PETRA IV.
NEW DIMENSIONS

Development towards a new BPM system for the PETRA IV project at DESY

Online Libera Workshop
June 2021

Gero Kube
Hamburg, 10.6.2021

- Introduction
- PETRA IV Project at DESY
- BPM System for PETRA IV
- Laboratory Investigations at I-Tech
- Long Term Stability Measurements at PETRA III

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

DESY Accelerator Complex (Hamburg, Germany)

User Facilities

PETRA III @ DESY

History

PETRA IV. NEW DIMENSIONS

- 1978 – 1986: e^+e^- collider (up to 23.3 GeV / beam)
- 1988 – 2007: pre-accelerator for HERA (p @ 40 GeV, e @ 12 GeV)
- since 2007: dedicated 3rd generation light source, commissioned in 2009 TDR: DESY 2004-035

  → 14 beamlines (15 experimental stations) operating in parallel

- from 2014: staged extension project W. Drube et al., 2016 https://doi.org/10.1063/1.4952814

  → up to 12 additional beamlines (presently not all of them in operation)

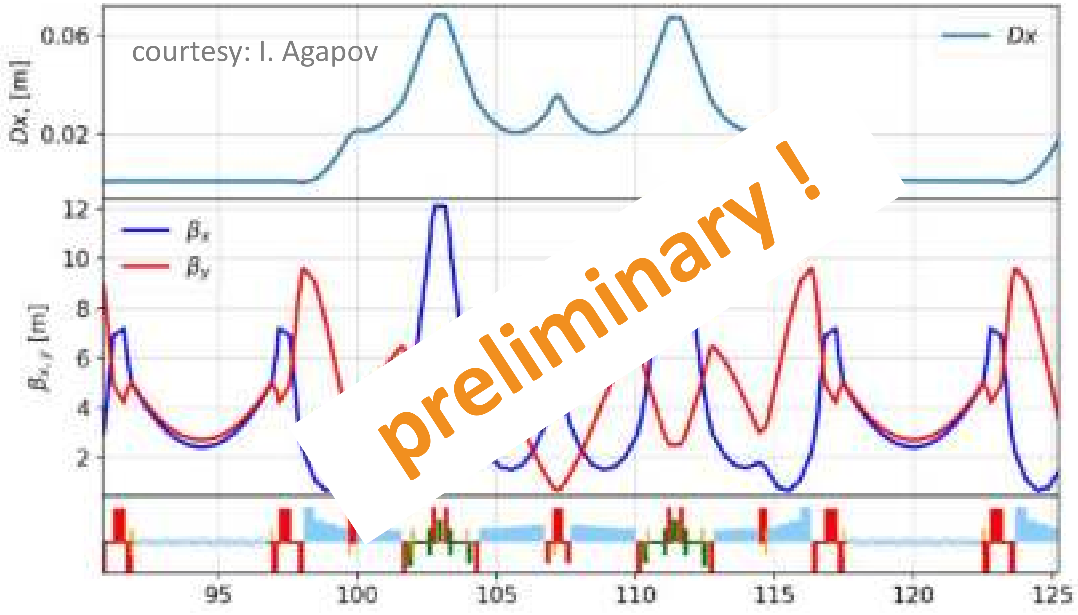
Parameter			
Energy	6		GeV
Circumference	2304		m
Emittance (hor. / vert.)	1.2 / 0.012		nm rad
Total current	100		mA
Number of bunches	960	40	
Bunch population	0.5	12	10^{10} e^-
Bunch separation	8	192	ns

PETRA IV @ DESY

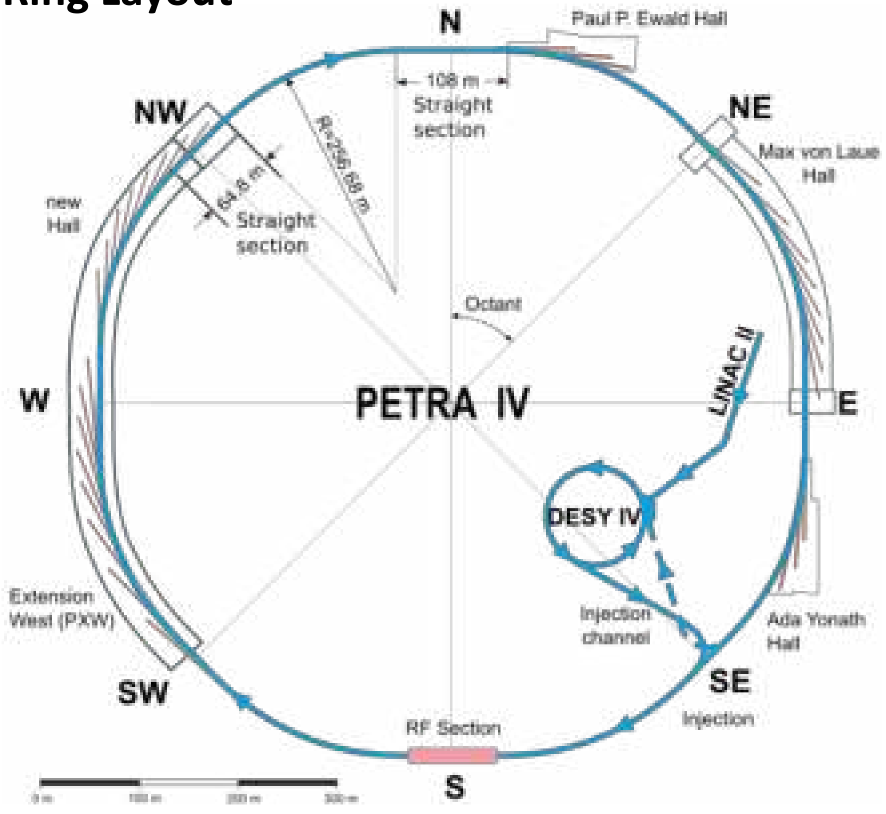
Diffraction Limited Storage Ring → Multi Bend Achromat Lattice

Lattice Overview

- most likely: H6BA (proposal P. Raimondi, ESRF)
  - → large dispersion, weak sextupoles
- natural emittance ~50 pm.rad
  - → recovered by damping wigglers



Ring Layout



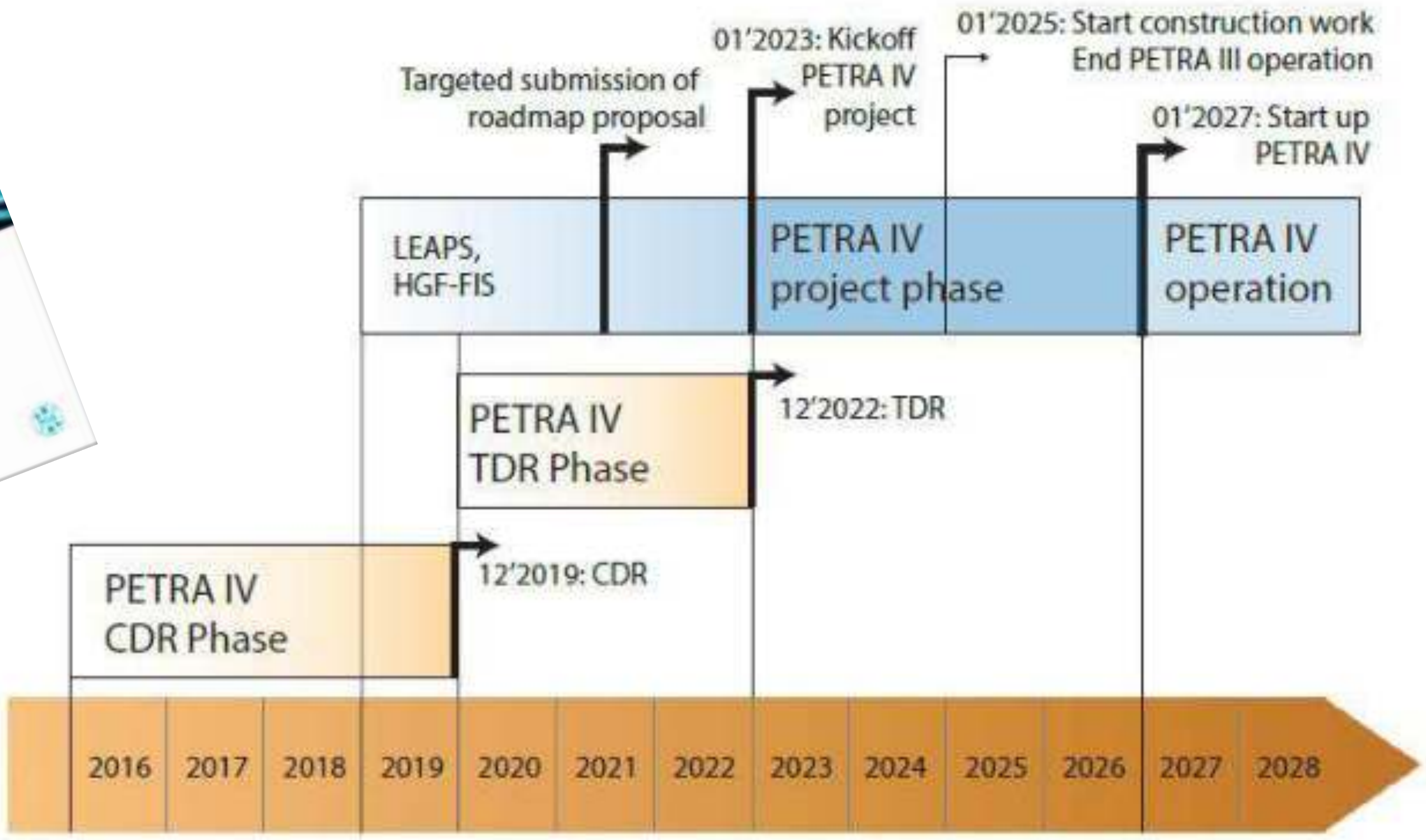
Design parameter	PETRA III		PETRA IV	
Energy / GeV	6		6	
Circumference / m	2304		2304	
Operation mode	Continuous	Timing	Brightness	Timing
Emittance (horz. / vert.) / pm rad	1300 / 10		< 20 / 4	< 50 / 10

PETRA IV @ DESY

Timeline

CDR

DOI: 10.3204/PUBDB-2019-03613



C.G. Schroer et al., PETRA IV: Upgrade of PETRA III to the Ultimate 3D X-ray Microscope. Conceptual Design Report

Beam Position Monitor (BPM) System for PETRA IV

PETRA IV
NEW DIMENSIONS

Requirements

Performance (Electronics)

• resolution on single bunch / turn	(0.5 mA / bunch)	< 10 µm
• resolution on closed orbit	(200 mA in 1600 bunches @ 1 kHz BW)	< 100 nm (rms)
• beam current dependence	(60 dB range, centered beam)	± 2 µm
• long term stability	(measured over 6 days, temperature span ±1°C within a stabilized rack)	< 1 µm

First Turn Steering Tolerances (Mechanics & Electronics) < 500 µm

- manufacturing (pickup, feedthroughs, …)
- alignment
- electrical offset

BPM System for PETRA IV

Boundary Conditions

Number of BPMs: about 700

- 9 BPMs per cell / 64 cells → 576 BPMs in arcs
- 8 BPMs in short, 12 BPMs in long straight sections

656 BPMs (incl. spares: ~700)

➡ cost / space are important factors

≤ 10 k€ (per channel)

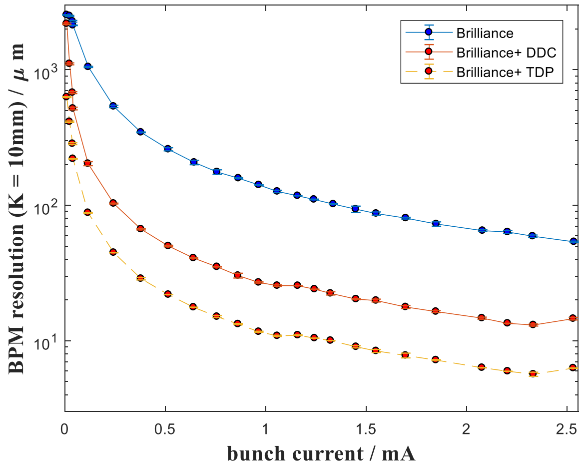
In-house Development: no time and manpower ➡ commercial solution

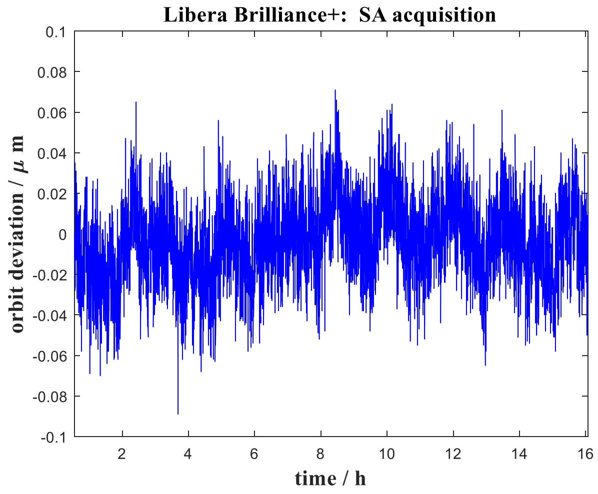
Libera Brilliance: will not fulfil requirements

G. Kube *et al.*, Proc. IBIC2019, Malmö, Sweden, WEPP005

Libera Brilliance+: would fulfil requirements

- in use at MAX-IV
- planned for APS-U





BPM System for PETRA IV

Long Term Stabilization

Drawback Libera Brilliance+

- long term stabilization starts at RF front-end ➡ influence of cable paths !

Critical Aspect for PETRA IV

- large machine circumference
- limited space in old tunnel segments
- large number of BPMs

  → additional access points required to bring BPM cables out of tunnel

- climate conditions at access points yet undefined

➡ stabilization of cable paths !

BPM System for PETRA IV

DESY Strategy

Stabilization

- well proven technology → crossbar switching
- stabilization of cable paths → separate analogue switching part from LB+ and bring it as close as possible to BPM

DESY Lab Strategy: MTCA.4 as technical platform

Development Project with I-Tech

- prototype development of MTCA.4 based BPM system
- crossbar switching with separated switching matrix

first Proof-of-Principle Measurements

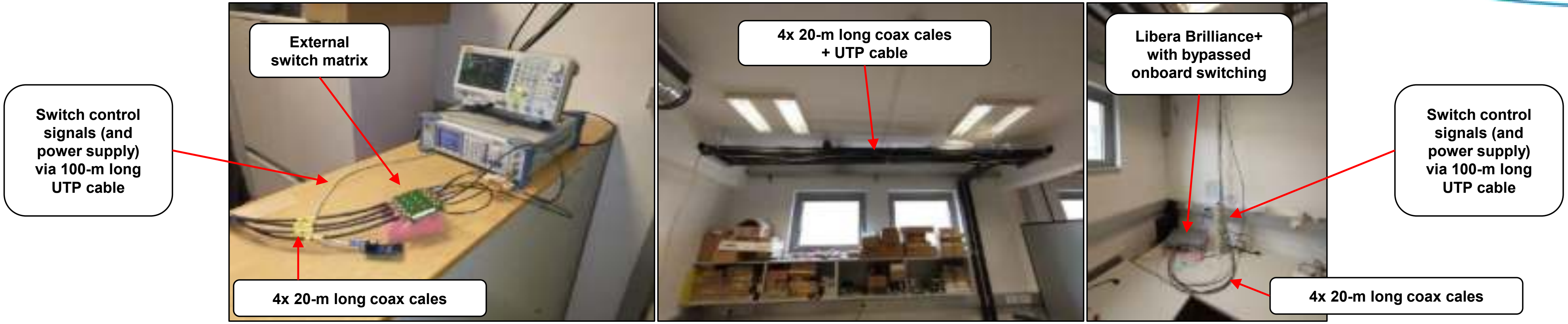
- lab measurements at I-Tech
- measurements with beam at PETRA III

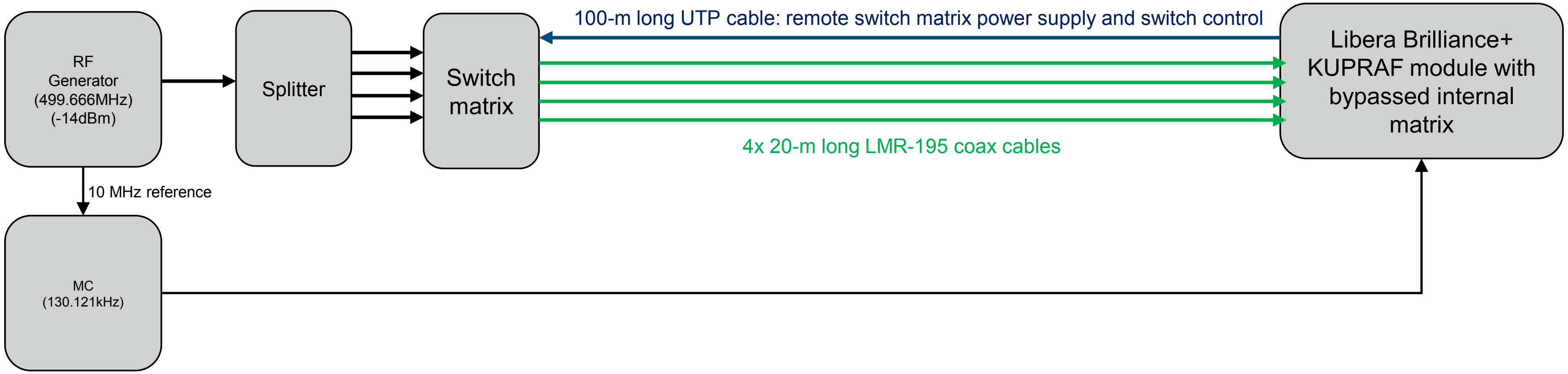
Remote Switching: Test at I-Tech

INSTRUMENTATION TECHNOLOGIES

PETRA IV. NEW DIMENSIONS

Concept





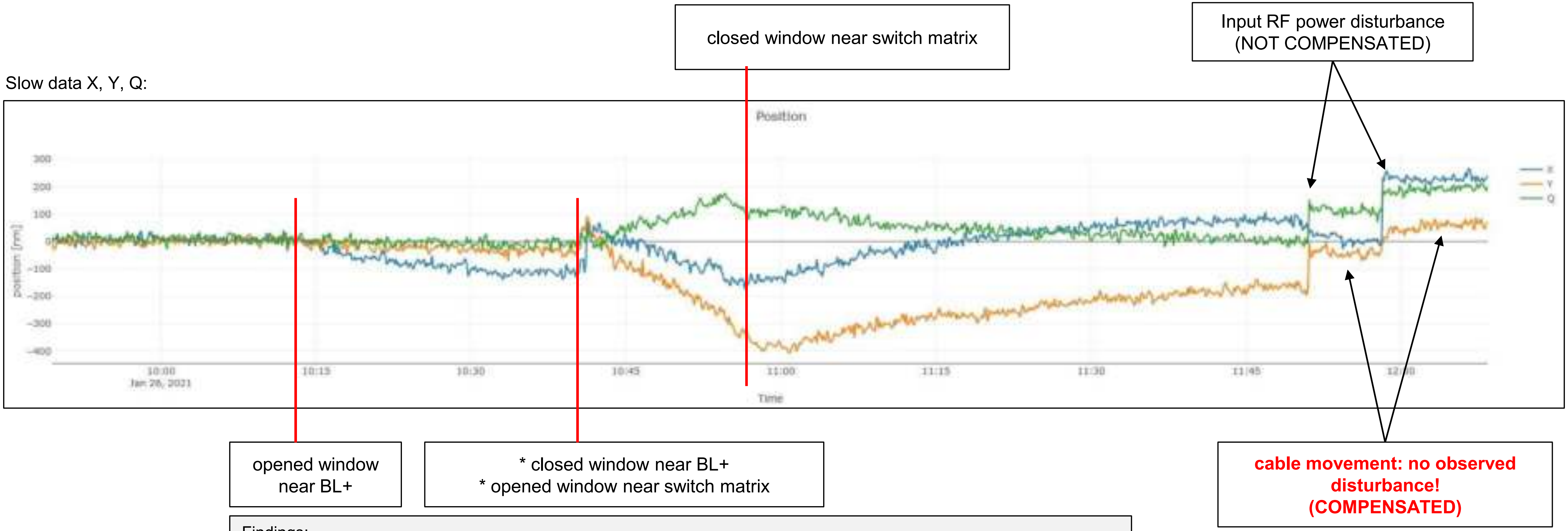
courtesy: Luka Bogataj (I-Tech)

Remote Switching: Test at I-Tech

Concept

Preliminary Results

Slow data X, Y, Q:



Findings:
- Insensitivity to short term disturbance in cables
- Long term stability defined by switch matrix
- Power supply and control signal distribution via 100-m long UTP cable is feasible
- Beam current dependence, single bunch performance and crosstalk is comparable to local switching concept

courtesy: Luka Bogataj (I-Tech)

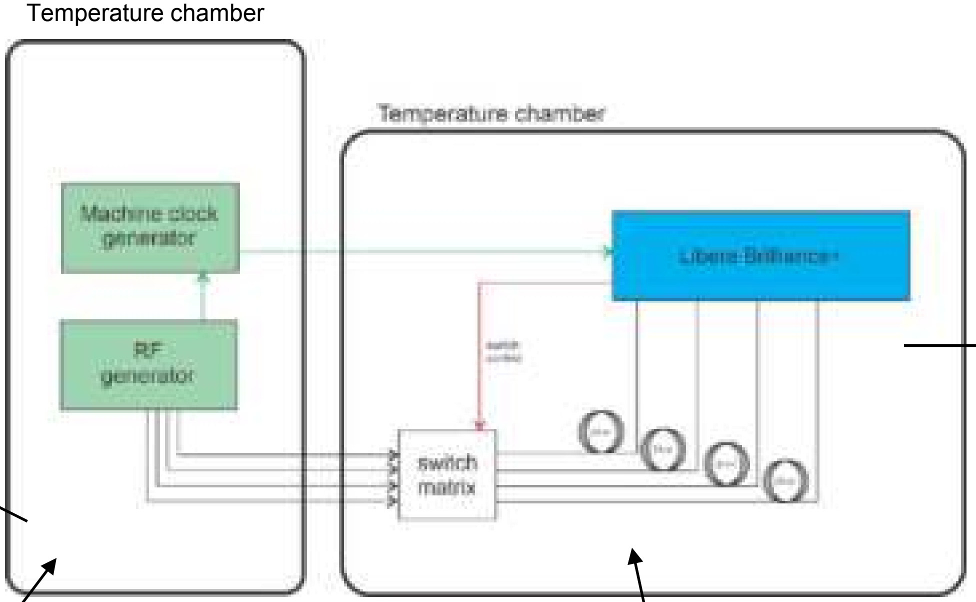
Remote Switching: Test at I-Tech

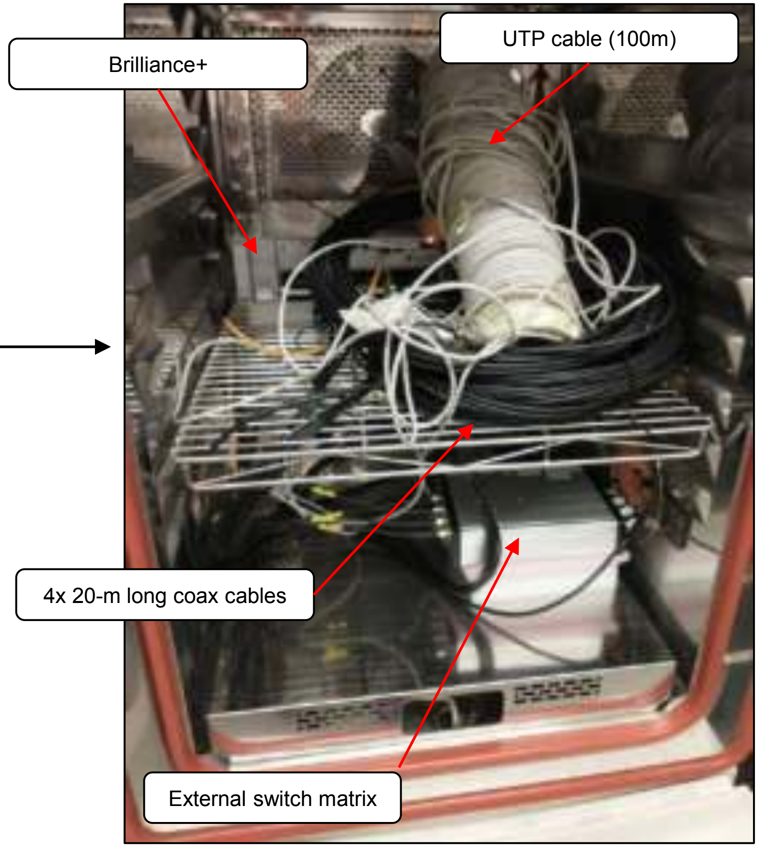
INSTRUMENTATION TECHNOLOGIES

PETRA IV. NEW DIMENSIONS

Temperature Chamber Experiment

to further evaluate remote switching concept, temperature chamber was used to control environment:





constant temperature

signal source (with power splitter) was placed in constant evironment to minimize its effect on measurement.

Temperature profile
(25°C-30°C-25°C-20°C-25°C-30°C…)

courtesy: Luka Bogataj (I-Tech)

Remote Switching: Test at I-Tech

INSTRUMENTATION TECHNOLOGIES

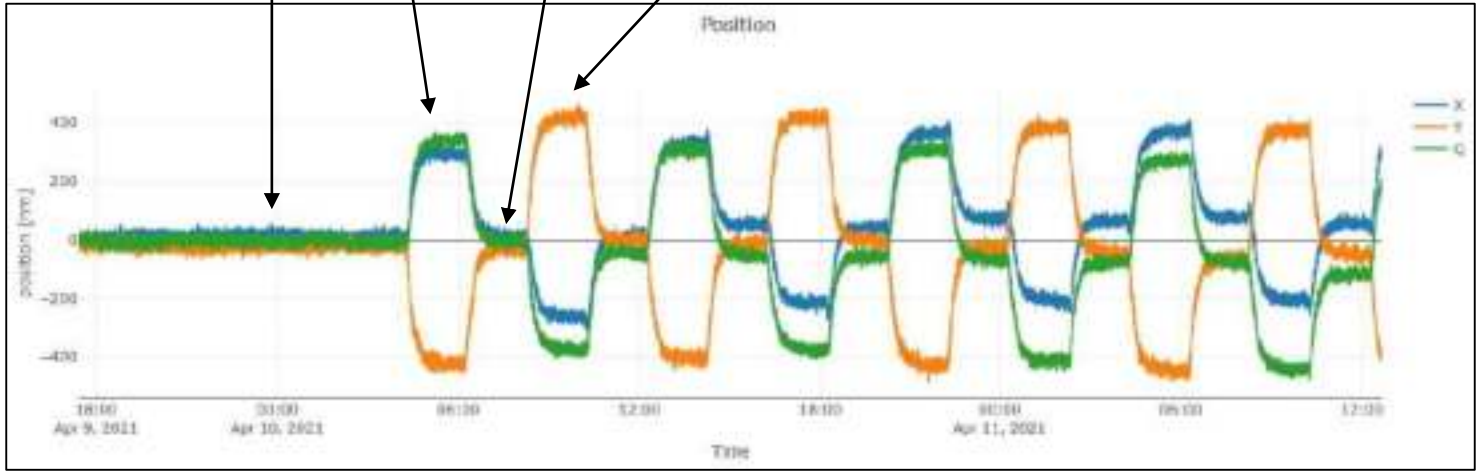
PETRA IV
NEW DIMENSIONS

Temperature Chamber Experiment

Results:

25°C | 30°C | 25°C | 20°C — temperature of switch matrix, <u>cables</u> and Brilliance+

Slow data X, Y and Q:



X, Y and Q temperature coefficient (nm/K):

	X	Y	Q
Temperature coefficient (nm/K)	64	-81	71

temperature coefficient of remote switching concept is comparable to onboard switching with no external cables!

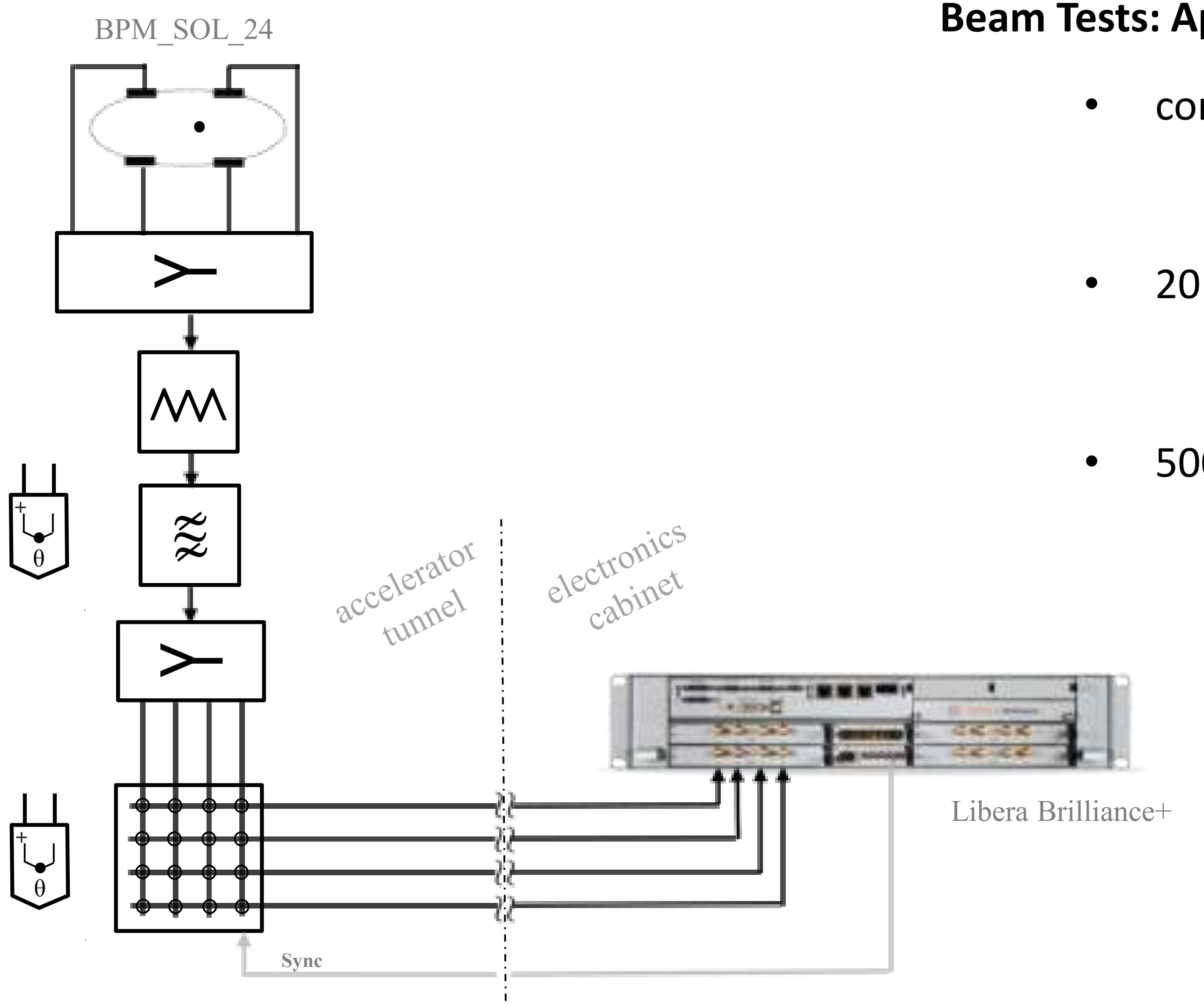
temperature coefficient of external switch matrix dominates total temperature coefficient.

no need for length matched coaxial cables!

courtesy: Luka Bogataj (I-Tech)

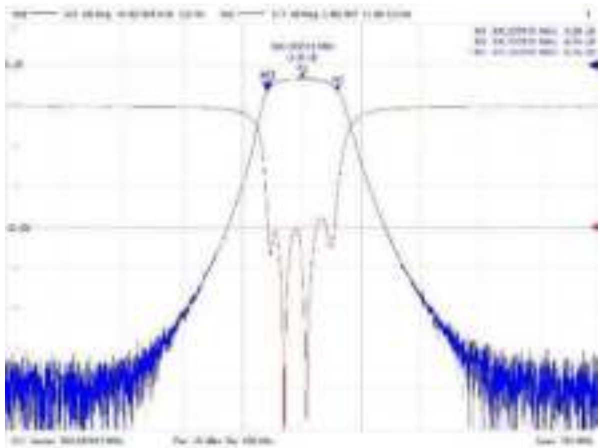
Measurements at PETRA III

Test Setup



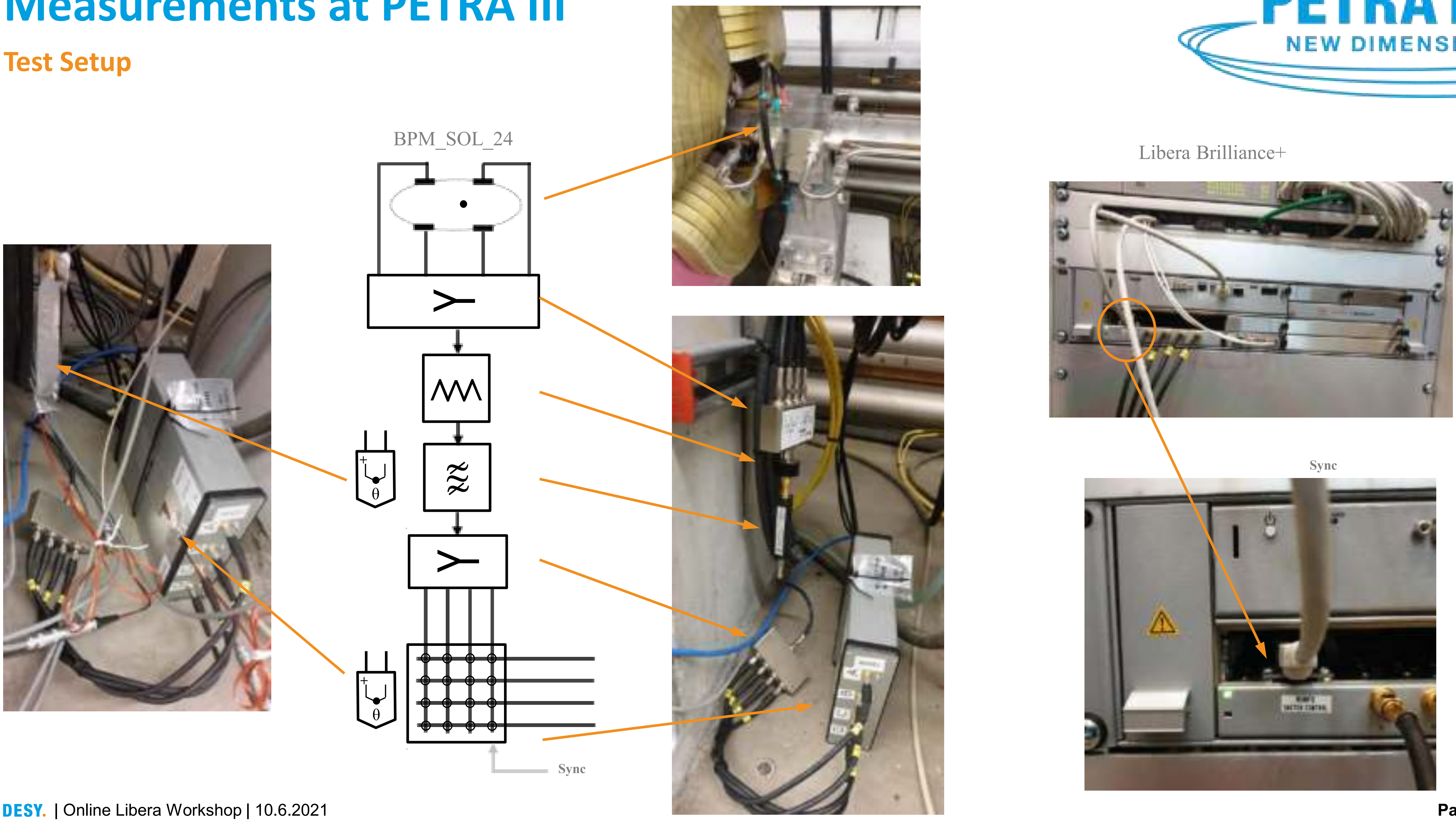
Beam Tests: April / May 2021

- combiner / splitter
  - → MACOM DS-409-4
- 20 dB attenuator
  - → Radiall 20dB
- 500 MHz bandpass filter
  - → Wainwright Instruments WBK500-15-5SS



Measurements at PETRA III

Test Setup

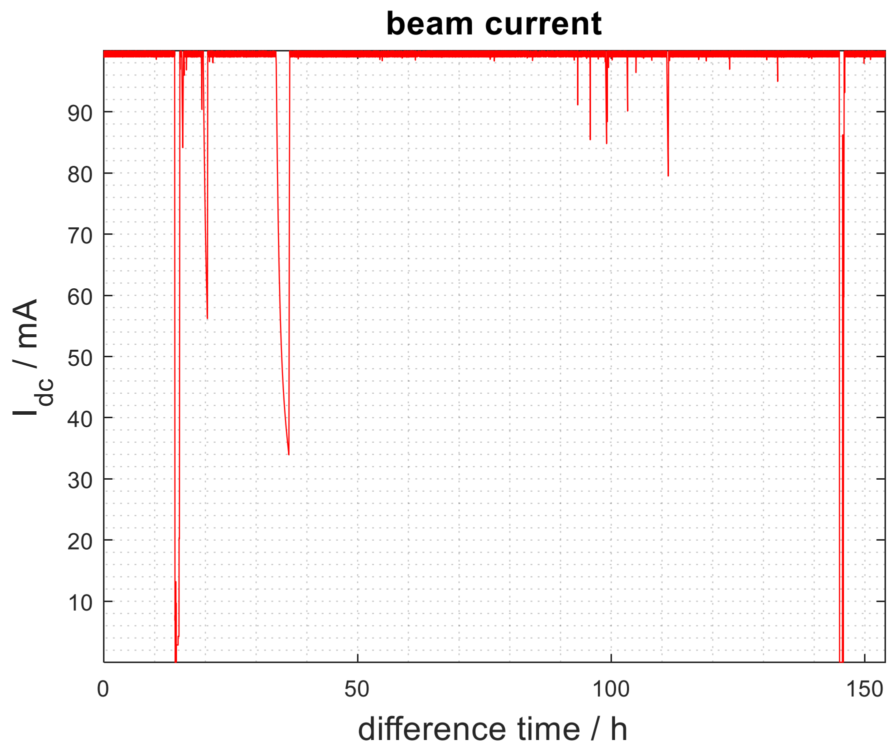


Measurements at PETRA III

Long Term Measurement #1

Beam Condition

- user run: 40 bunches @ 100mA
- 2x beam losses, in between several partial beam losses

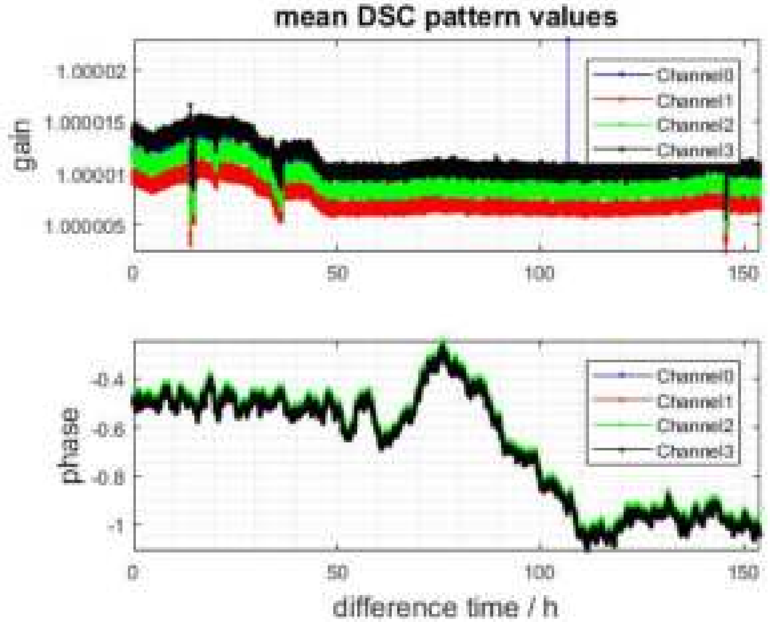


Procedure

- take about 50,000 SA samples
- start of measurements: switch AGC on for 15s

  → afterwards switch AGC off → -35 dB gain

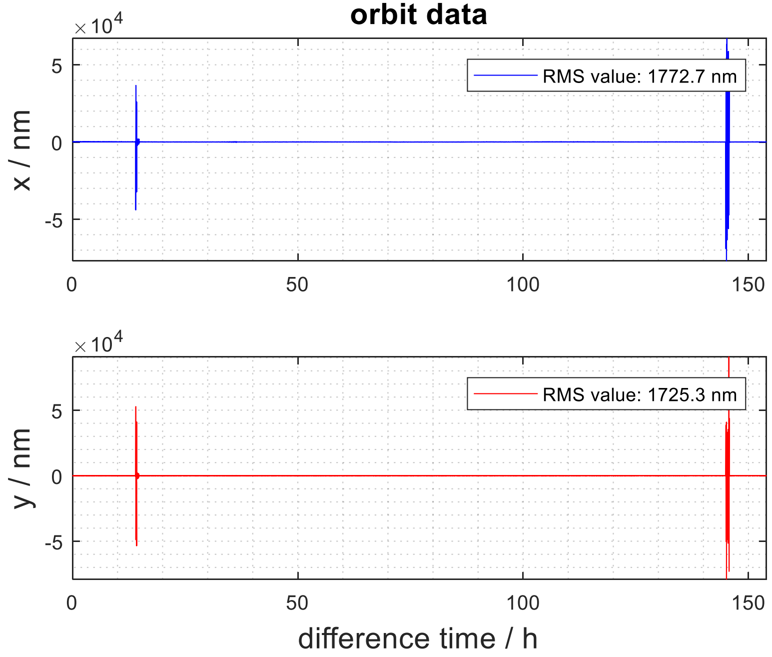
- DSC & Switching: on



Measurements at PETRA III

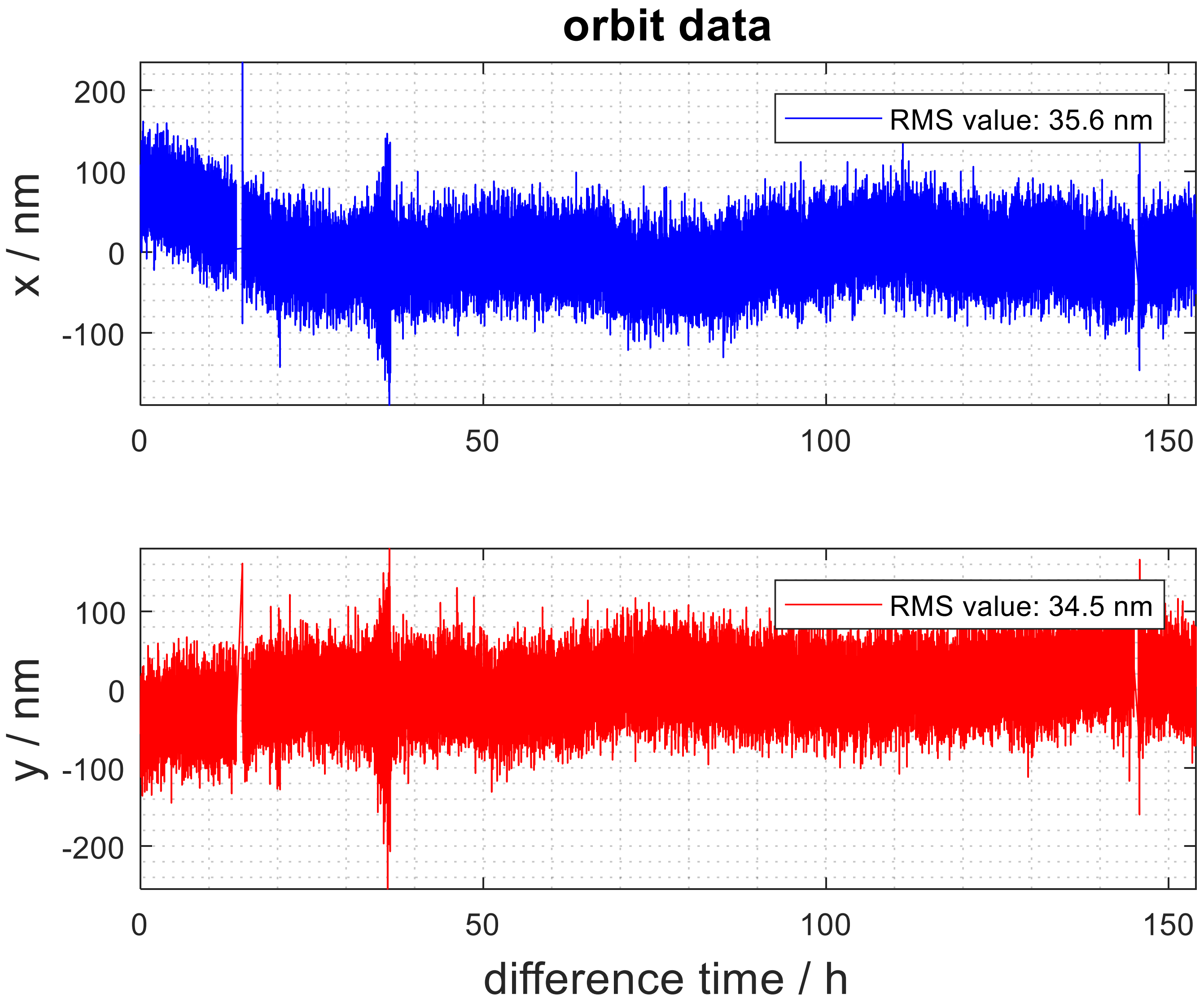
Long Term Measurement #1

Orbit RMS Value



- exclude time of beam loss and refill

  → consider only data for I_{dc} > 25mA

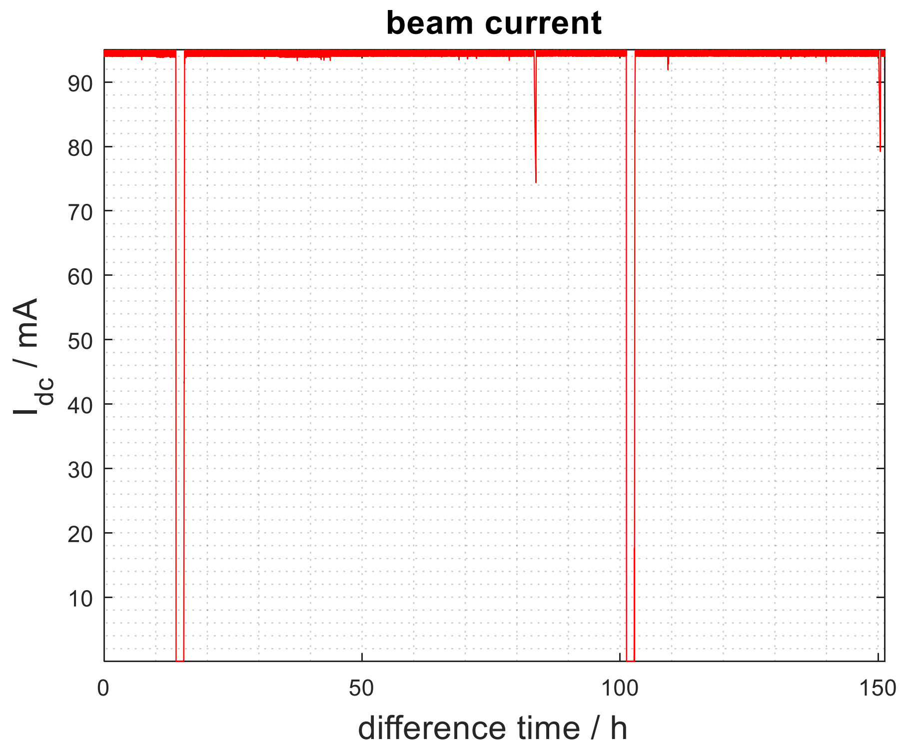


Measurements at PETRA III

Long Term Measurement #2

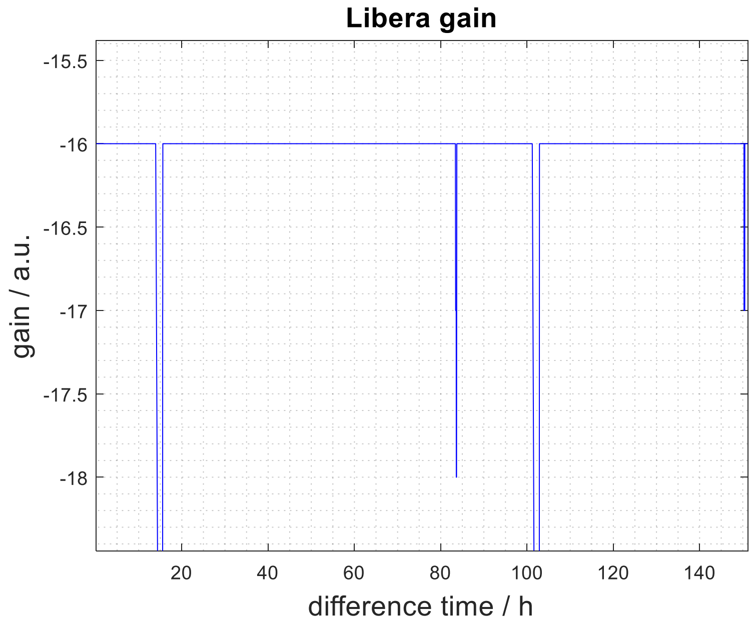
Beam Condition

- user run: 40 bunches @ 95mA
- 2x beam losses, 2x delay in top-up sequence



Procedure

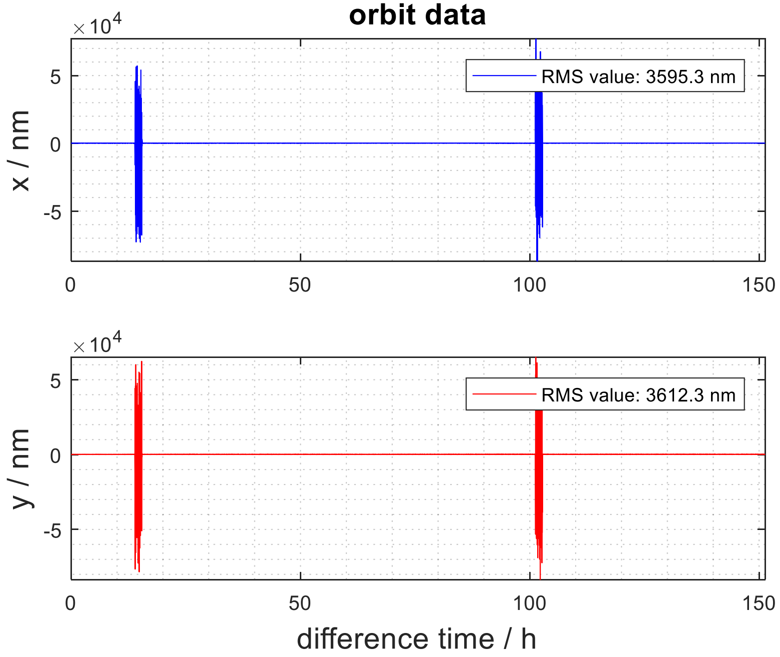
- 20dB attenuator removed in signal chain
- take about 50,000 SA samples
- keep AGC on
- DSC & Switching: on



Measurements at PETRA III

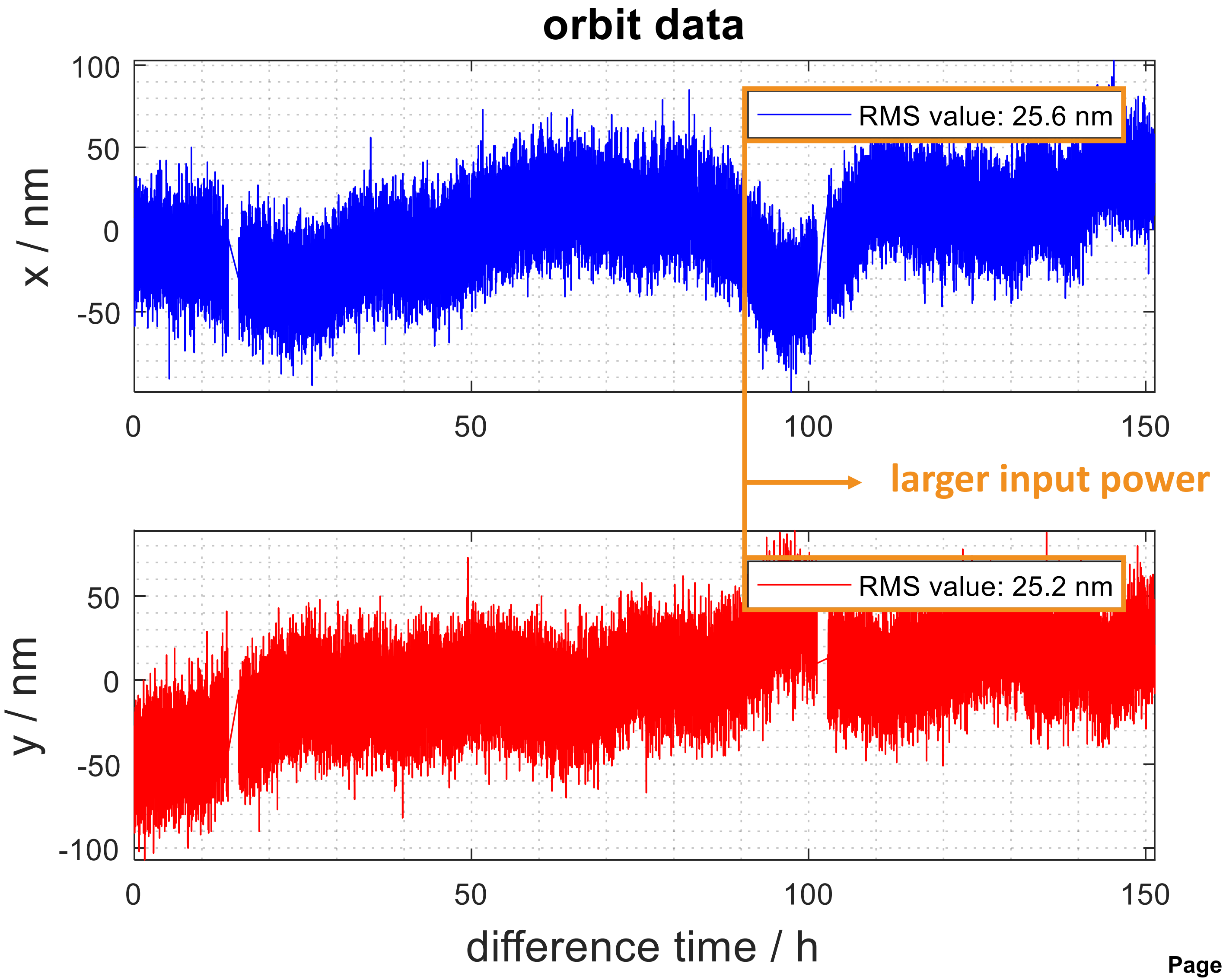
Long Term Measurement #2

Orbit RMS Value



- exclude time of beam loss and refill

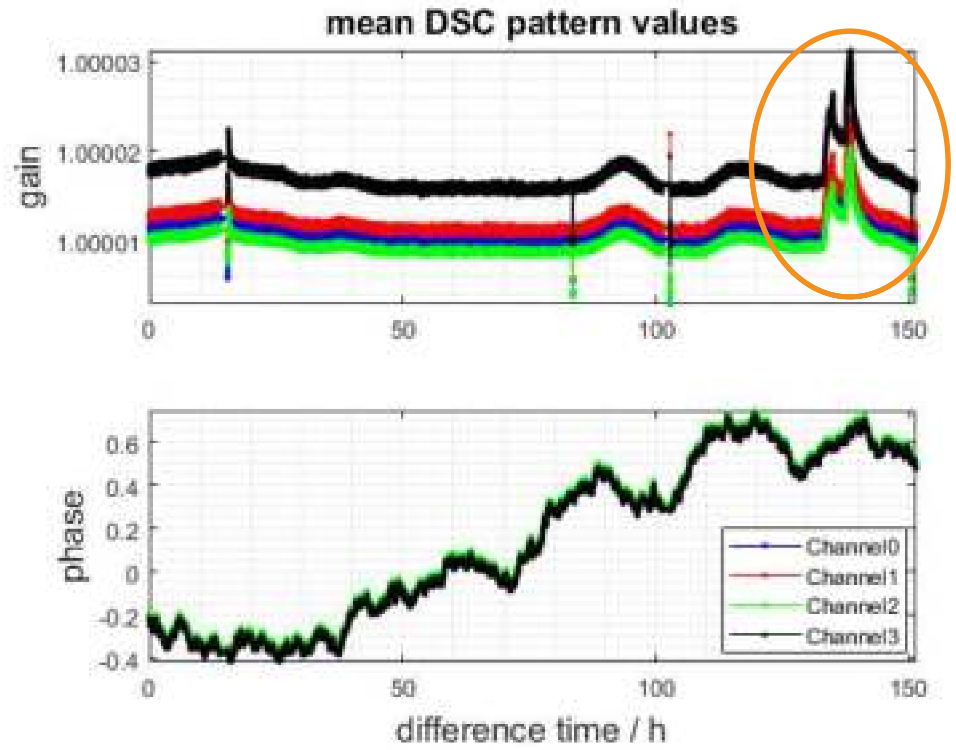
  → consider only data for I_{dc} > 25mA



Measurements at PETRA III

Long Term Measurement #2

DSC coefficients



correlation

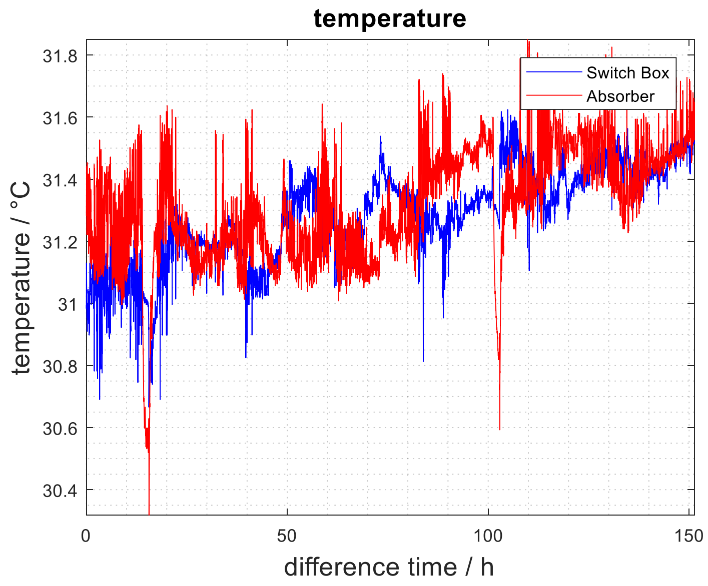
with rack

temperature

no obvious correlation

with tunnel

temperature



Summary and Outlook

PETRA IV

- new diffraction limited storage ring project at DESY
- based on multi-bend achromatic lattice
- commissioning → should start 01/2027

Proof-of-Principle Measurements

- lab tests at I-Tech
- long term measurements at PETRA III
- further investigations will follow (radiation hardness, …)
- on the whole looks very promising

  → will follow the concept

BPM System for PETRA IV

- about 700 BPMs required
- technical platform MTCA.4
- cable paths critical, require stabilization

  → concept of external crossbar switching

Acknowledgment

- I-Tech for hosting the workshop
- Diana Bertè for the workshop organization
- the audience for their attention

Contact

DESY. Deutsches
Elektronen-Synchrotron

www.desy.de

Gero Kube
Machine Diagnostics and Instrumentation (MDI)
gero.kube@desy.de
+49 40 8998 3077