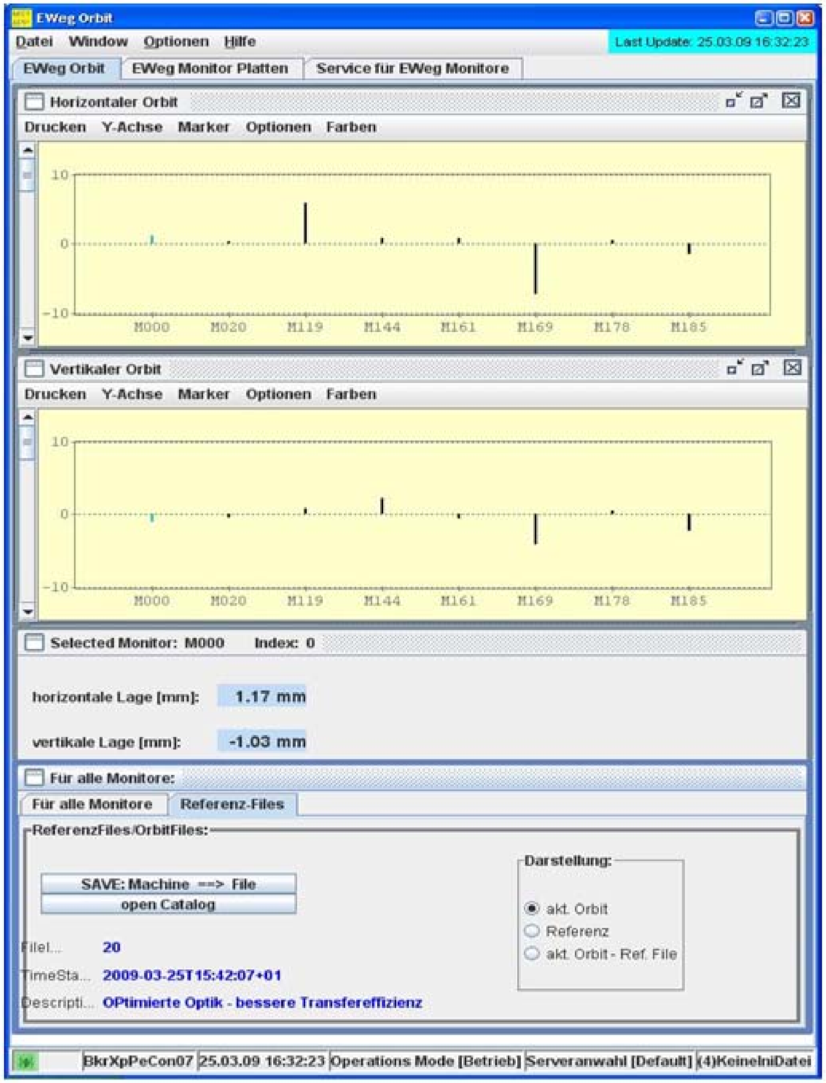


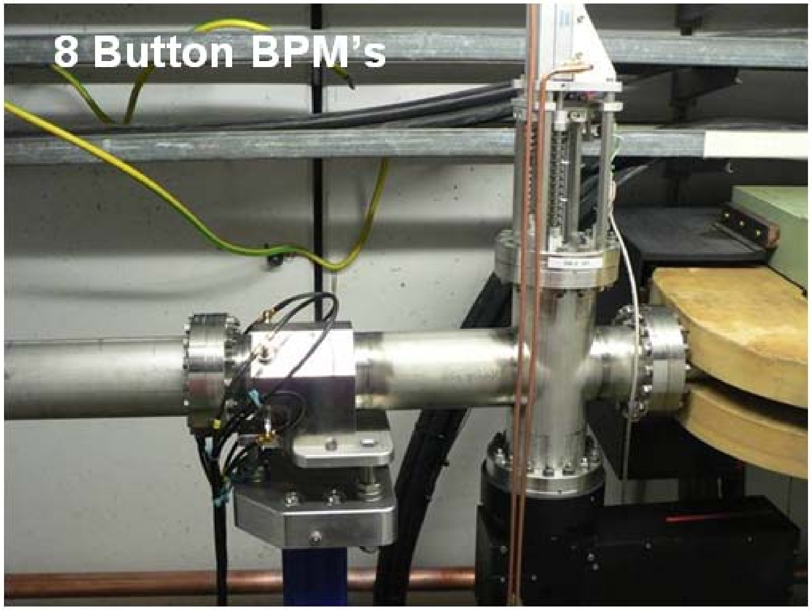


First beam through transferline on 24.03

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

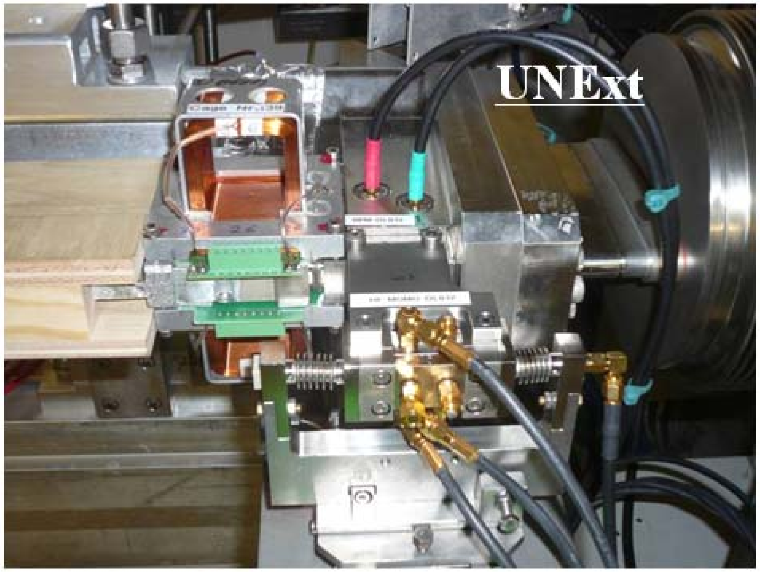
Transfer line BPM's & scrapers

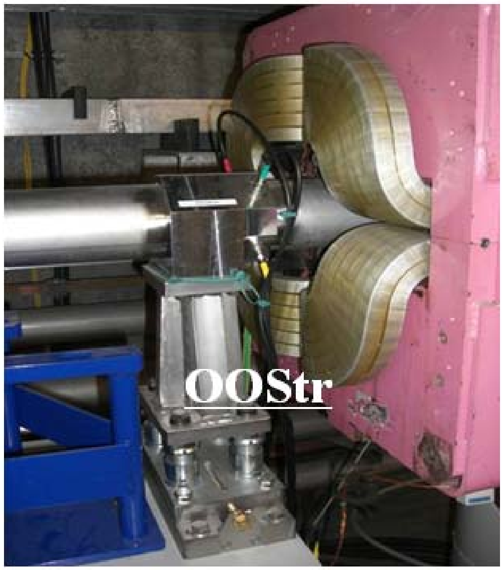


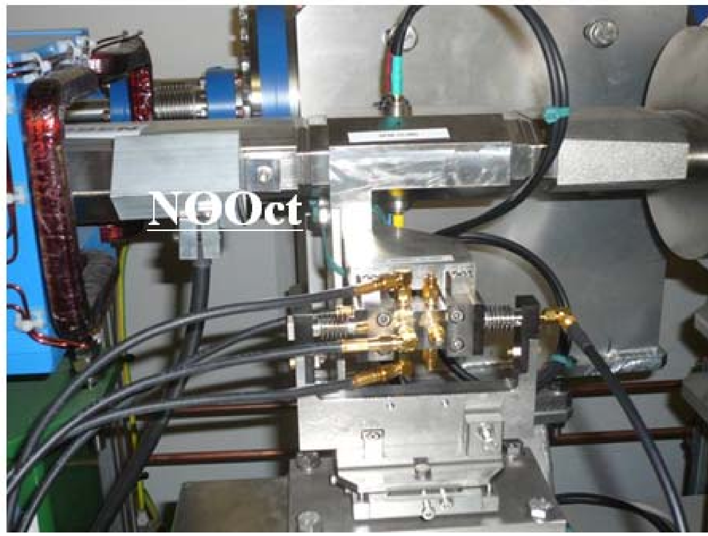


Detailed information on these BPMs
→ F. Schmidt-Föhre MOPD20

Different BPM's in PETRA III







BPM Readout electronic

Extensive tests of Libera Electron done:

✓ Slow orbit and TbT resolution

✓ Fast data readout for fast orbit feedback.

✓ Temperature dependence

✓ …

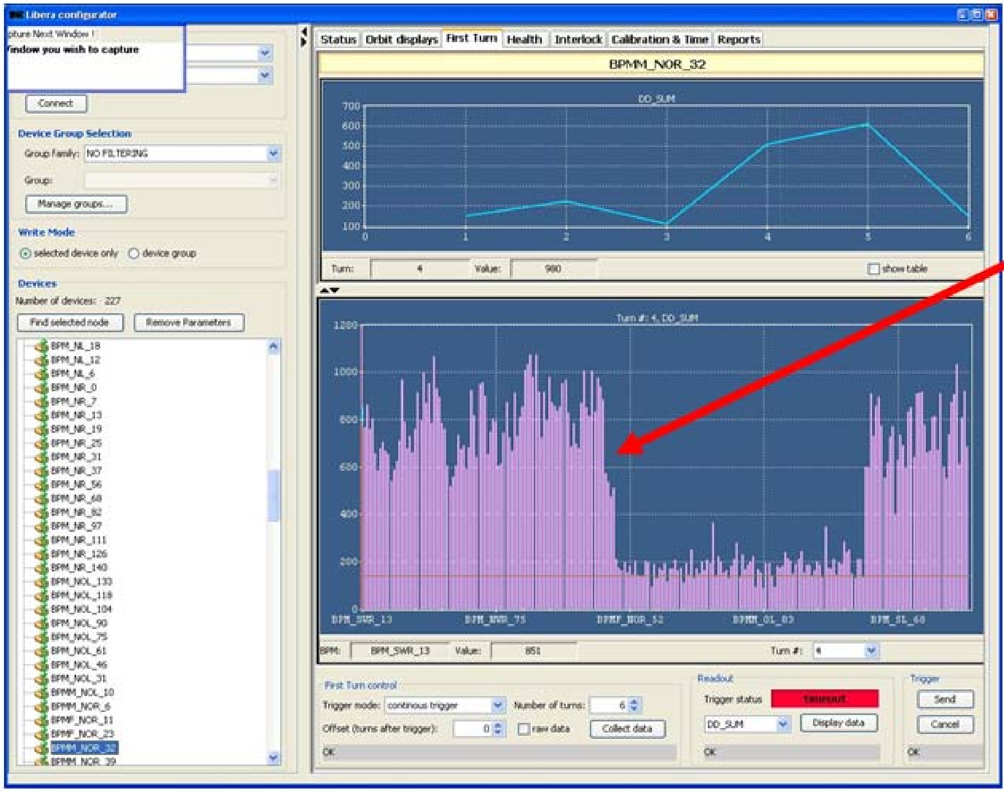
o Bunch pattern and current dependence (however, not so important for top-up operation)

=> LIBERA Brilliance (improved specs.)

240 pieces arrived after less than 1 year. Few rejected, minor problems

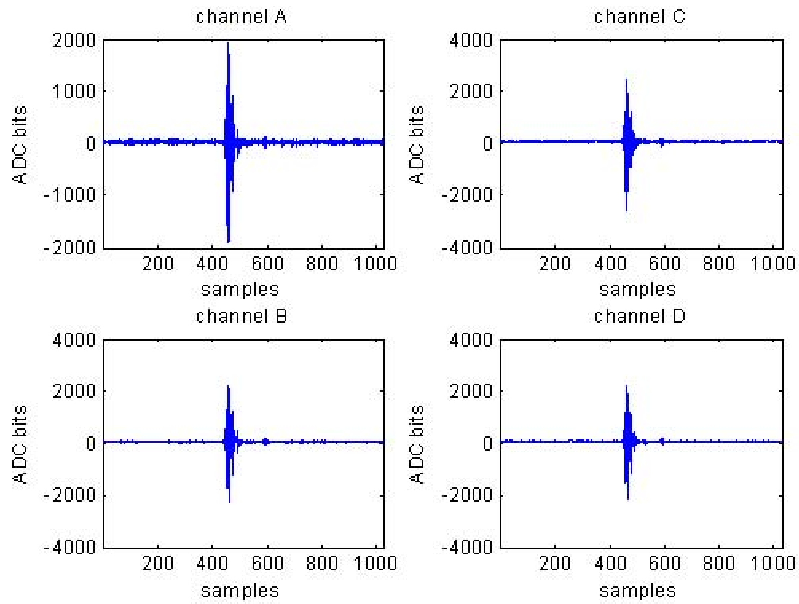
Commissioning (1)

Beam to first half of the machine on April 3 and up to the new octant On April 7



BPM electonics working well right from the start (*)

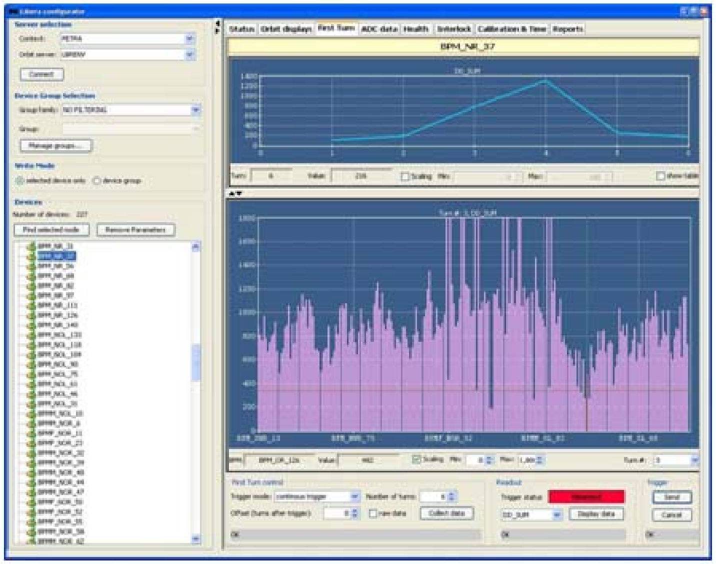
Figure shows the sum signal of BPM's

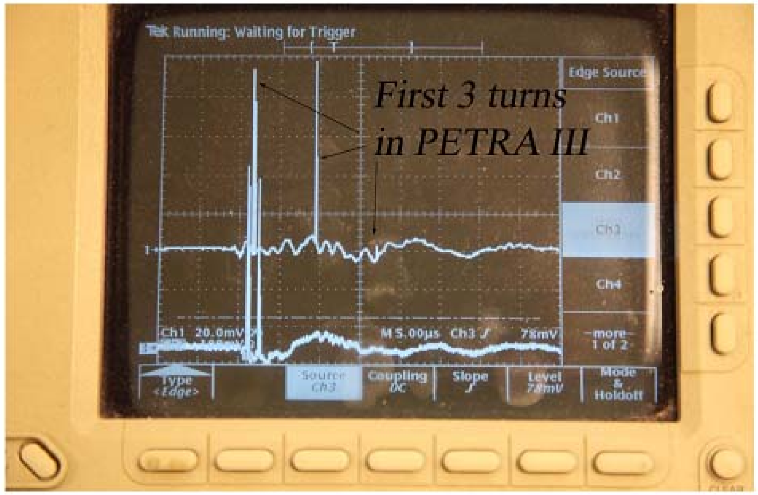


(*) Detailed information on BPM electronic commissioning → I. Krouptchenkov TUPD03

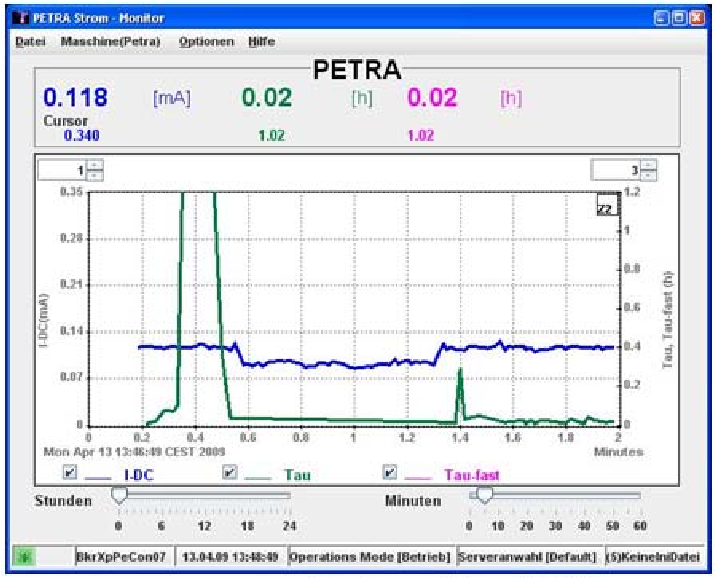
Commissioning (2)

First turns on *April 12* after two quads with wrong polarity were indentified and correctly powered and optics was locally changed to circumvent a problem with a quad that tripped because the cooling water was blocked

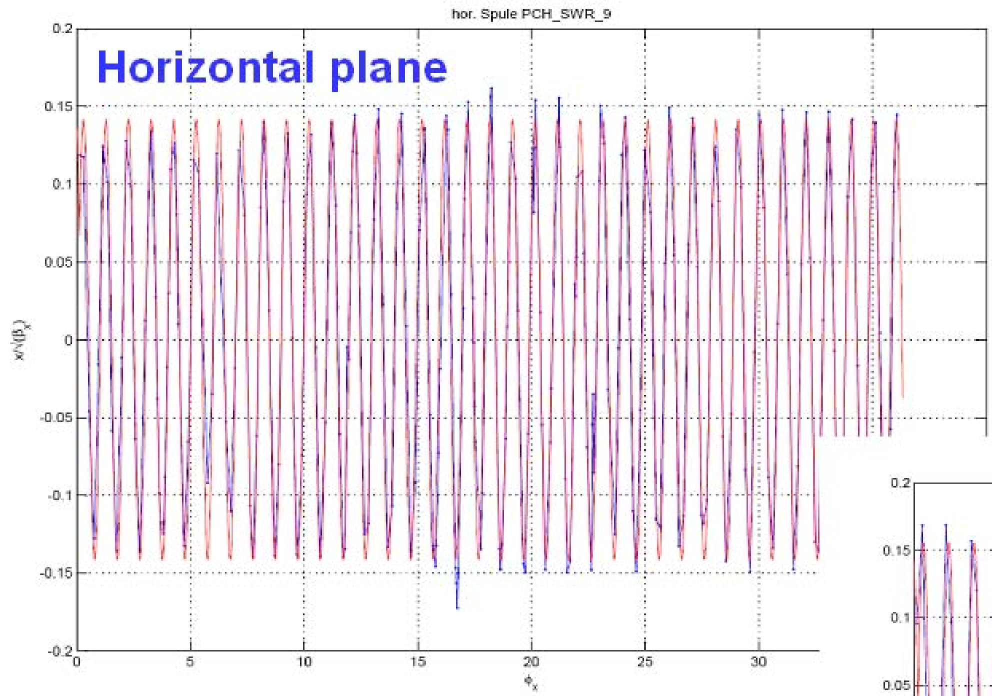


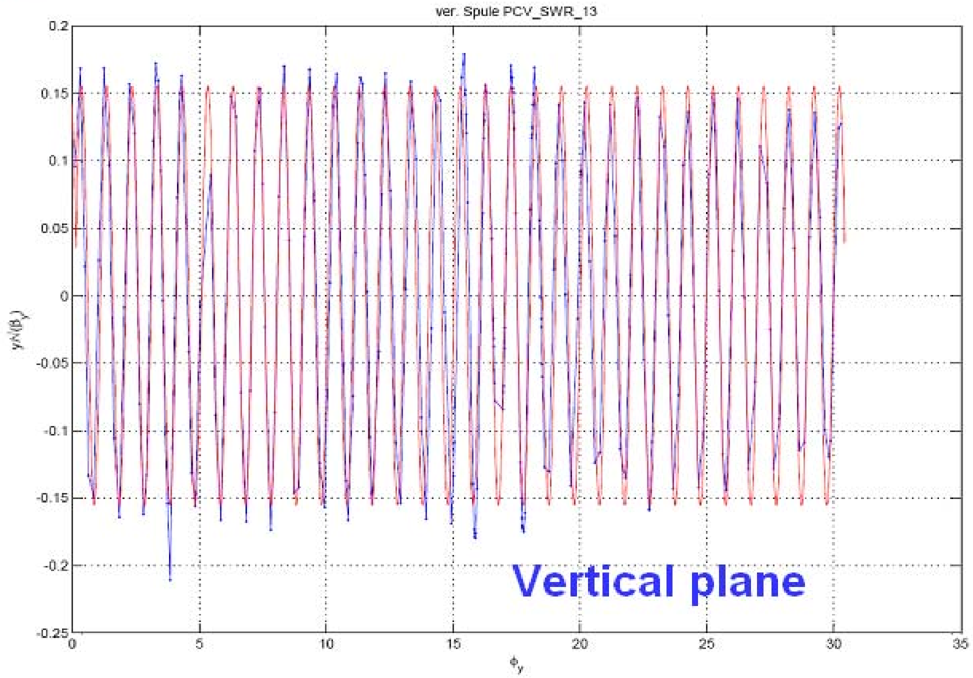


Beam was stored on *April 13*
(one bunch with 20 µA i.e. about 10^9 e+)
RF – phase right and
orbit empirically corrected in the new octant



Rough check of optics determination of integer Part of Tune



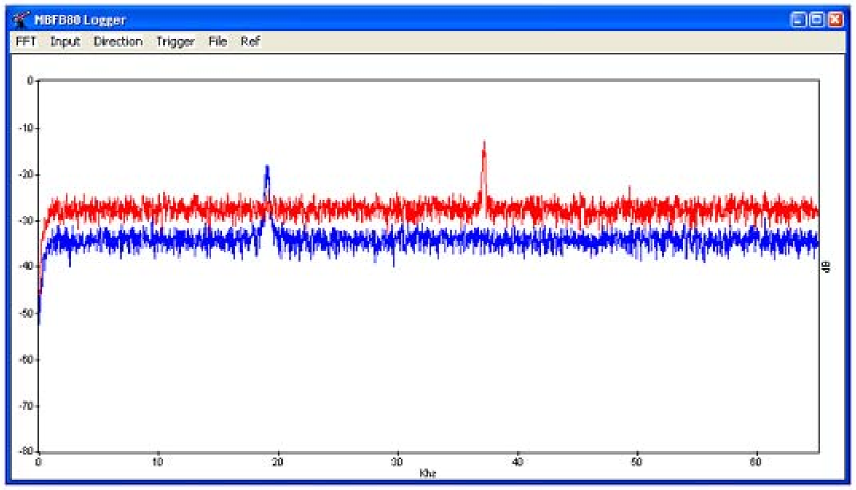


Fitted response agrees very well
In the horizontal plane with theory
Whereas there are phase errors in
The vertical plane close to the new
octant

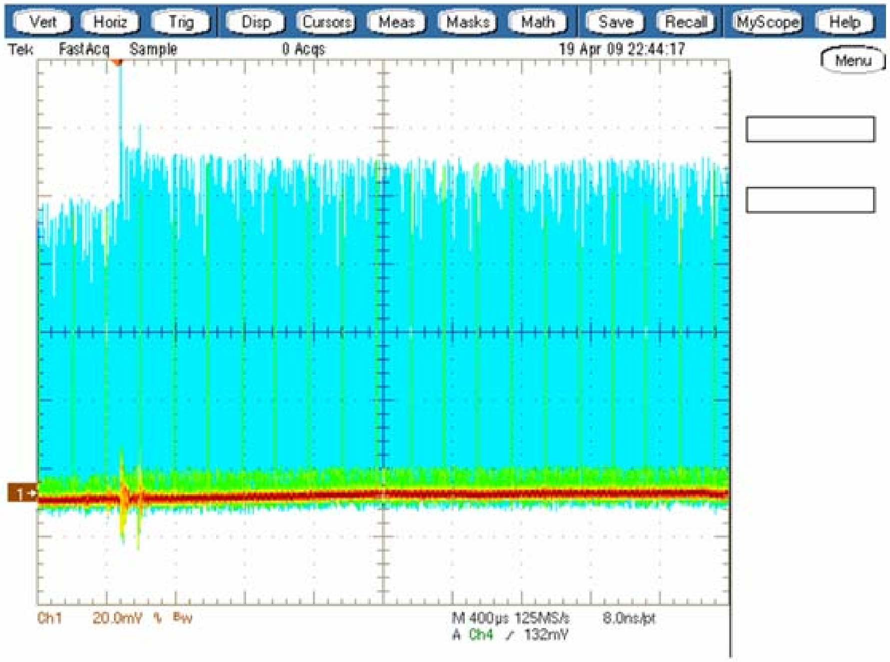
Optics …

- tunes measured and set close to design Qx ≈ 0.2 & Qy ≈ 0.3
- measured and corrected chromaticity
- changed the dipole field in old octants with respect to new octant (probably to much)

Tune measurement via noise excitation

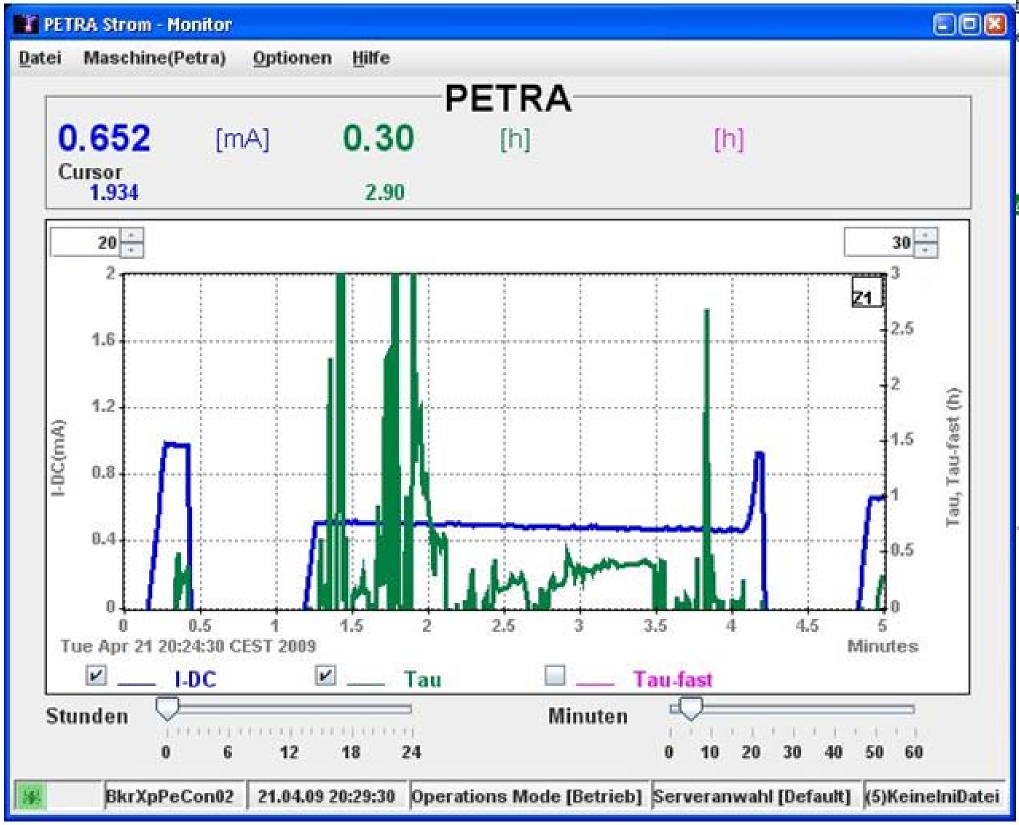


On Axis injection eff. Close to 100 % up to 200 µA perpulse

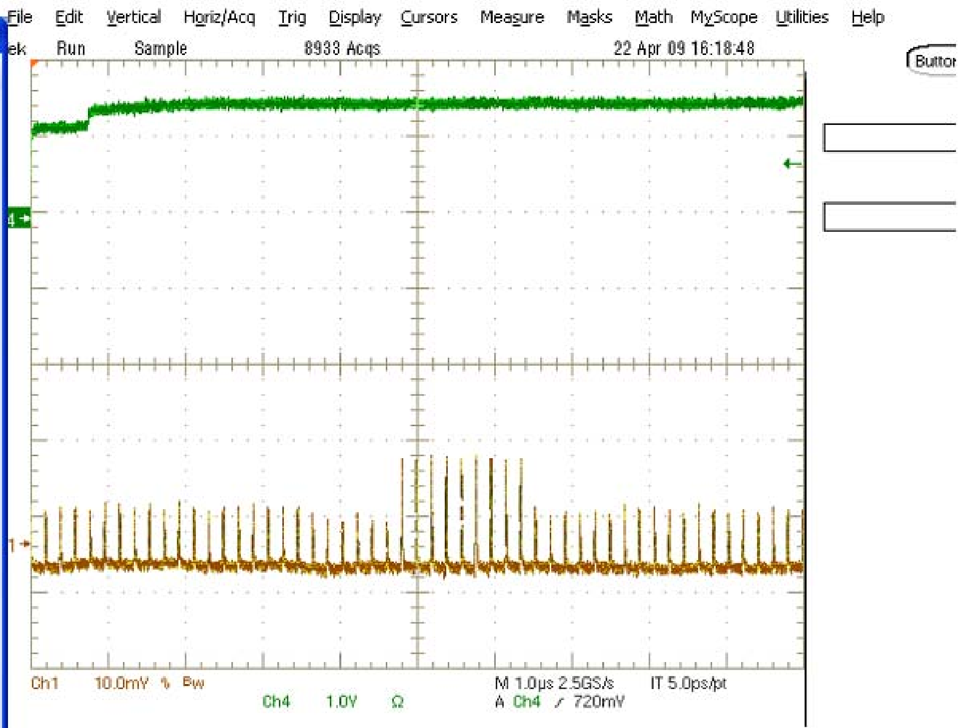


Accumulation on April 22

Single bunch accumulation



Multibunch accumulation (40 bunches)
After correction of kicker timing



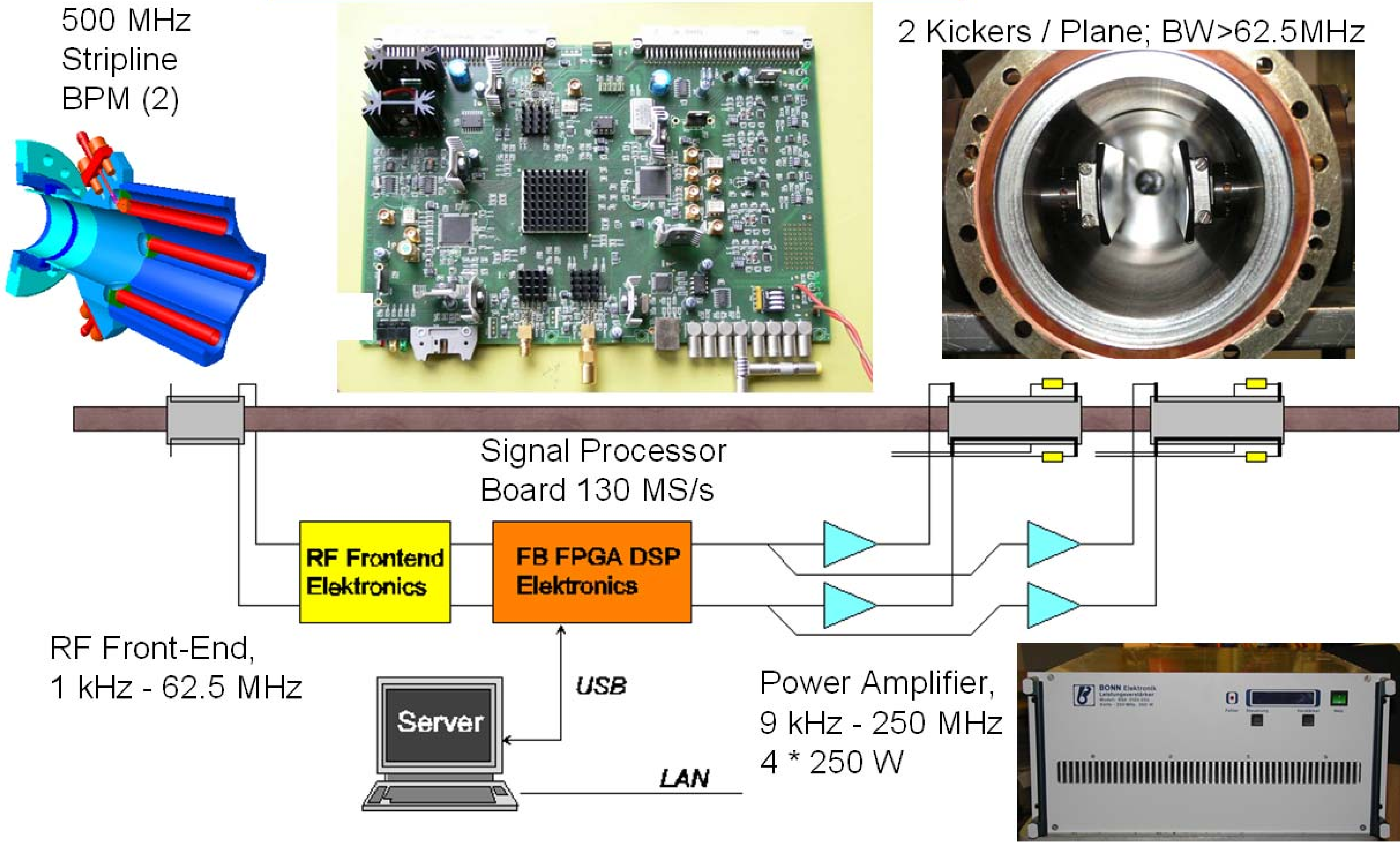
Protection of BPM's & electronics

- BPM electronic:
  - High Peak current (bunchlength 3.5 mm without wigglers)
    → high peak Voltage
    potential danger for electronics
    → limit single bunch current to ≤1 mA
    & attenuators equivalent to Upeak ≤ 80 V @ 3mm COD
- BPM's: HOM heating ($P_{trans} \leq 5W$; $k_{loss} = 46$ V/nC)
  - Calculation (transient heating)

$$I_{tot} \leq \sqrt{N} \cdot 3.6\, mA$$

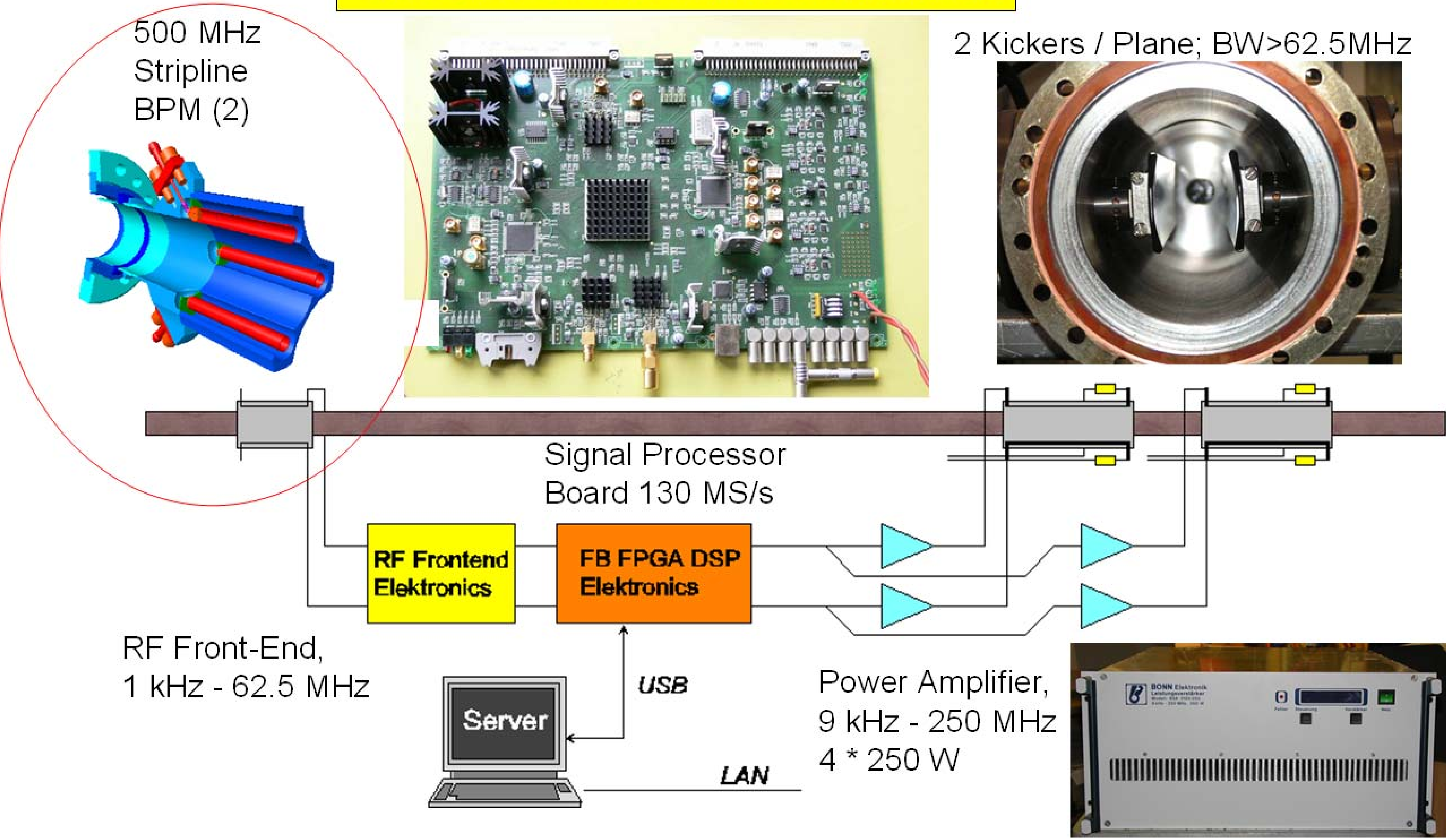
  - Temperature measurements at certain BPMs in preparation for next phase

Transversal Multibunch Feedback



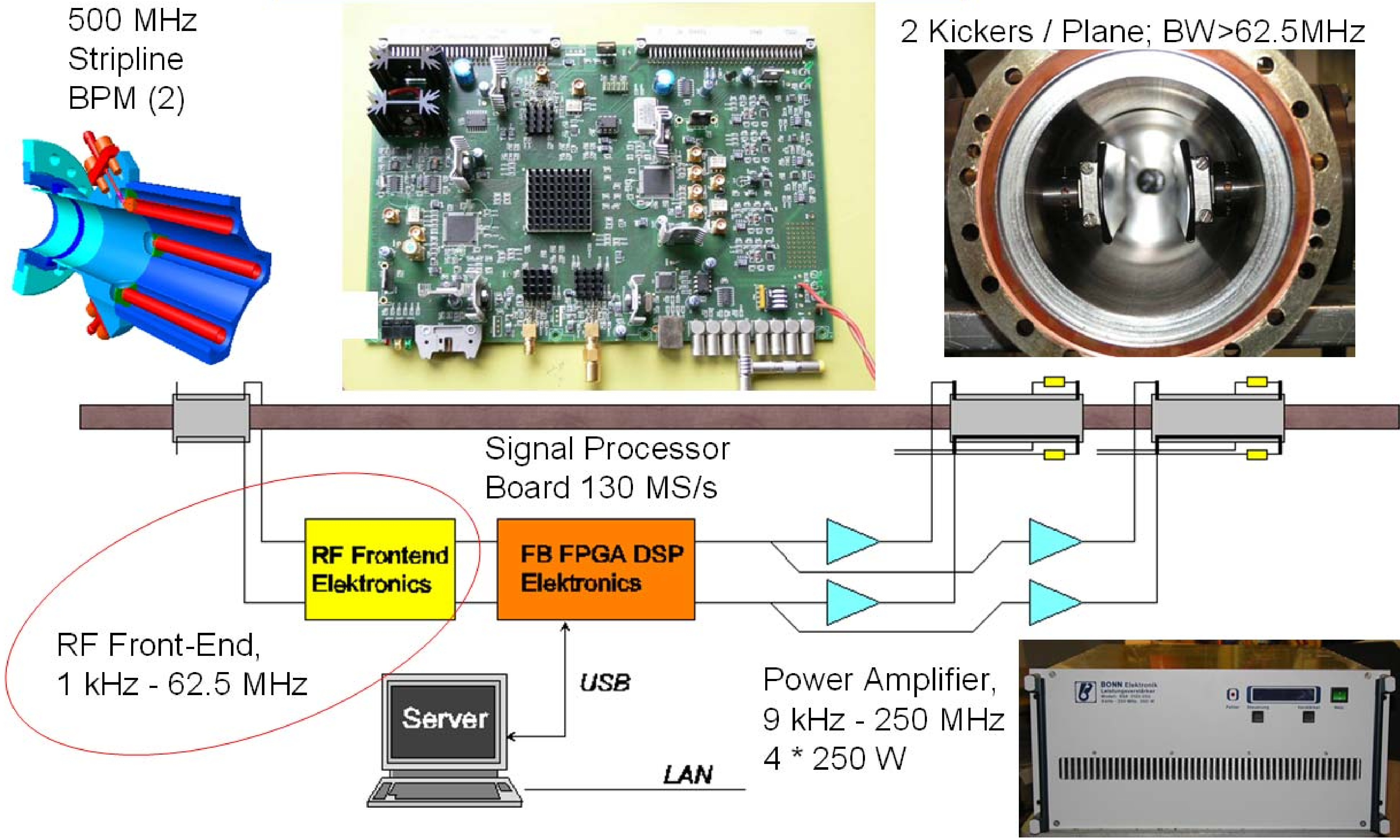
The required minimum bandwidth is 62.5MHz determined by the shortest distance between bunches being 8 ns. Upgrade to 2 ns (250 MHz) possible

Transversal Multibunch Feedback



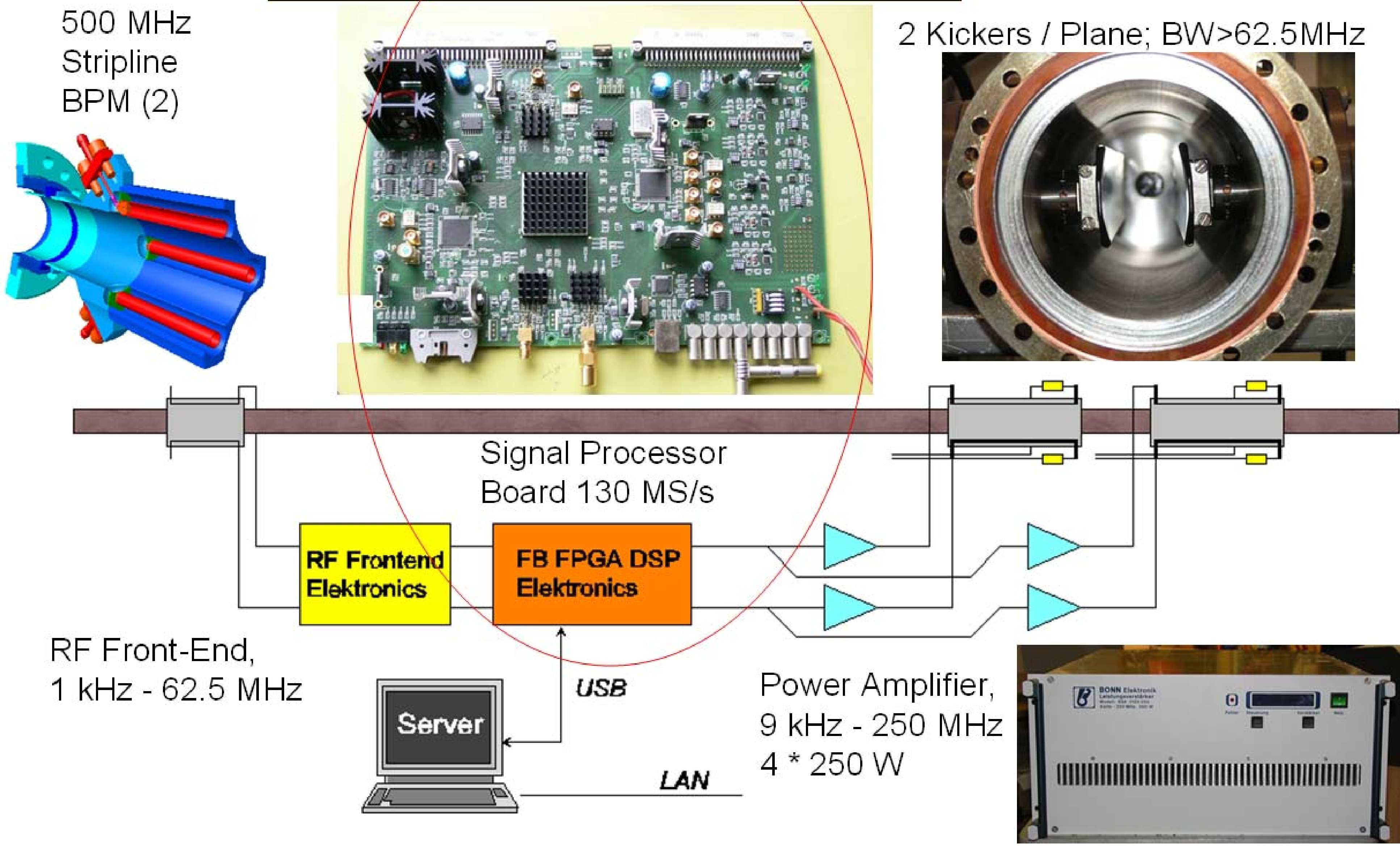
The required minimum bandwidth is 62.5MHz determined by the shortest distance between bunches being 8 ns. Upgrade to 2 ns (250 MHz) possible

Transversal Multibunch Feedback



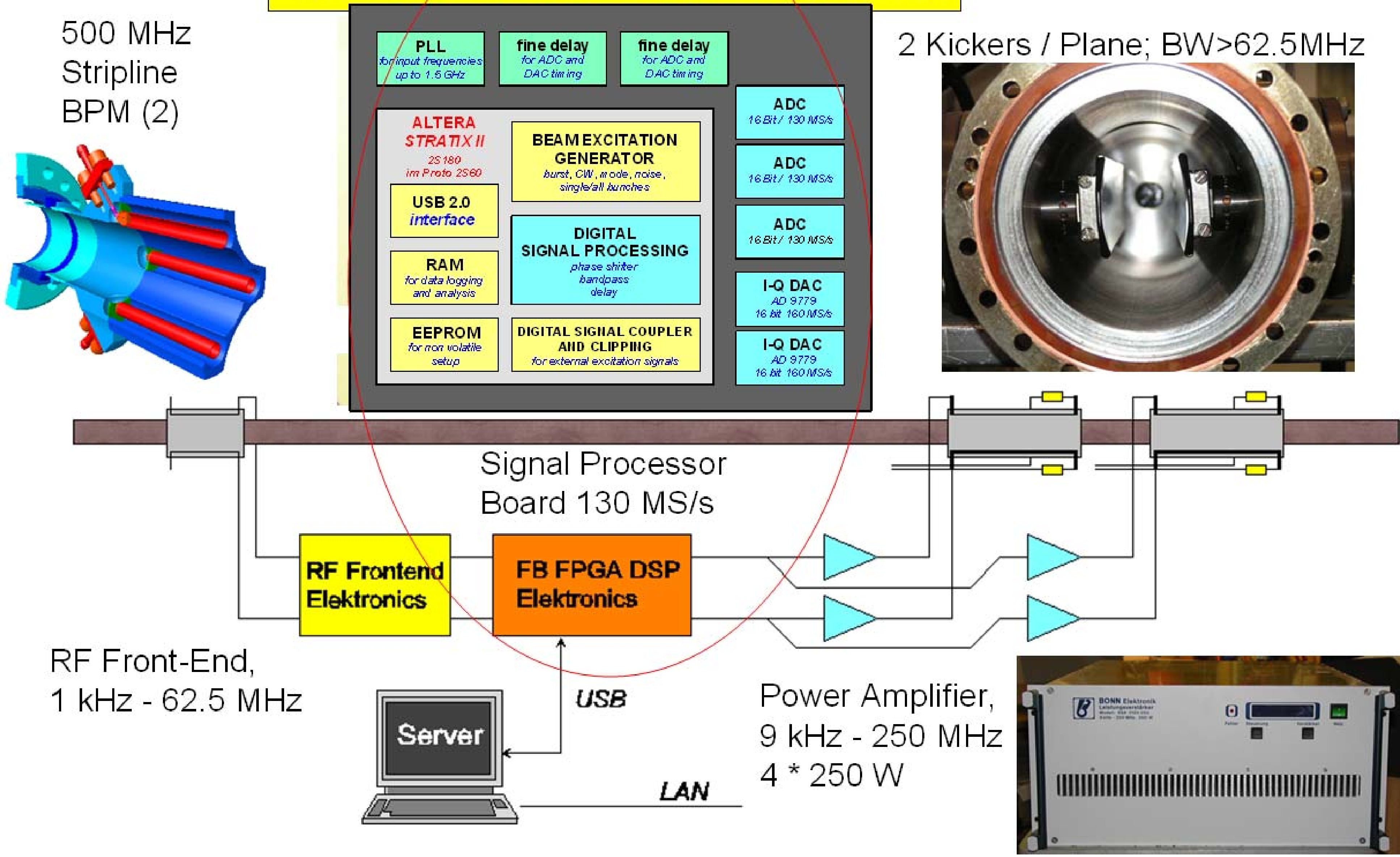
The required minimum bandwidth is 62.5MHz determined by the shortest distance between bunches being 8 ns. Upgrade to 2 ns (250 MHz) possible

Transversal Multibunch Feedback



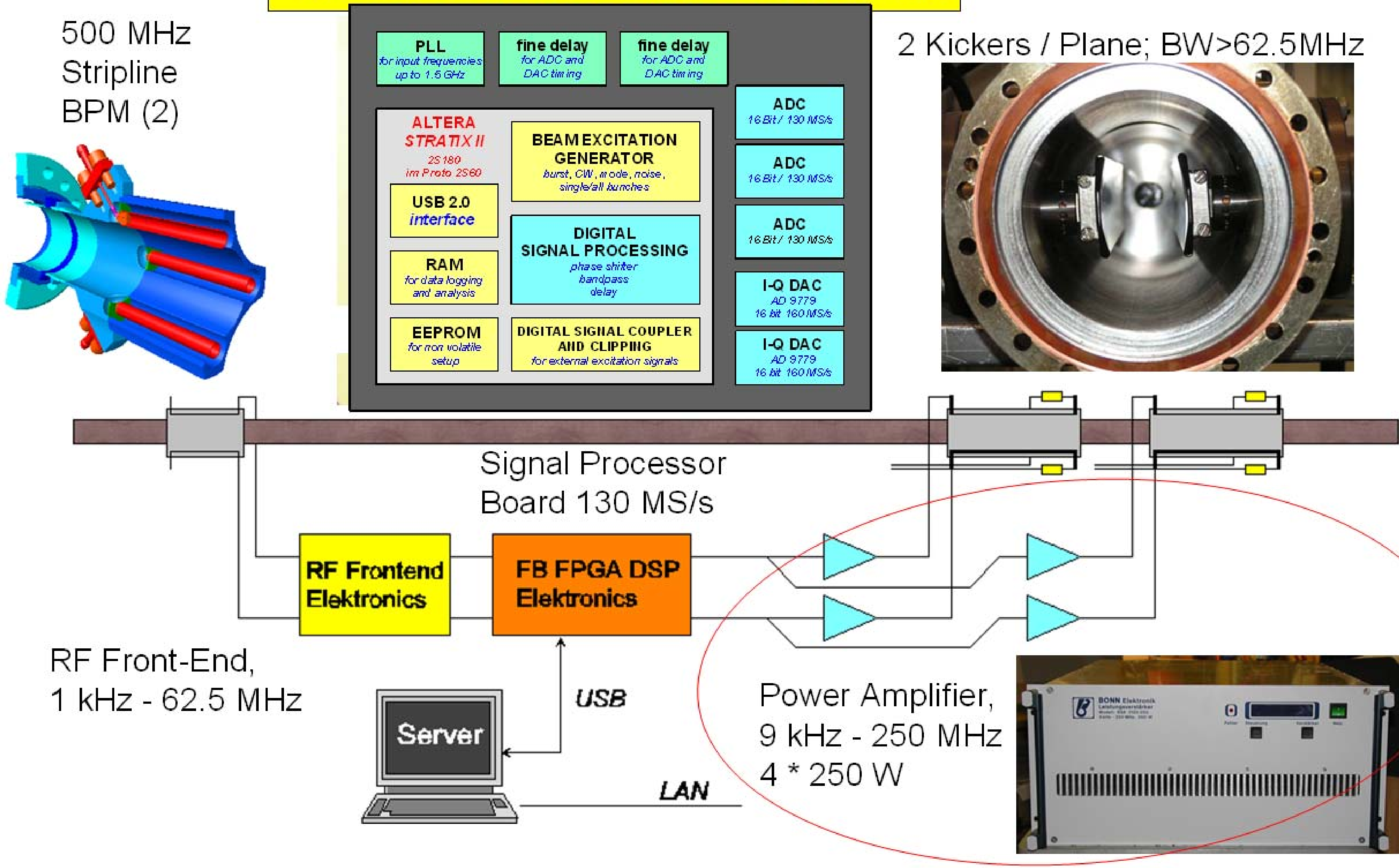
The required minimum bandwidth is 62.5MHz determined by the shortest distance between bunches being 8 ns. Upgrade to 2 ns (250 MHz) possible

Transversal Multibunch Feedback



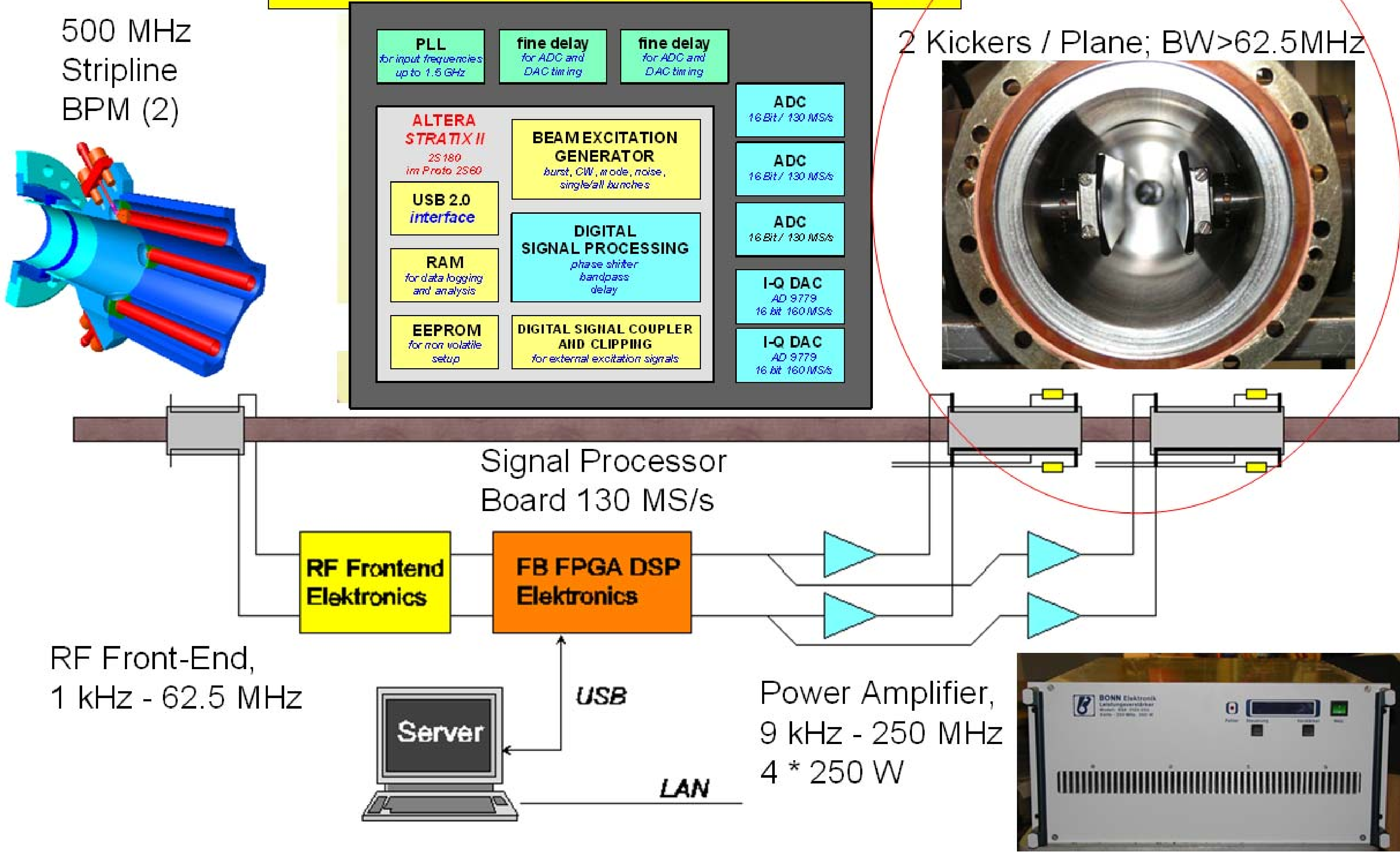
The required minimum bandwidth is 62.5MHz determined by the shortest distance between bunches being 8 ns. Upgrade to 2 ns (250 MHz) possible

Transversal Multibunch Feedback



The required minimum bandwidth is 62.5MHz determined by the shortest distance between bunches being 8 ns. Upgrade to 2 ns (250 MHz) possible

Transversal Multibunch Feedback

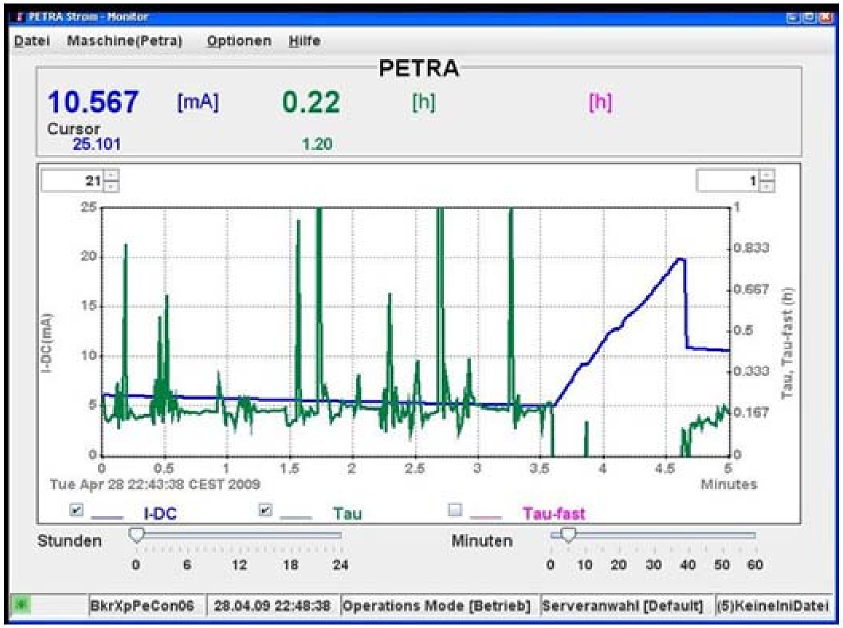


The required minimum bandwidth is 62.5MHz determined by the shortest distance between bunches being 8 ns. Upgrade to 2 ns (250 MHz) possible

Multibunch feedback

'old' PII transverse feedback in Operation on April 27

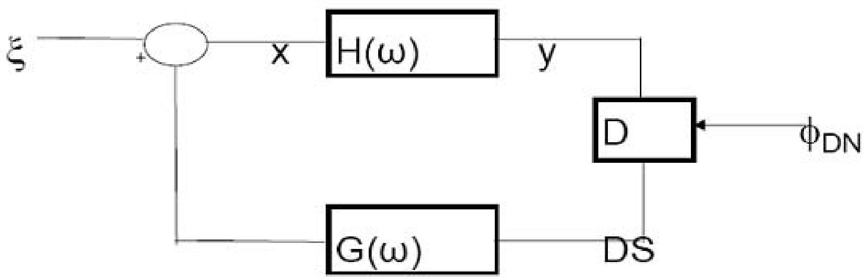
Maximum current:
20 mA (1/5 of design) in 40 bunches

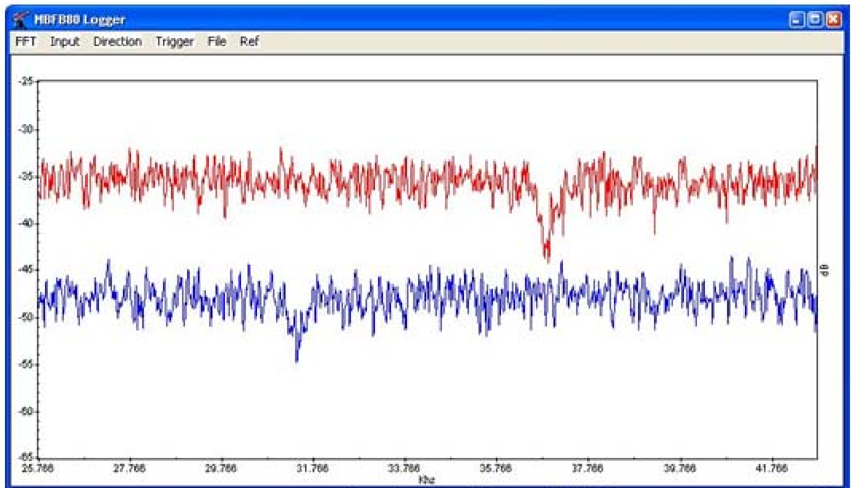


Tune measurement with FB

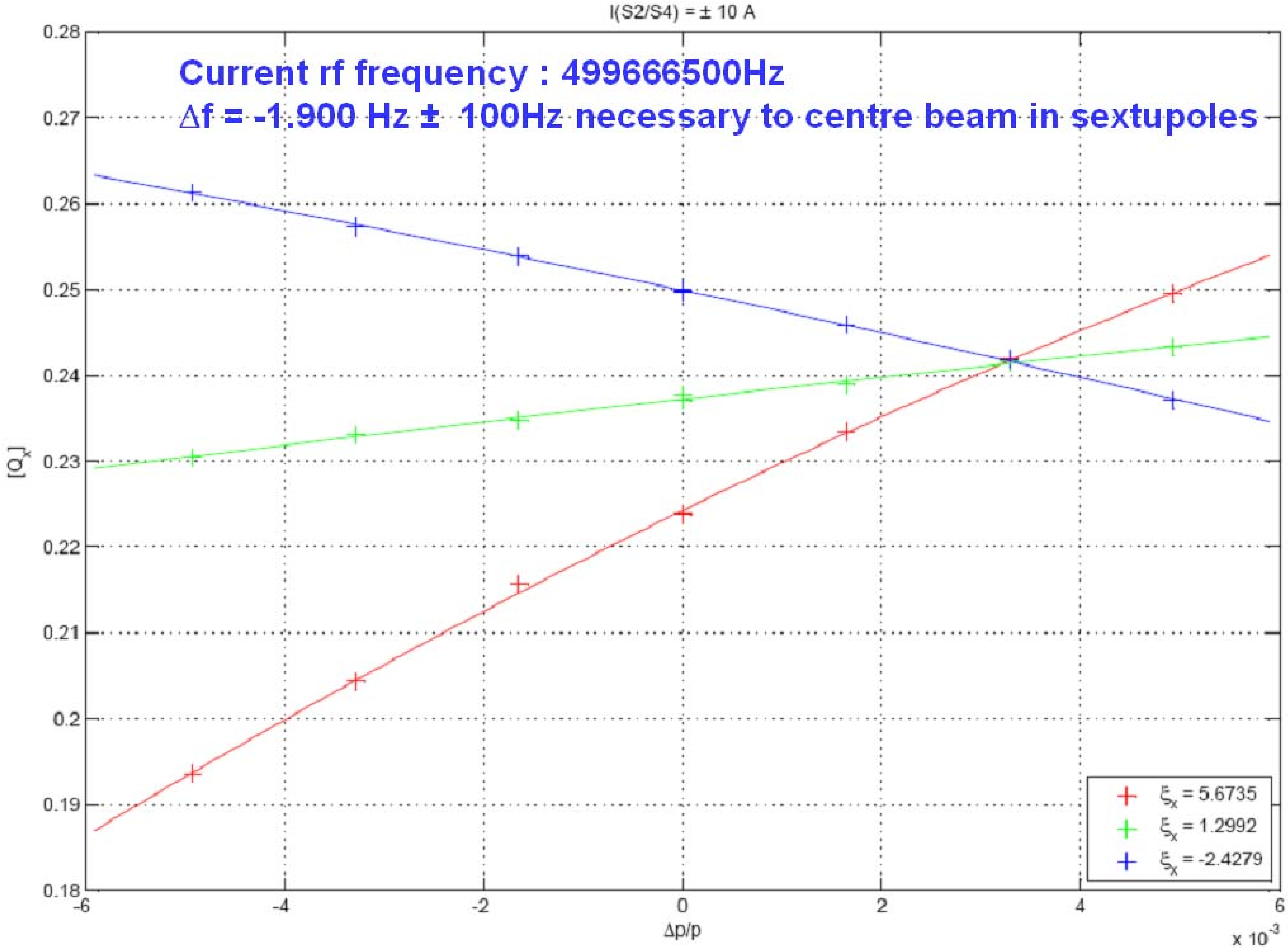
$$H(\omega) = \frac{1}{\omega_0^2 - \omega^2}; \quad G(\omega) = i\omega\Gamma;$$

$$DS(\omega) = \frac{1}{\omega_0^2 - \omega^2 + i\omega\Gamma}\xi + \frac{\omega_0^2 - \omega^2}{\omega_0^2 - \omega^2 + i\omega\Gamma}\phi_{DN}$$



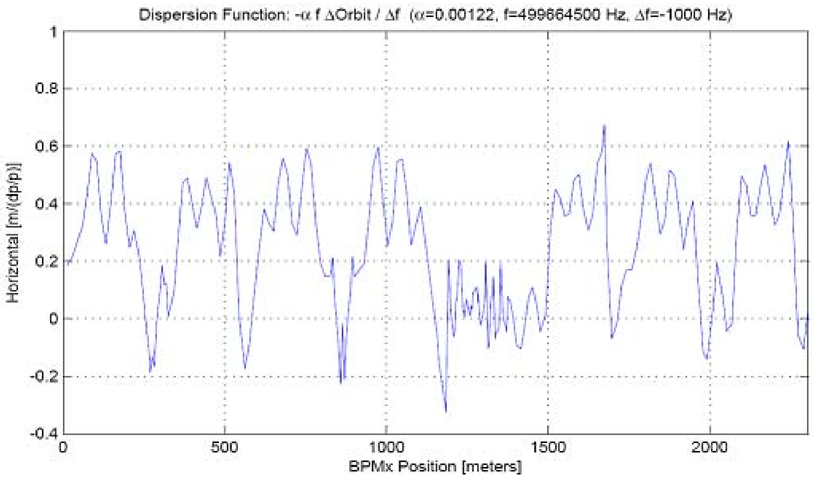


Centre frequency

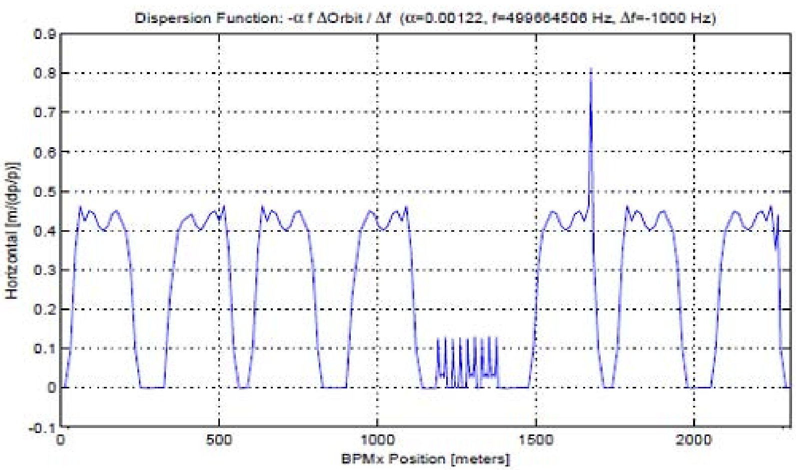


Dispersion

Horizontal dispersion

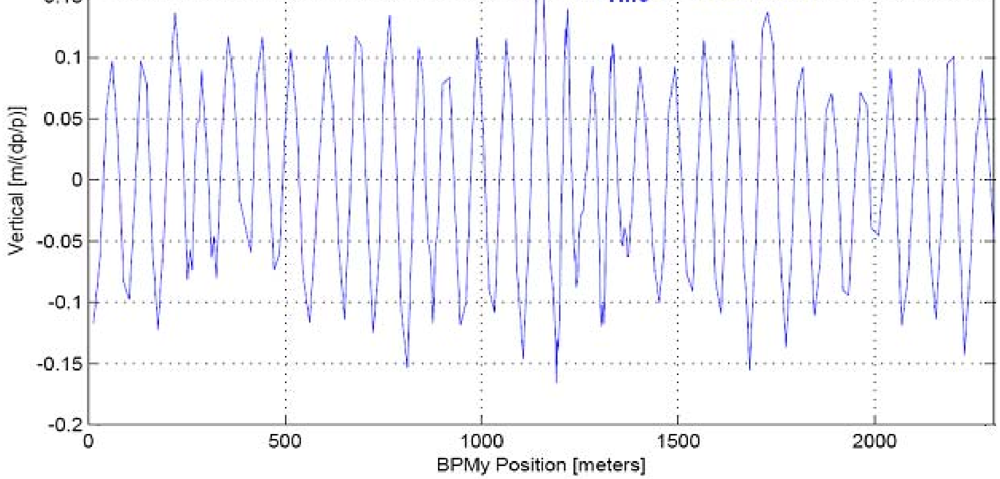


The distortion of the D_x is
due to a wrong relation between
The two dipol fields and kicks
That produce dispersion

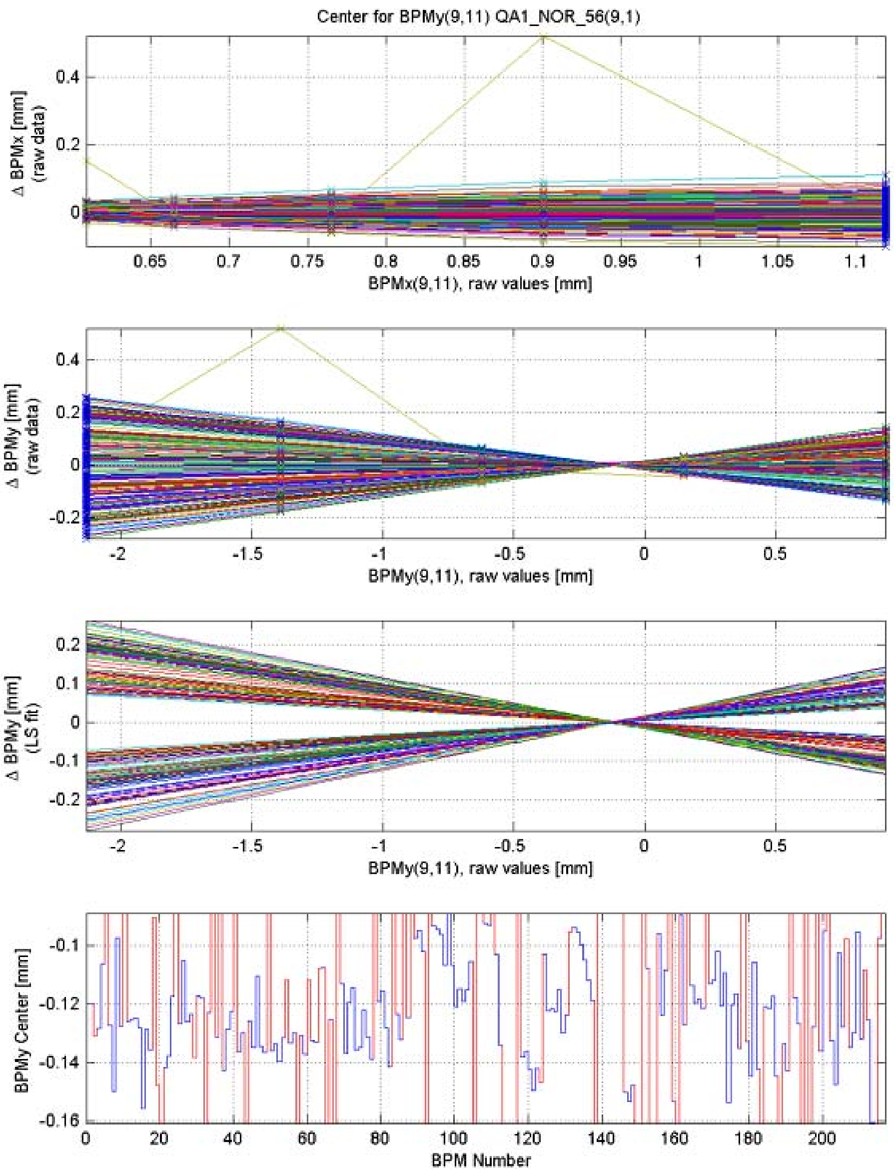


Vertical dispersion

The distortion of D_y is
compatible with closed
orbit distortions of about
$Y_{rms} \approx 1.2$ mm



Test of BBA



First test of BBA
Monitor NOR 55   Quad QA1 NOR 56

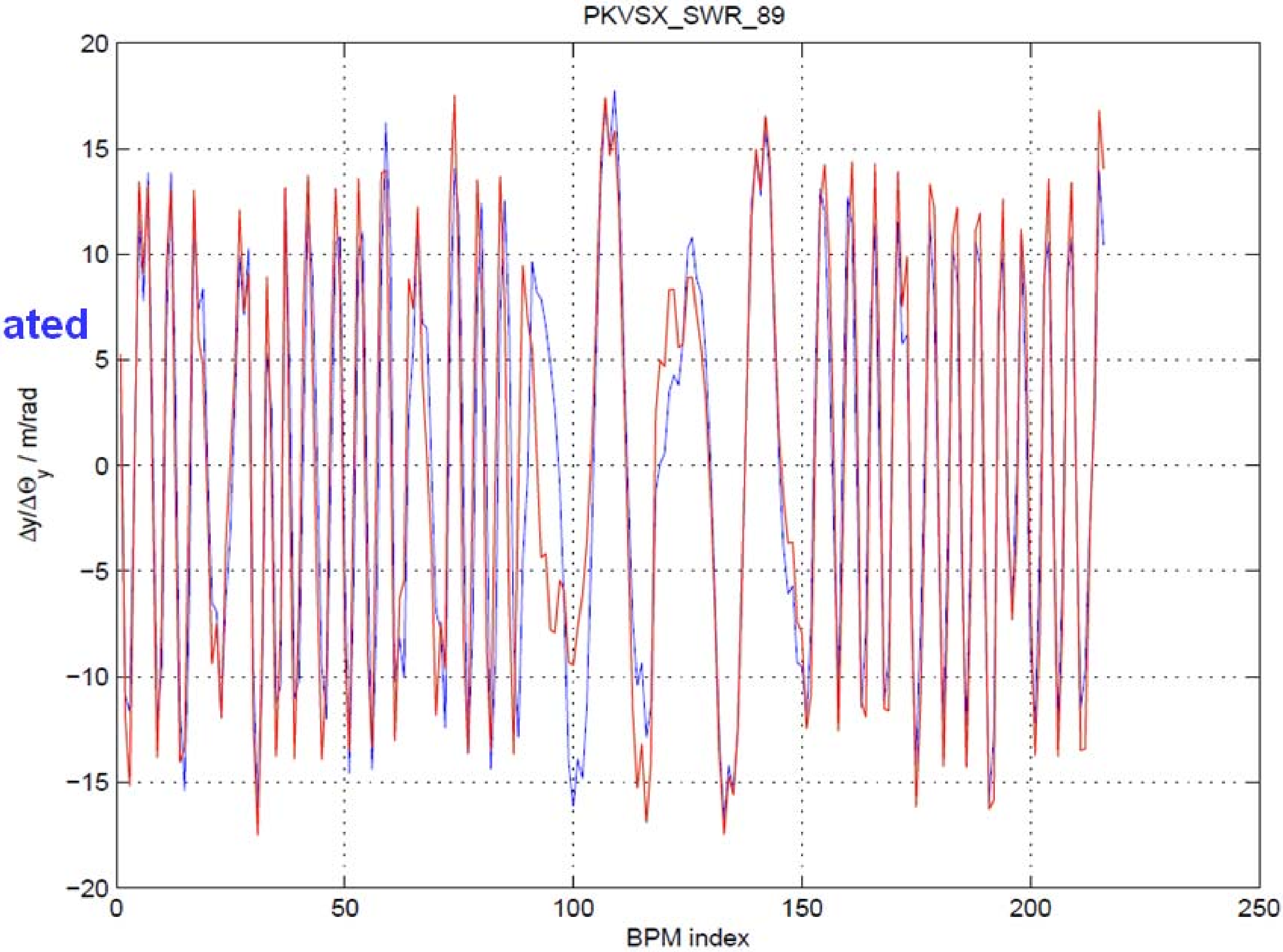
First picture: raw data x
Second picture: raw data y
Third picture: only sensitive BPM
Forth picture: calc. offset of NOR55 with data of all other BPM's

$x = (+0.42 \pm 0.02)$ mm ,
$y = (-0.12 \pm 0.02)$ mm

ORM Test

The ORM procedure has
Been tested with a few
Horizontal or vertical
Corrector magnets
Respectively.

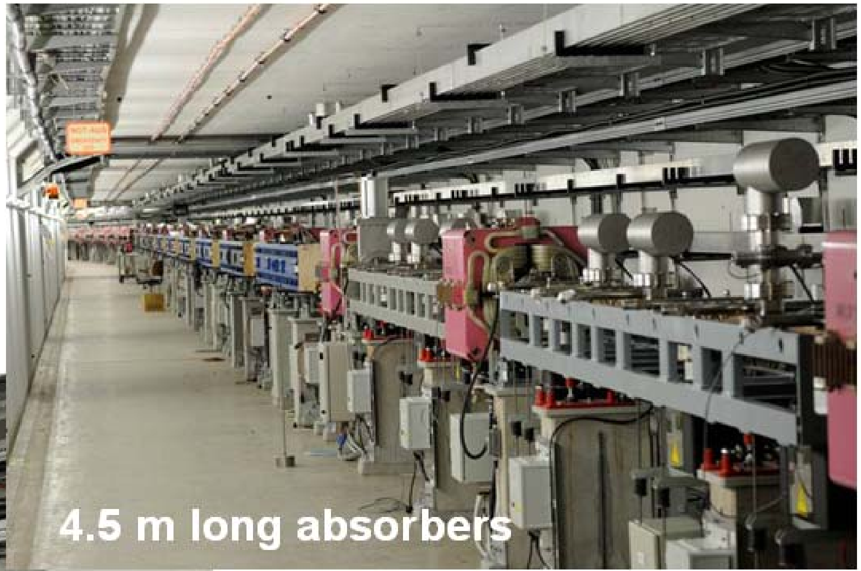
The data is currently investigated



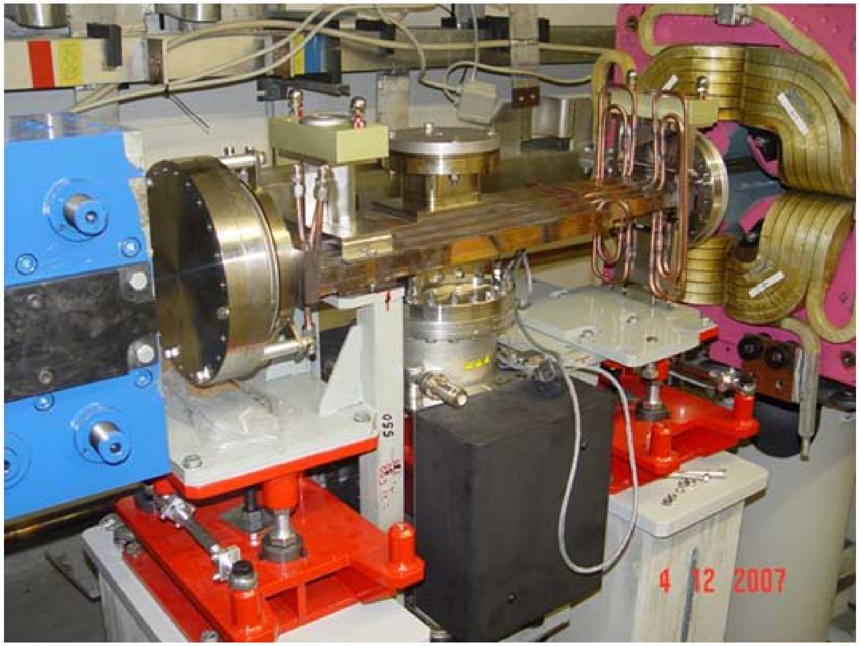
Damping wiggler sections
safe removal of radiation power

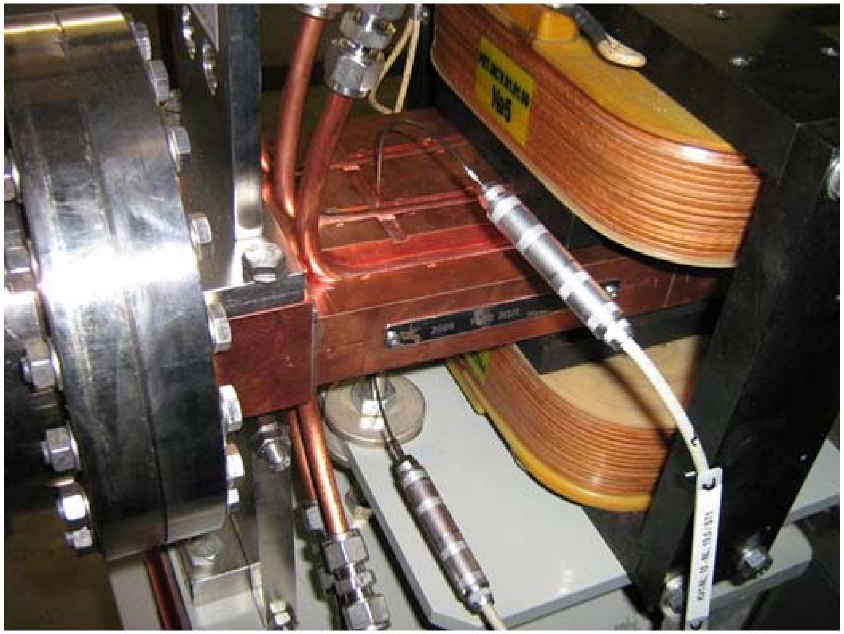
Up to 400 kW of SR-power has to be removed;
12 absorbers installed and power has to be distributed correctly otherwise absorbers will be damaged

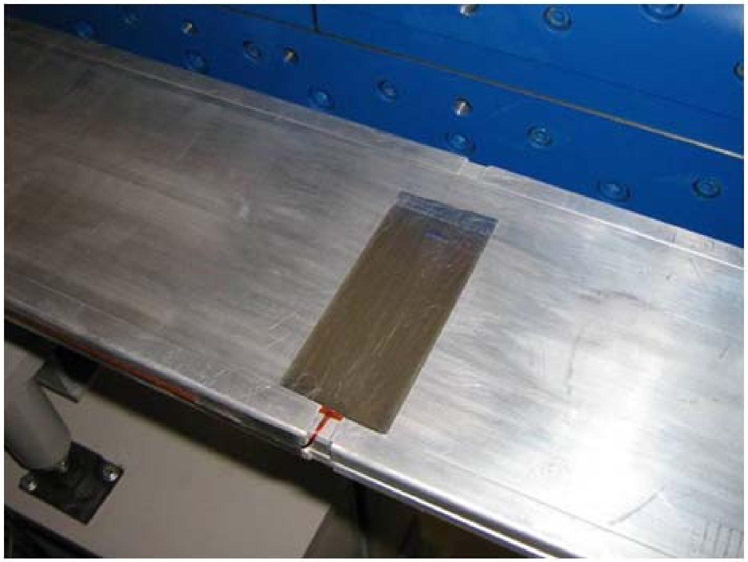
sensors control absorber temperature at critical positions



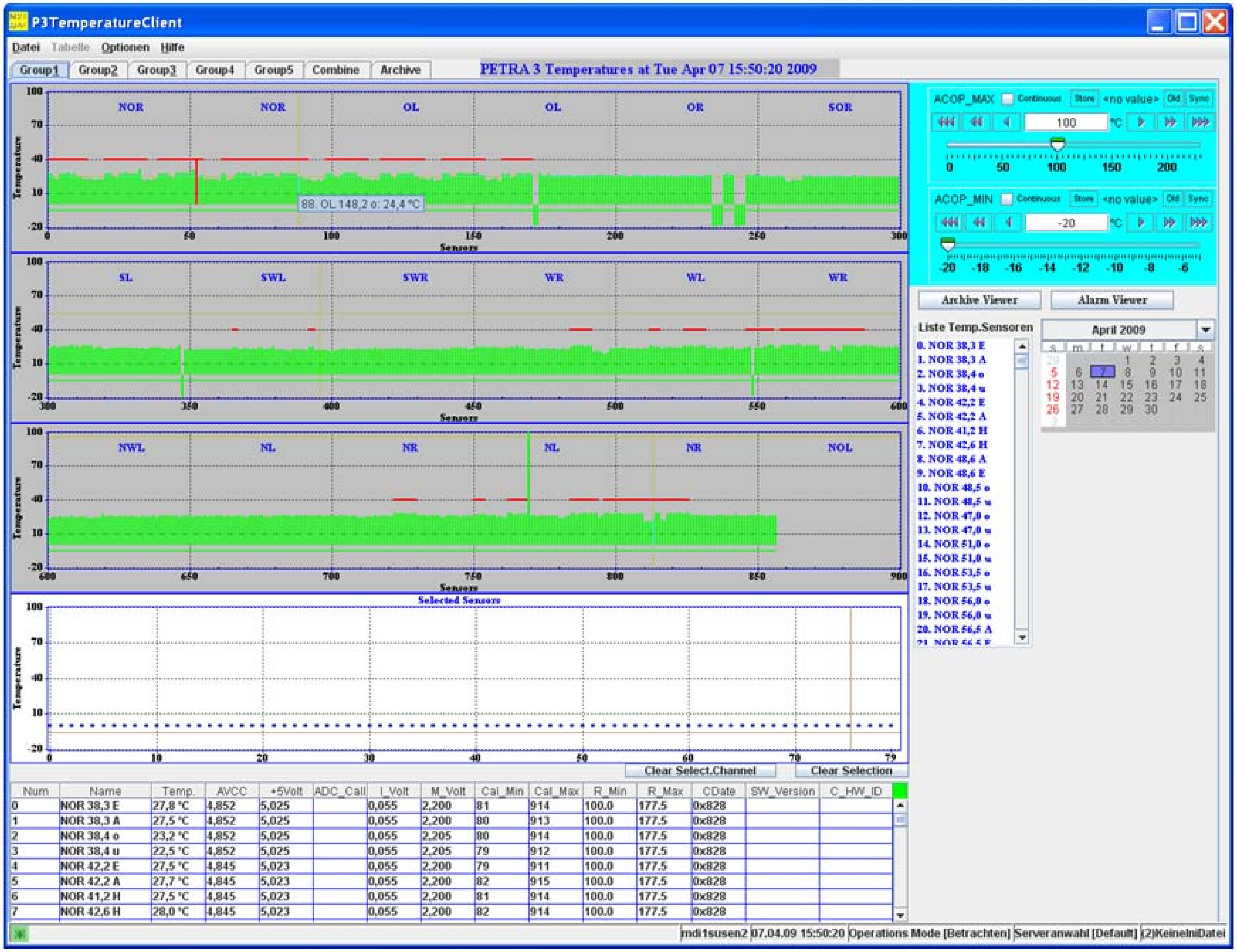
Temperature sensors







Temperature Sensors



Num	Name	Temp.	AVCC	+5Volt	ADC_Call	I_Volt	M_Volt	Cal_Min	Cal_Max	R_Min	R_Max	CDate	SW_Version	C_HW_ID
0	NOR 38,3 E	27,8 °C	4,852	5,025		0,055	2,200	81	914	100.0	177.5	0x828		
1	NOR 38,3 A	27,5 °C	4,852	5,025		0,055	2,200	80	913	100.0	177.5	0x828		
2	NOR 38,4 o	23,2 °C	4,852	5,025		0,055	2,205	80	914	100.0	177.5	0x828		
3	NOR 38,4 u	22,5 °C	4,852	5,025		0,055	2,205	79	912	100.0	177.5	0x828		
4	NOR 42,2 E	27,5 °C	4,845	5,023		0,055	2,200	79	911	100.0	177.5	0x828		
5	NOR 42,2 A	27,7 °C	4,845	5,023		0,055	2,200	82	915	100.0	177.5	0x828		
6	NOR 41,2 H	27,5 °C	4,845	5,023		0,055	2,200	81	914	100.0	177.5	0x828		
7	NOR 42,6 H	28,0 °C	4,845	5,023		0,055	2,200	82	914	100.0	177.5	0x828		

Temperature thresholds
For certain sensors

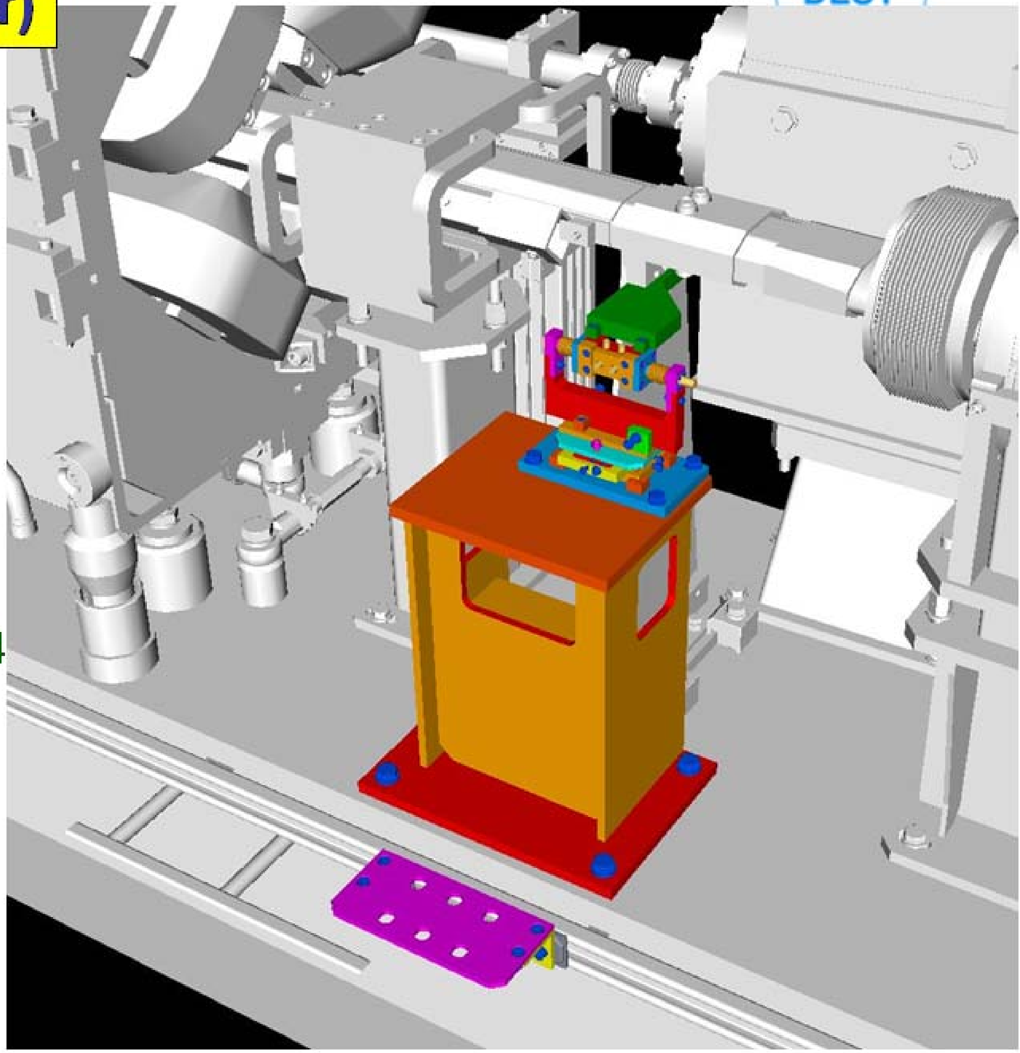
If temperature exceeds
Threshold warning to
*M*achine *P*rotection *S*ystem
And if necessary beam is
Dumped

Detailed information on *MPS*
→ T. Lensch, M. Werner
TUPD25

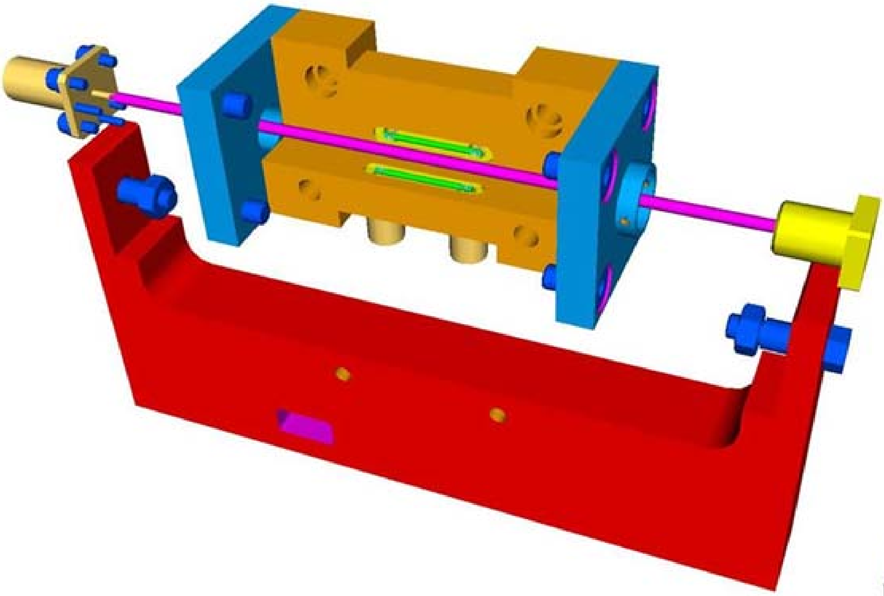
HF-MoMo (Movement Monitor)

Near the undulators the movement of the BPMs (relative to ground) will be measured with a resolution of better 1 μm. Different **encoder systems** were studied

− **Test of a commercial system in PETRA II failed:**
radiation problems, high failure rate.



- Choice of in-house wire-systems HF-MoMo
- 145 MHz signal on λ/4 antenna picked up by 4 stiplines. Readout BPM like, bandwidth 1Hz.
- Gap 8x8mm, linear 2x2 mm.

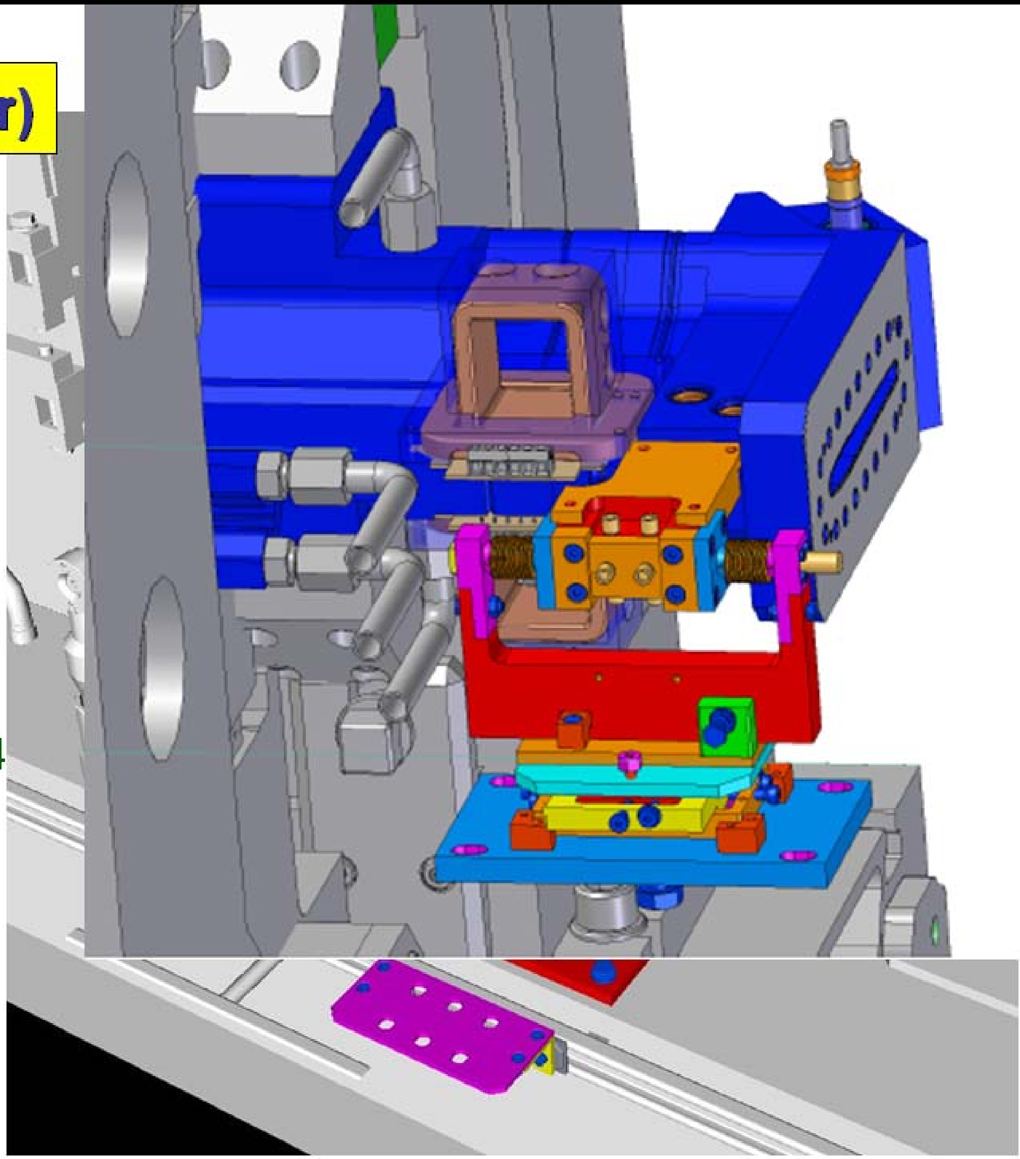


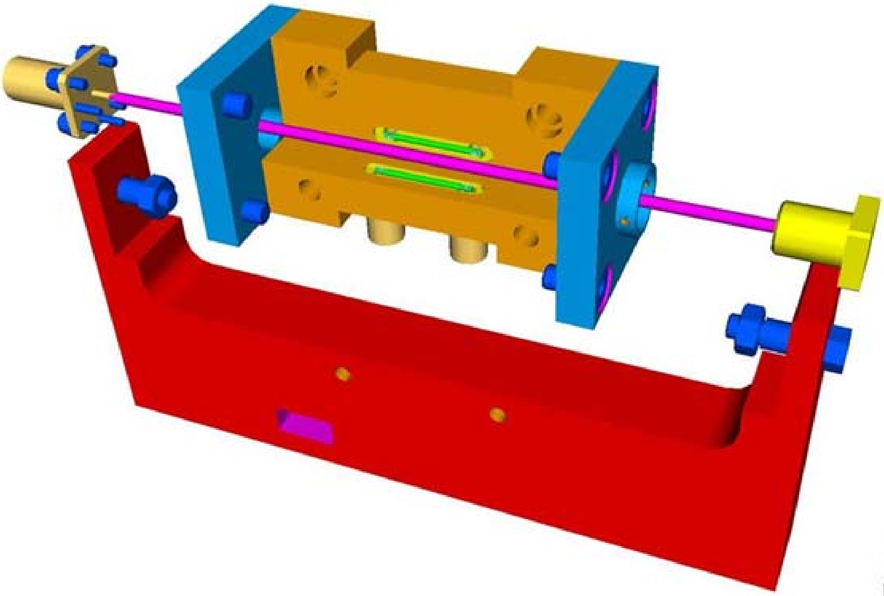
HF-MoMo (Movement Monitor)

Near the undulators the movement of the BPMs (relative to ground) will be measured with a resolution of better 1 μm. Different **encoder systems** were studied

− **Test of a commercial system in PETRA II failed:**
radiation problems, high failure rate.

- Choice of in-house wire-systems HF-MoMo
- 145 MHz signal on $\lambda/4$ antenna picked up by 4 stiplines. Readout BPM like, bandwidth 1Hz.
- Gap 8x8mm, linear 2x2 mm.



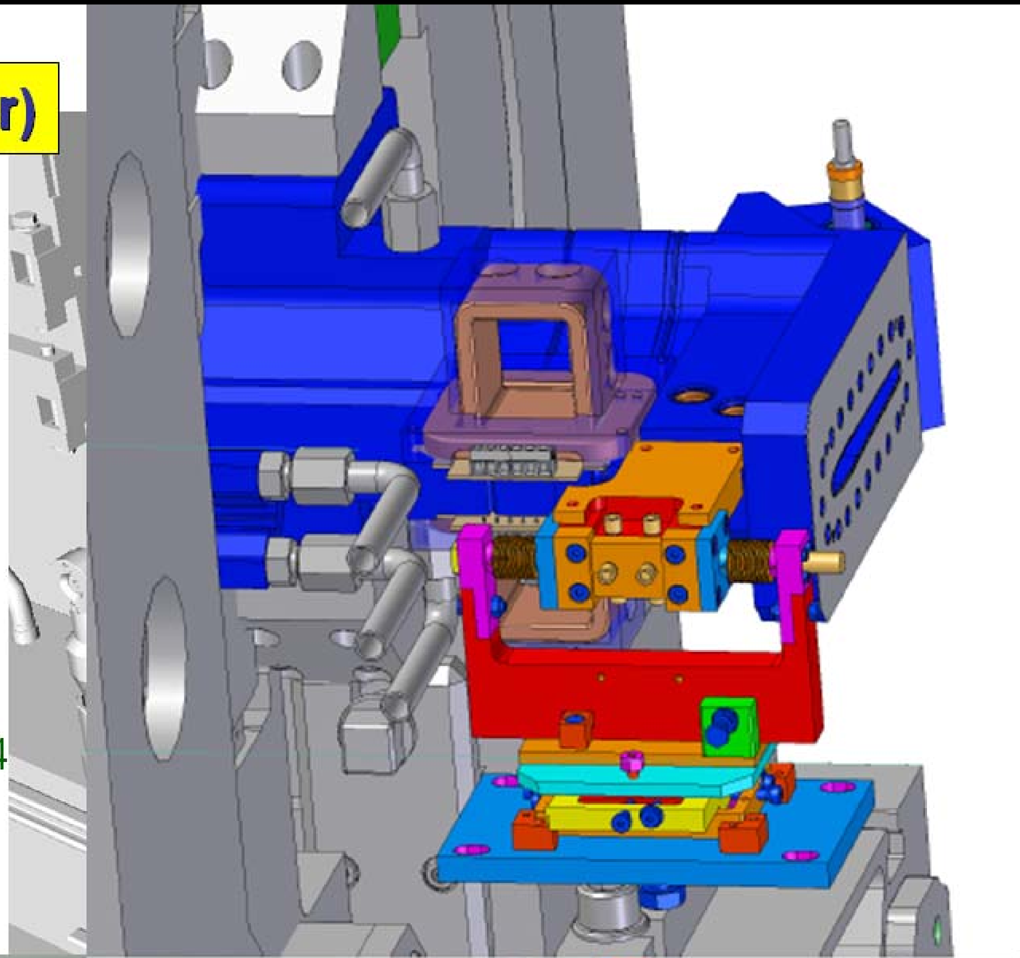


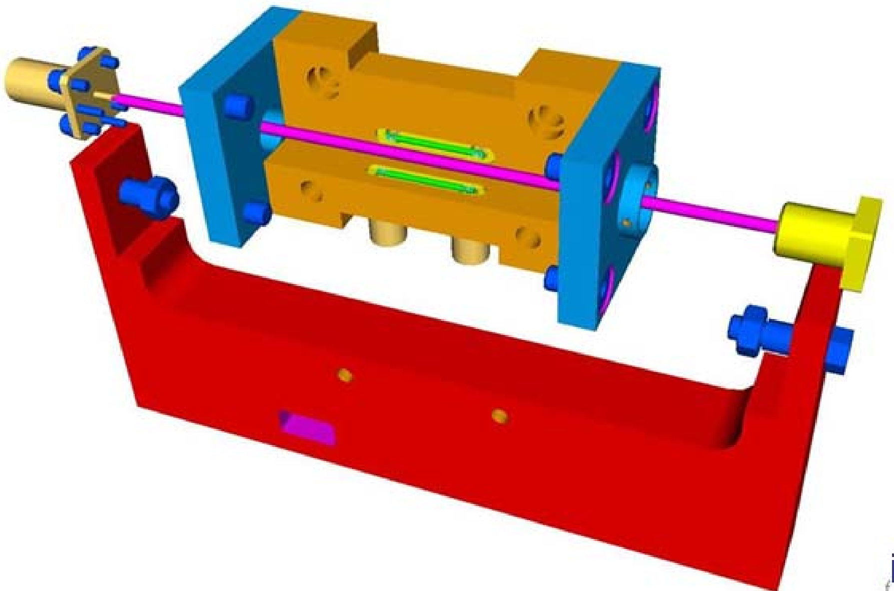
HF-MoMo (Movement Monitor)

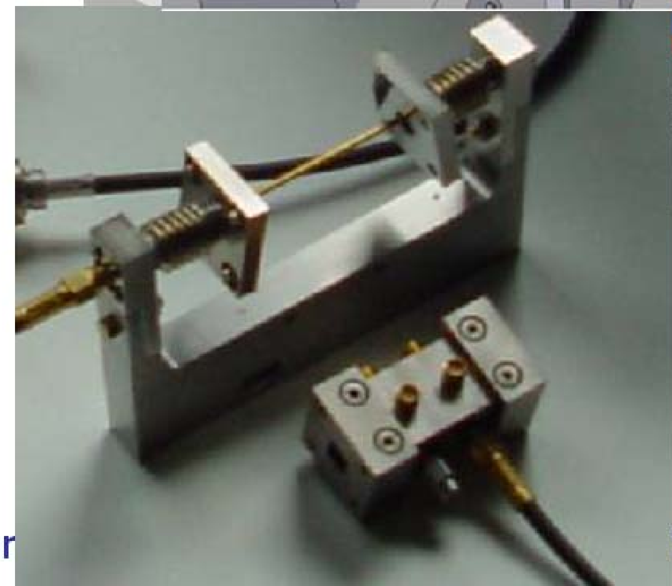
Near the undulators the movement of the BPMs (relative to ground) will be measured with a resolution of better 1 μm. Different **encoder systems** were studied

− **Test of a commercial system in PETRA II failed:**
radiation problems, high failure rate.

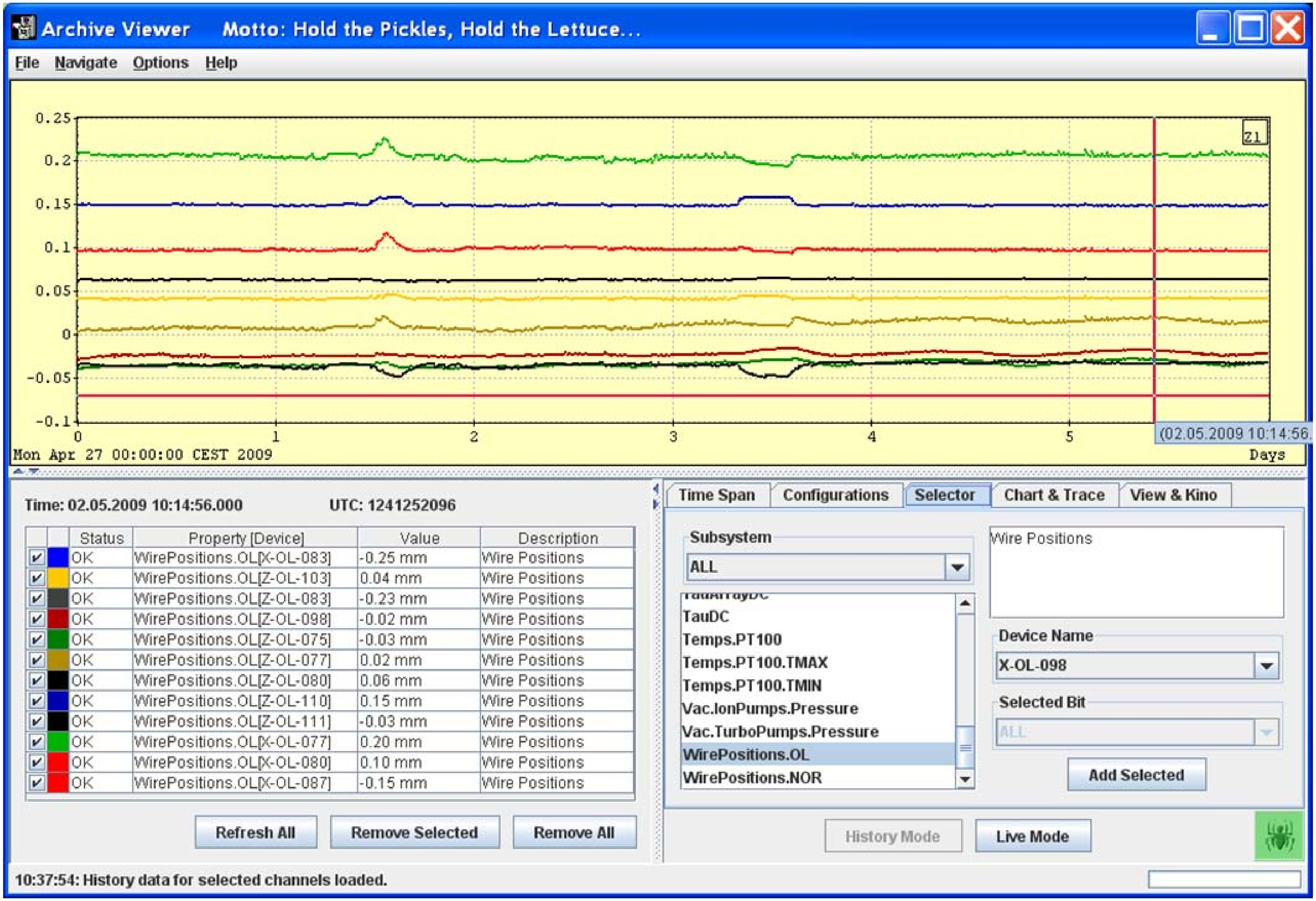
- Choice of in-house wire-systems HF-MoMo
- 145 MHz signal on $\lambda/4$ antenna picked up by 4 stiplines. Readout BPM like, bandwidth 1Hz.
- Gap 8x8mm, linear 2x2 mm.







HF- MOMO Measurements



Emittance Diagnostics: X-ray Beamline

- principle

  20 keV synchrotron radiation from bending magnet to image beam spot onto high resolution CCD camera system

- X-ray imaging optics

  Imaging via 2 interchangeable x-ray optical systems

  - Pinhole camera (standard operation)

    pinhole Ø 20 µm, resolution ≈ 20 µm

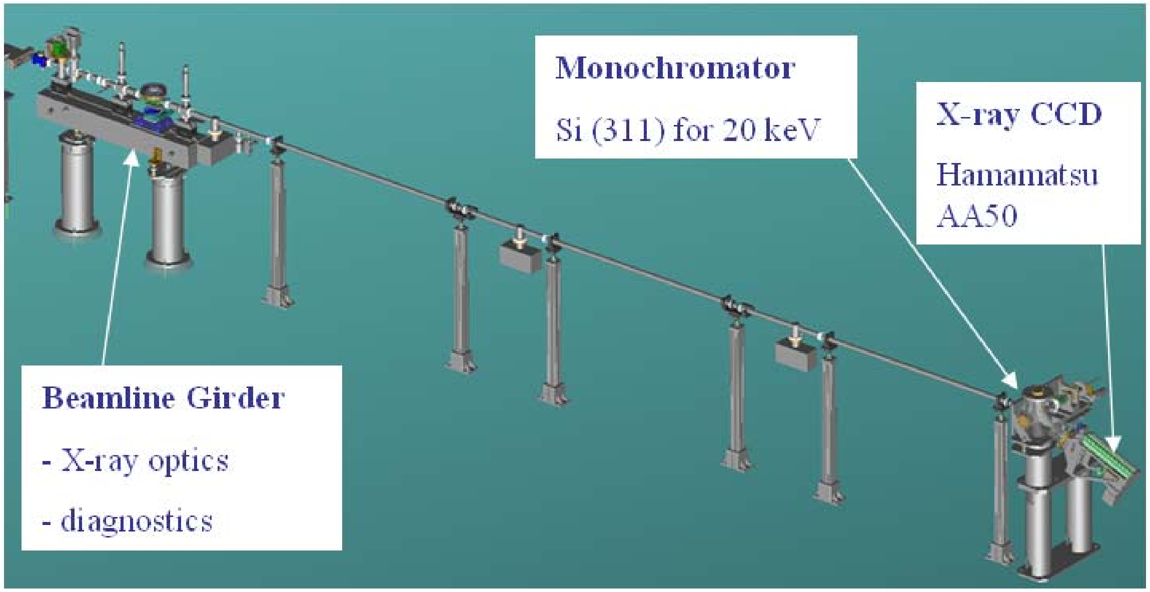
  - Compound refractive lenses (high resolution)

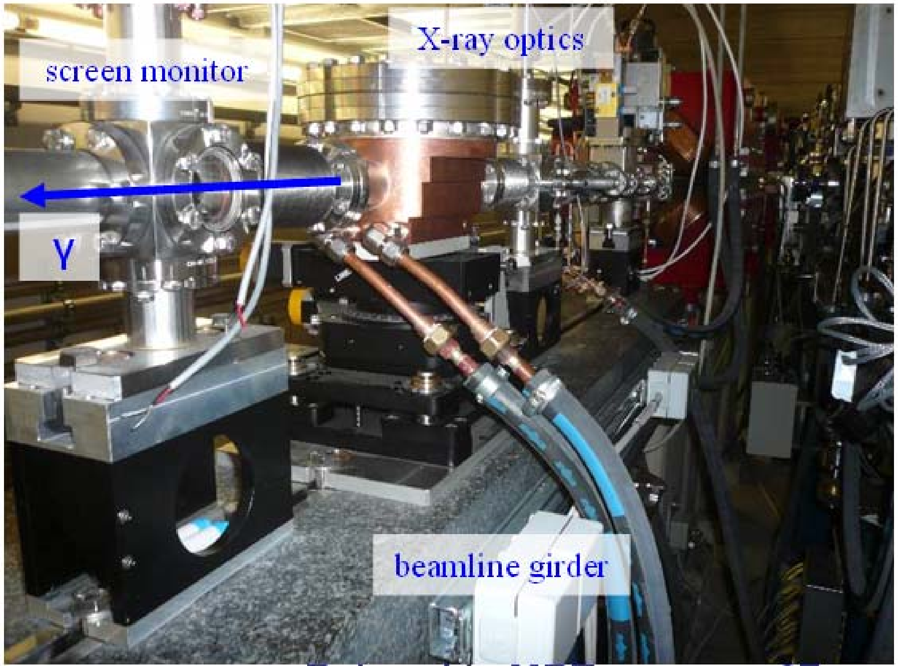
    31 lenses, material: Be

    resolution ≈ 2 µm

- status

  installation finished
  commissionning in next phase





Emittance Diagnostics: X-ray Beamline

- **principle**

  20 keV synchrotron radiation from bending magnet to image beam spot onto high resolution CCD camera system

- **X-ray imaging optics**

  Imaging via 2 interchangeable x-ray optical systems

  - Pinhole camera (standard operation)

    pinhole Ø 20 μm, resolution ≈ 20 μm

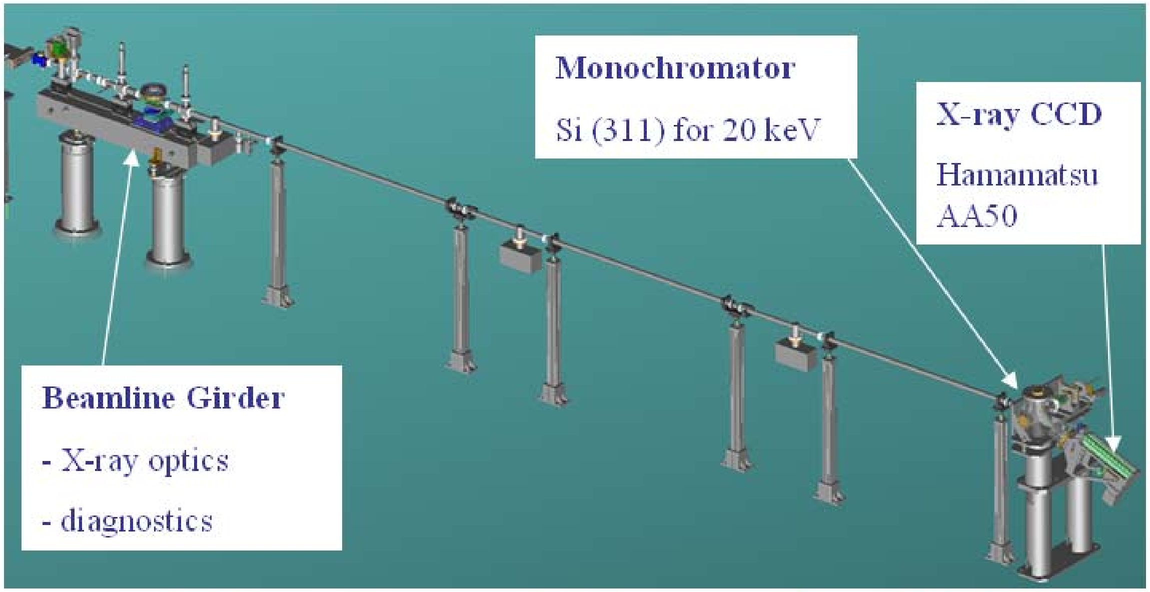
  - Compound refractive lenses (high resolution)

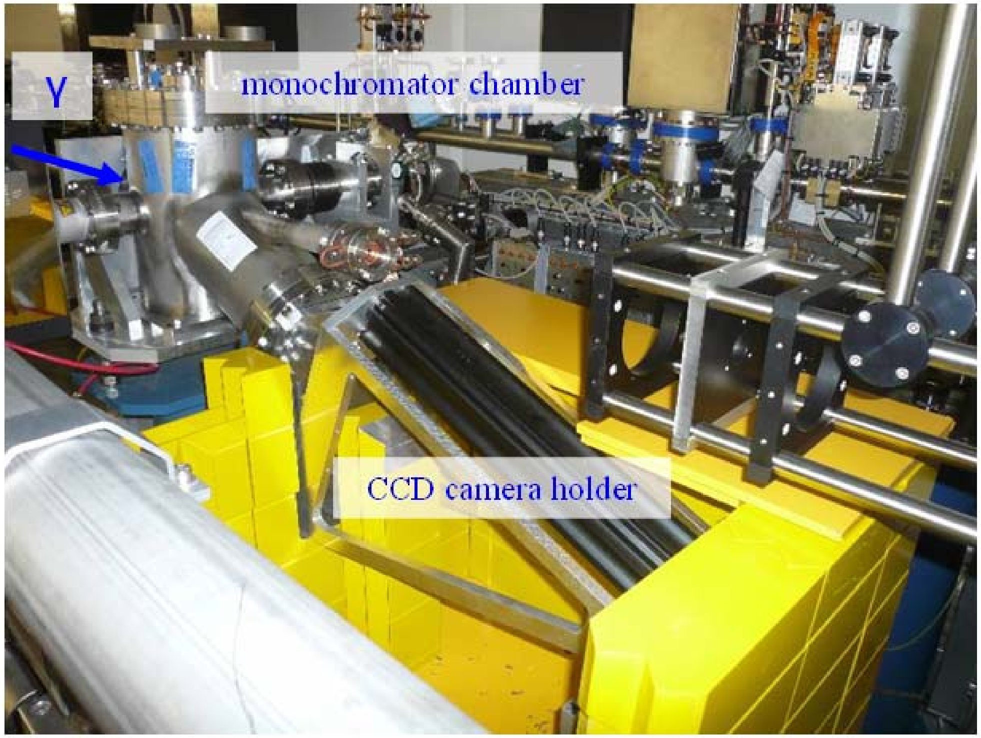
    31 lenses, material: Be

    resolution ≈ 2 μm

- **status**

  installation finished
  commissionning in next phase





Emittance Diagnostics: X-ray Beamline

- principle

  20 keV synchr
  bending magn
  onto high reso
  system

- X-ray imagi

  Imaging via 2
  x-ray optical s

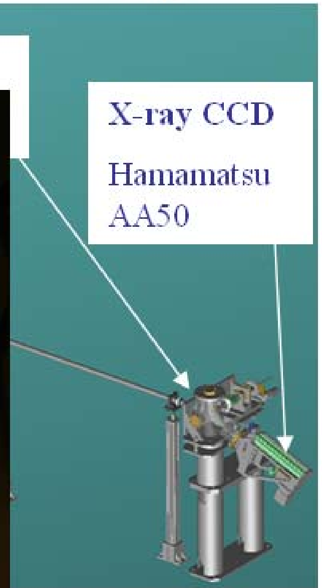
  - Pinhole cam

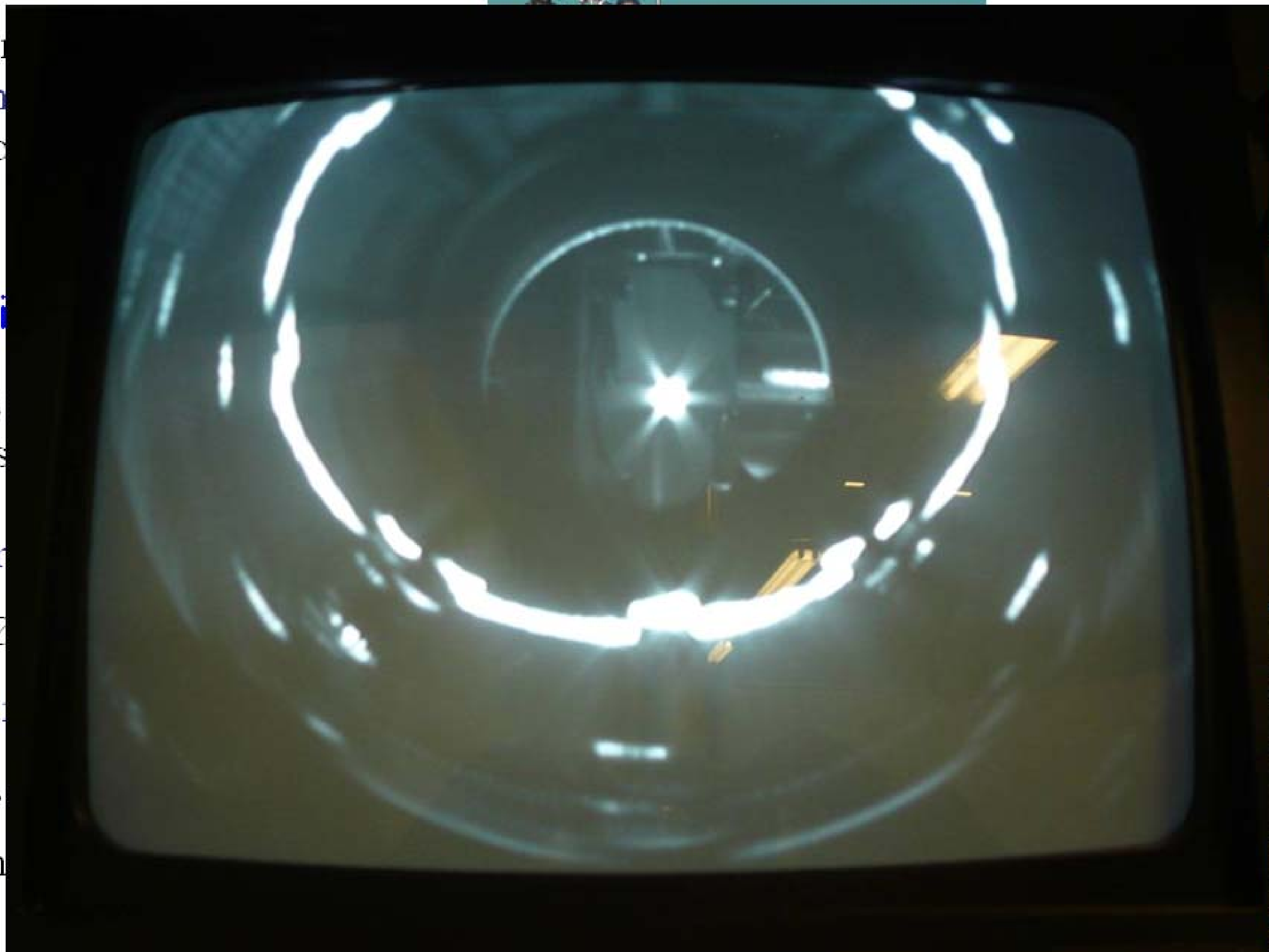
    pinhole Ø

  - Compound

    31 lenses,

    resolution





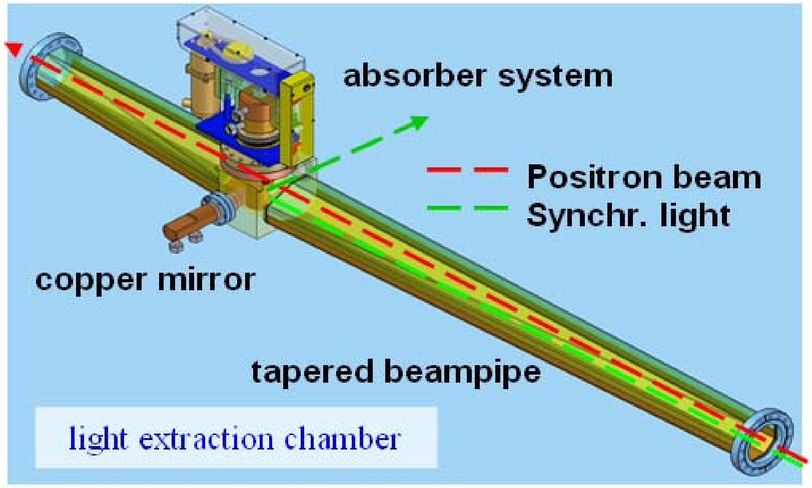
- status

  installation finished
  commissionning in next phase

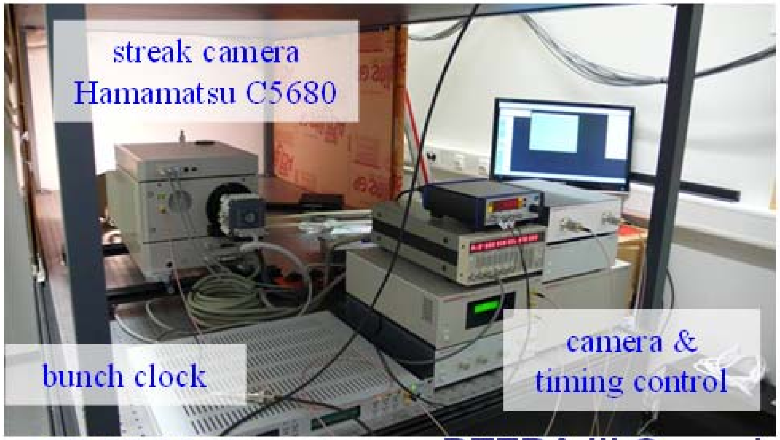
Bunch Length Diagnostics: optical Beamline

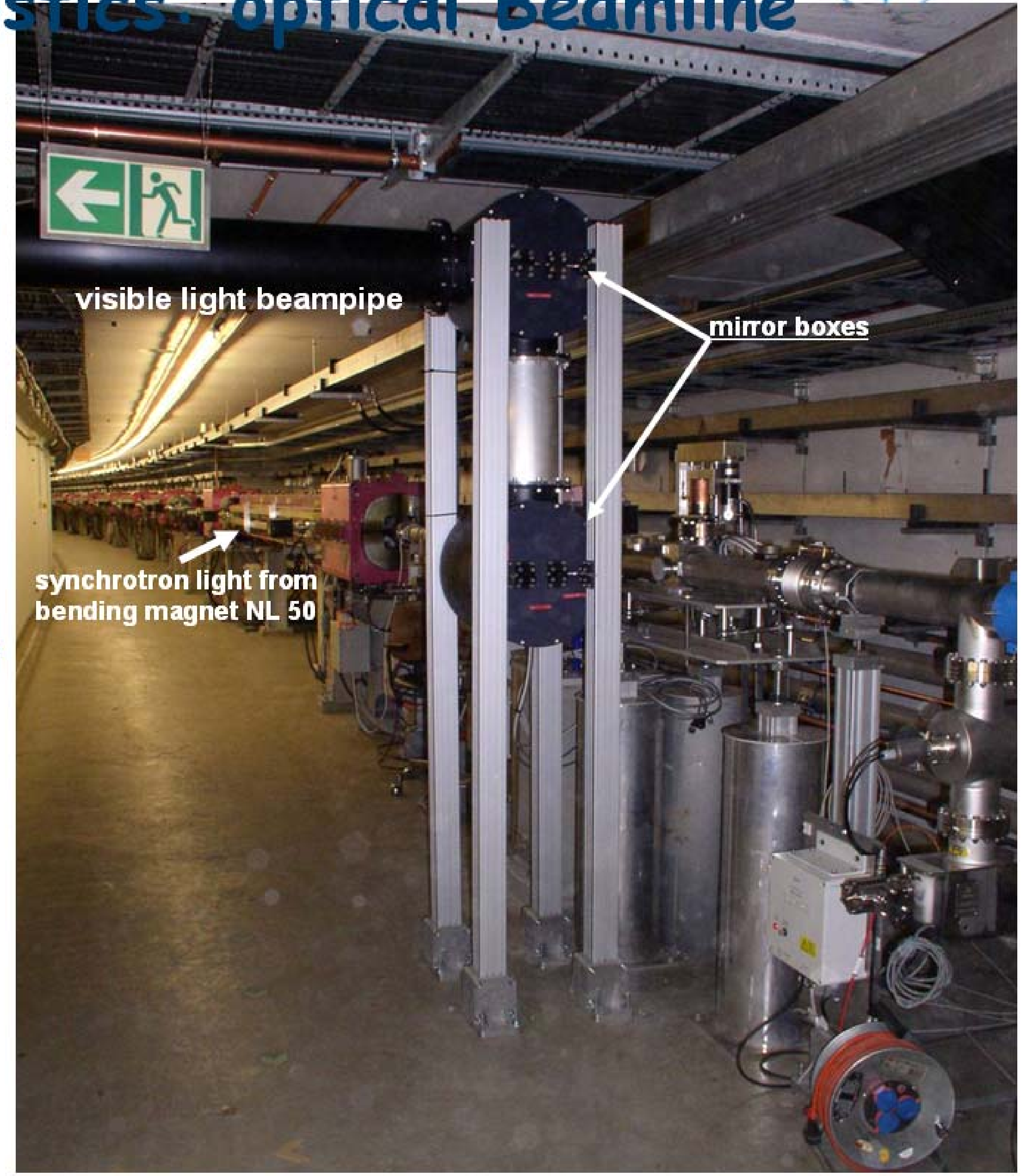
- Principle

visible synchrotron radiation from bending magnet



- Streak Camera System



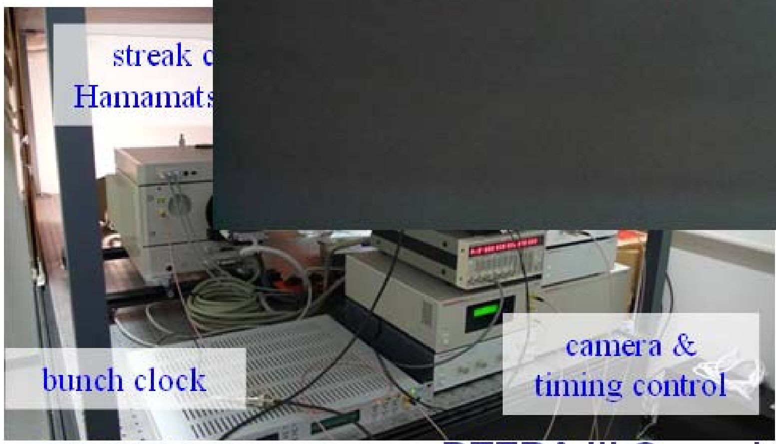


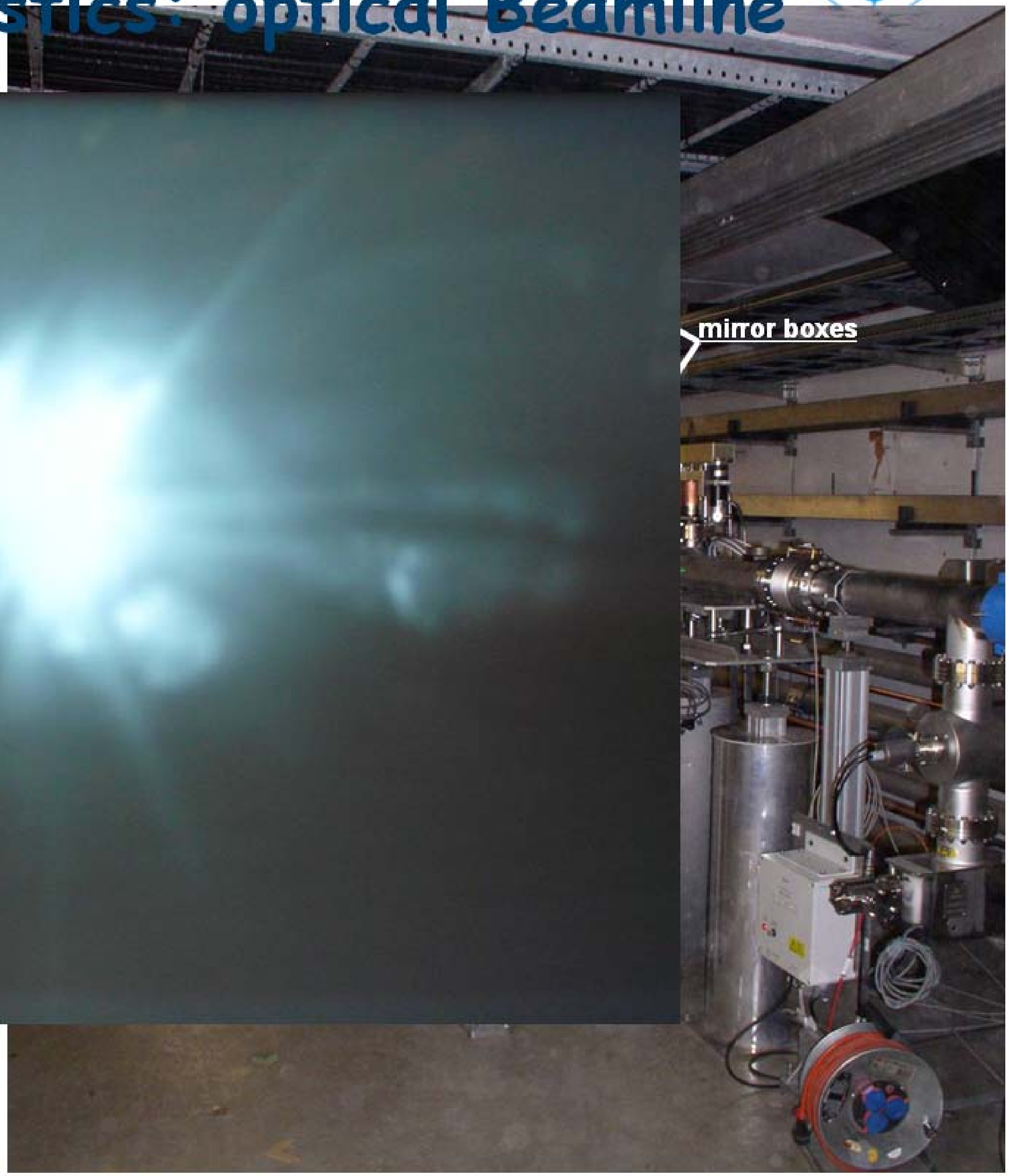
Bunch Length Diagnostics: optical Beamline

- Principle

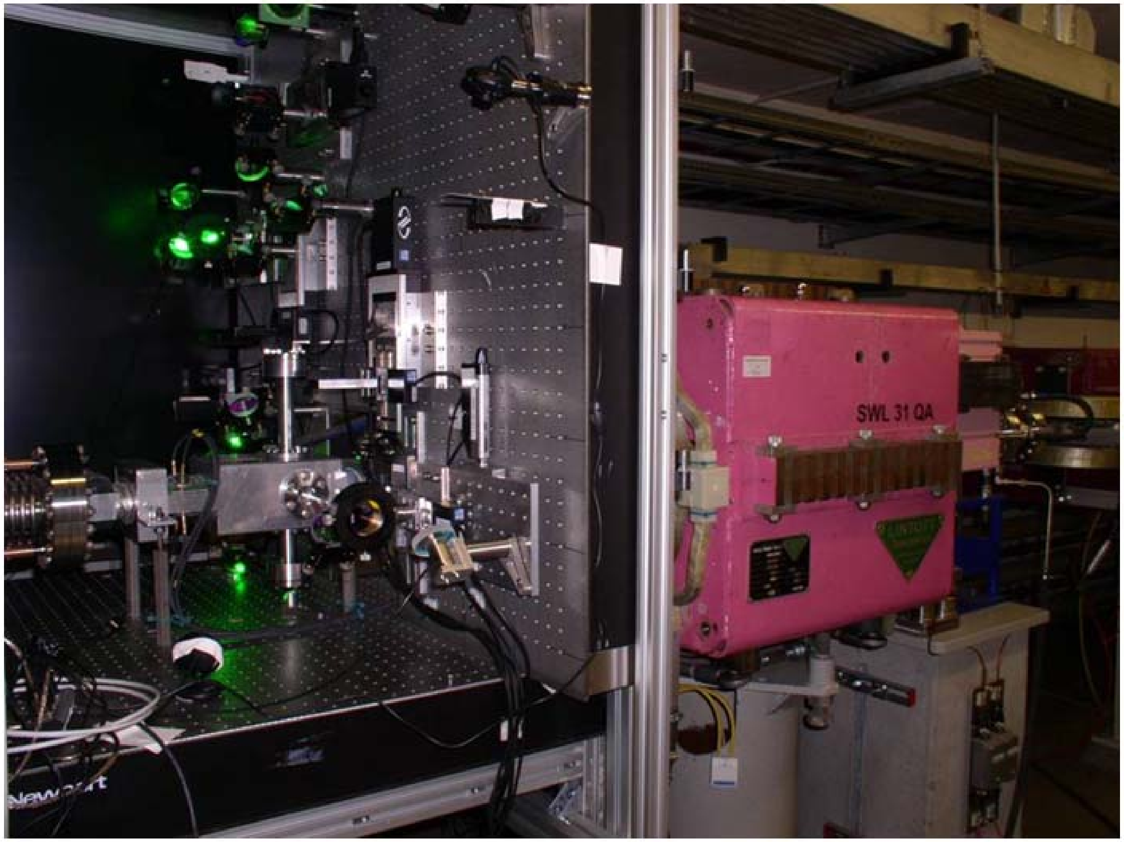
visible syn
bending m

- Streak C



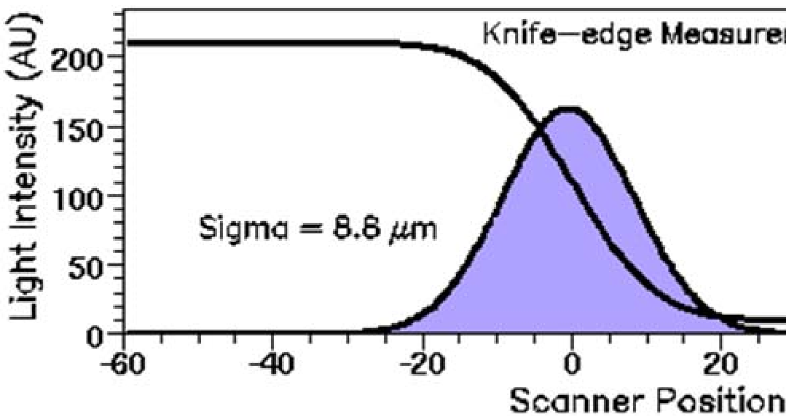


Laser Wire-Scanner



Laser-wire scanner optical setup at Petra SWL 32. Vertical and horizontal scans of the Laser versus the beam are possible

Puls length 100 ps
Scan within tens of seconds



A sample of laser spot size measurement at focus. A knife-edge scan is differentiated to obtain a gaussian. The laser-wire diameter is below 10um which is verified by in-situ calibrations.

Summary

- The first commissioning phase of PETRA III went smoothly and very fast.
- No major problem was encountered.
- Detailed investigation of the machine will be part of the next phase.

- The success of the first phase is certainly due to sufficient diagnostics that worked well right from the beginning.

- At this point also the support and commitment of those who took part in the commissioning is greatly acknowledged.

Thank you for your attention