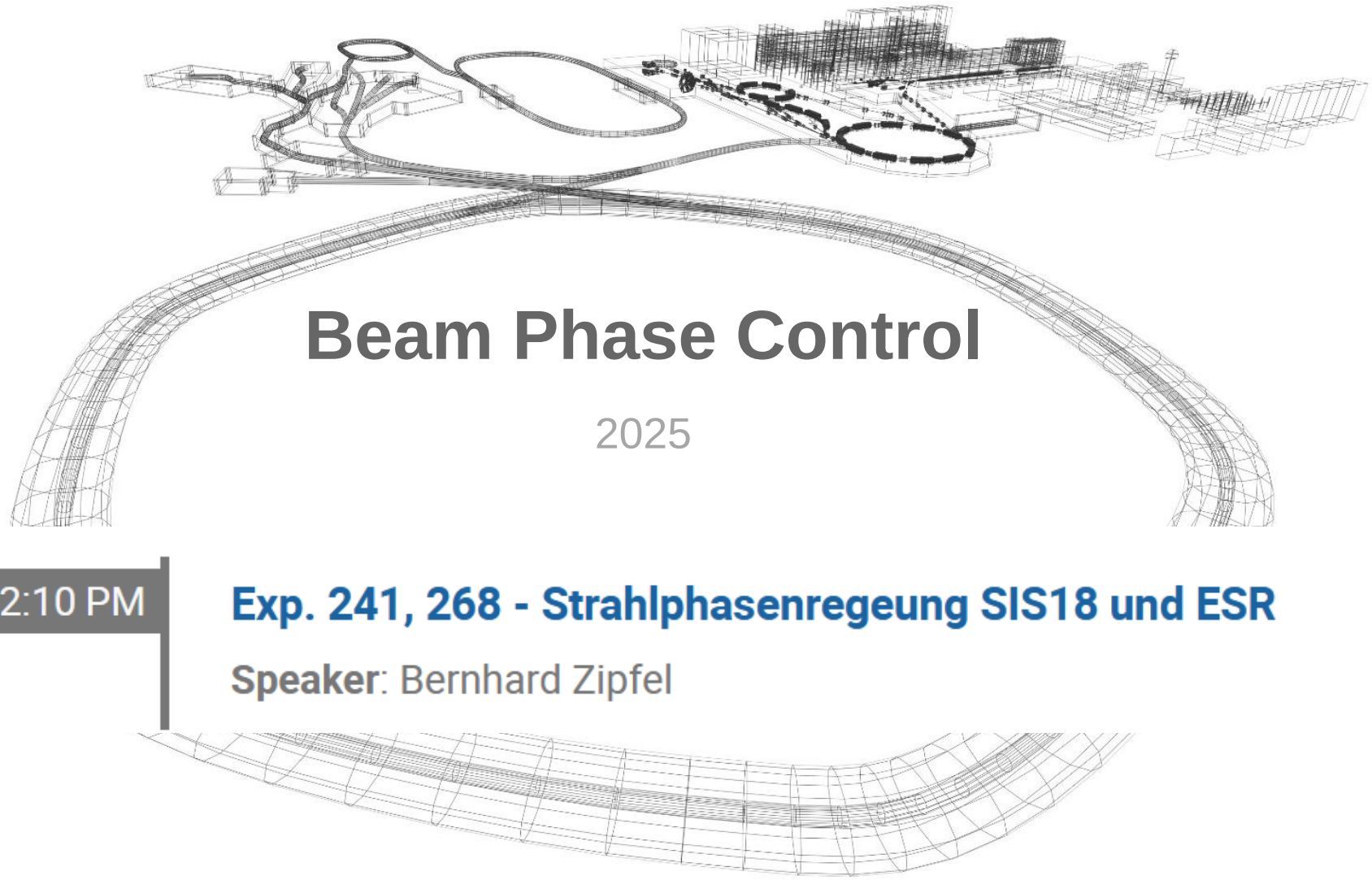


Beam Phase Control

2025

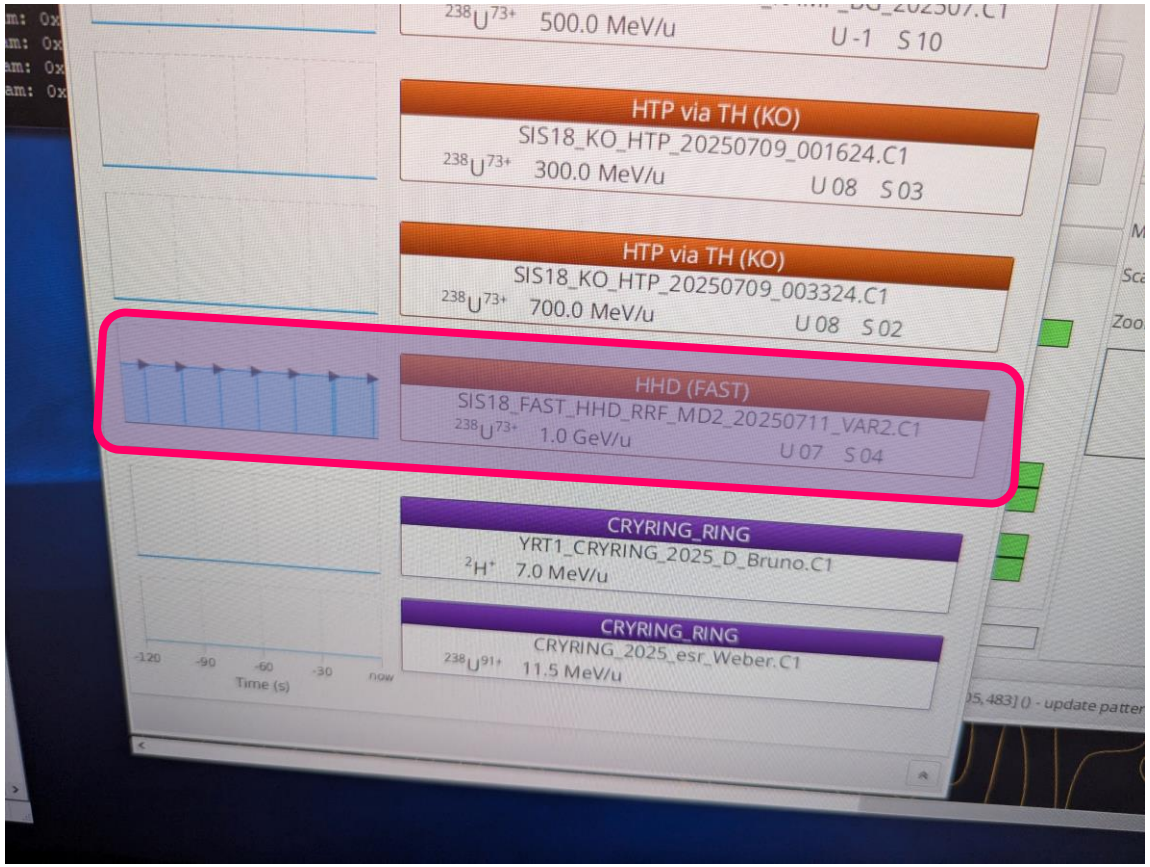
2:10 PM

Exp. 241, 268 - Strahlphasenregeung SIS18 und ESR

Speaker: Bernhard Zipfel

Exp.268: Commissioning BPC SIS18 (11./12.7.2025)

U^{73+} , SIS18 Ferrite Cavities, H=4, <2x10^8 Particles



SIS18_FAST_HHD_RRF_MD2_20250711_VAR2

Strahlparameter

Particle Symbol	238U
Ladung	73
Teilchenzahl	1.0E8
Beam Mode	PILOT_BEAM
Unilac VirtAcc	7
Unilac keine Anforderung	☐
Unilac kein Strahl	☐

Extraktion

Targetenergie	1000.0 MeV/u
Extraktionssteifigkeit	[18.40190366,] Tm
Extraktionsfrequenz	1211.82 kHz
Hor. Arbeitspunkt QH (Flattop)	4.285
Hor. Arbeitspunkt QH (Extr.)	4.29
Vert. Arbeitspunkt QV (Flattop)	3.278
Vert. Arbeitspunkt QV (Extr.)	3.29
Radiallage (Extraktion)	0.0 mm

Multi-Multiturn Injektion

Anzahl Injektionen	1
Kühlzeit	16.0 ms
Kühlerbump x (Position)	0.0 mm
Kühlerbump x (Winkel)	0.0 mrad
Kühlerbump y (Position)	0.0 mm
Kühlerbump y (Winkel)	0.0 mrad
GS10KX1 Korrektur	0.0 %
GS10KX2 Korrektur	0.0 %

HF Betriebsmode

Harmonischenzahl	4
Zweiharmonisch	☐
HF sequentiell	☐
BE 1,3,4,5,2	[false, false, fals
Kavitätentransfer aktiv	☐

Schnelle Extraktion

Kickwinkel	4.9 mrad
vordefinierter Bunch2Bucket Mode	☑
Bunch2Bucket Mode (Eingabe)	B2EXTRACTI
Bunch2Bucket Trigger Verschiebung	96.0 deg
Bunch2Bucket Phasen Differenz	0.0 deg

Injektion

Injektionsenergie	11.204 MeV/u
Injektionssteifigkeit	[1.57596505, 1. Tm
Injektionsfrequenz	212.6327 kHz
Hor. Arbeitspunkt QH (Inj.)	4.285
Vert. Arbeitspunkt QV (Inj.)	3.278
Radiallage (Injektion)	1.0 mm

Multiturn Injektion

Bumper-Abfallzeit	165 µs
Bumper-Amplitude	75.0 mm
Unilac-Verschiebung	40 µs
Chopper-Verzoegerung	70 µs
Chopper-Fenster	50.0 µs
Chopper Korrekturwinkel	0.0 mrad
GTK7MU5 Korrekturwinkel	0.0 mrad
GS12MU3I Korrekturwinkel	0.8 mrad
I-Septum Korrekturwinkel	0.0 mrad

Rampe und HF-Amplitude

Verrundungszeit	[32.0, 32.0] ms
Rampensteilheit	[1.4, 1.4] T/s
Einfangzeit	16.0 ms
Impulsbreite (DC)	0.14 %
Bucketfill (Bunching)	[[0.0, 1.43]]
Bucketfill (Ramp)	[[1.43, 1.43]]
Bucketfill (Pre-Extraction)	[[1.43, 1.43]]

Extraktionsbeulen

M-Septum-Bump	8.0 mm
Bypass Korrekturwinkel	0.0 mrad

Exp.268: Participants (11./12. 7.2025)

- Steering and Evaluation

B. Zipfel - Coordination, Preparation & FCT-Color plots,
D. Lens - Evaluation, Coordination & Triggering Data Acquisition
K. Groß - **HKR,** & LSA , Data Acquisition Data Supply (Yokogawa2)
H. Klingbeil - Evaluation DC-Trafo, FCT-Signal & Acq-PC, Data Acquisition Data Supply (Yokogawa1)
G. Thomin - Configuration, Acquisition und Analysis DSP-Systems BPC/ESR-BE1/SISBE1&BE2

- Preparation and Configuration Hardware und Data Acquisition and Control

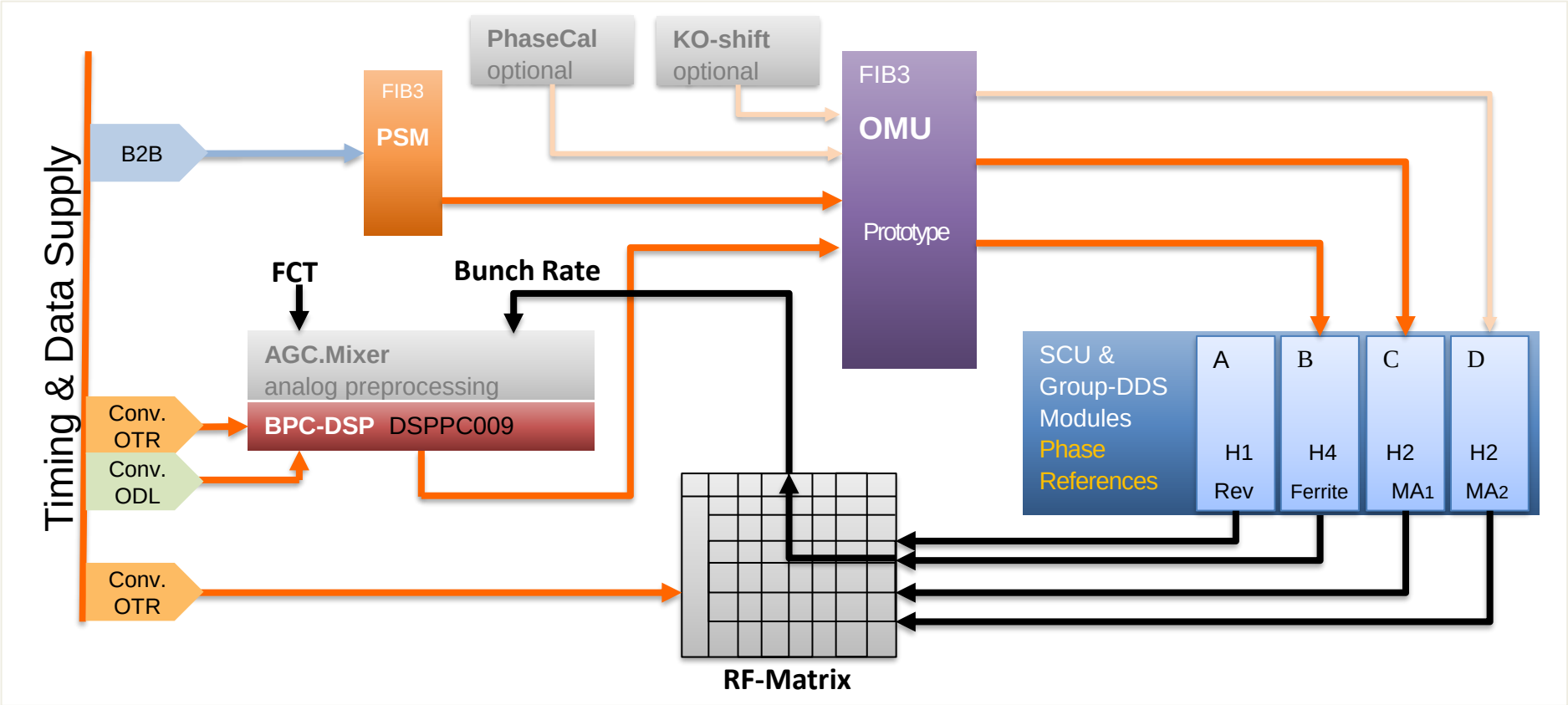
C. Thielmann - Monitoring and saving DC-Trafo-Data
C. Reinwald - Data Acquisition additional Scope
J. Wegmann - Triggering Data Acquisition und Data Acquisition SIS18-cycles (Scope data)
S. Orth - Data Acquisition Group-DDS Data (Scope)

M. Hardieck - Hardware Devellopement, Implementation and Preparation

C. Schmidt - HKR , Trimming

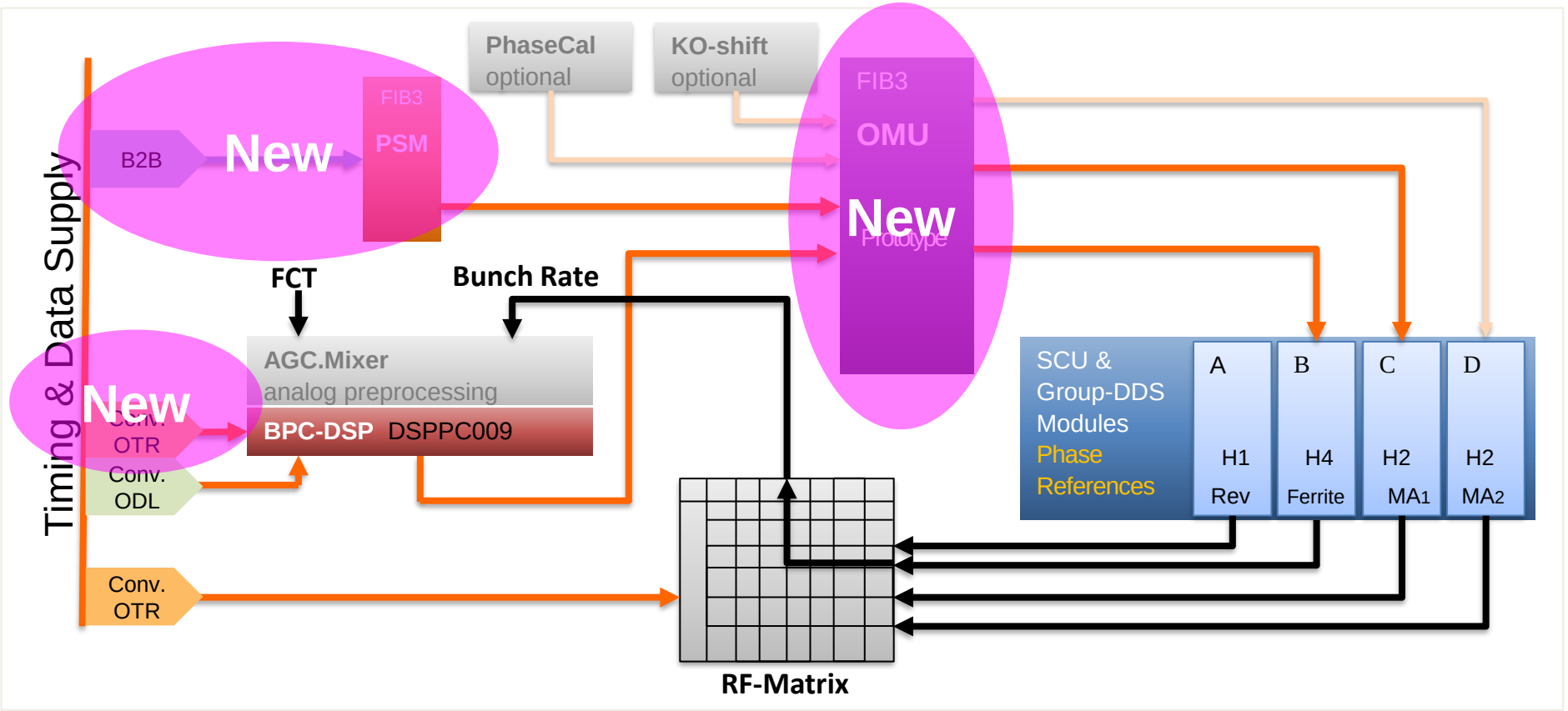
Topology including an Optical Mixing Unit

- Beam Phase Contol & Bunch to Bucket (Phase Shift Module)



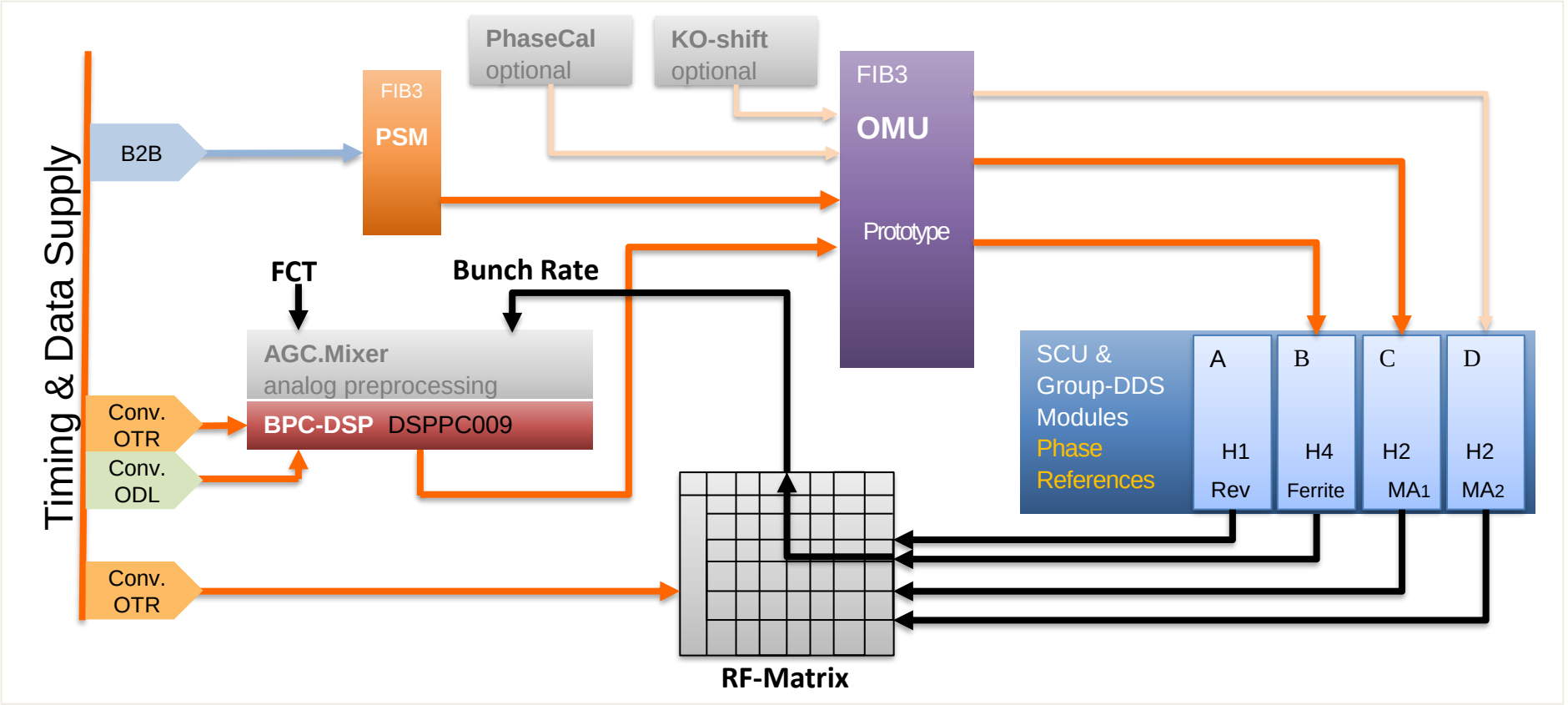
Upgrades for CCS integration last year

- Beam Phase Contol & Bunch to Bucket (Phase Shift Module)



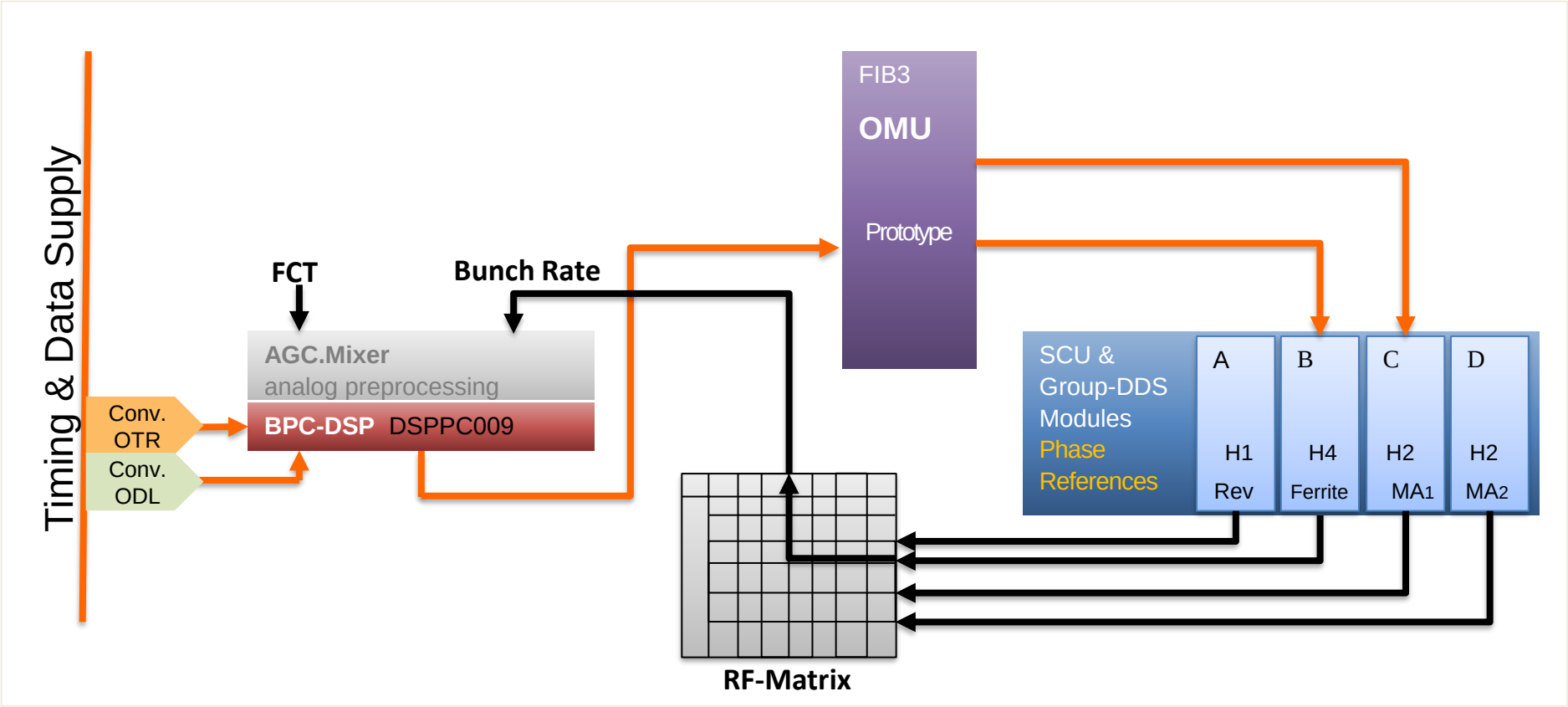
Topology BPC now available

- Beam Phase Contol & Bunch to Bucket (Phase Shift Module)



Topology BPC now available

- Beam Phase Contol & Bunch to Bucket (Phase Shift Module)



Demo of BPC phase modulation on 1MHz RF-signal

Beam Phase Control acting on Group-DDS Phase Reference (real time recording)

- **blue**: phase modulated group-DDS
- **green**: phase reference group-DDS

the phase shift between the signals is caused by the difference in length of the patch cables to the scope

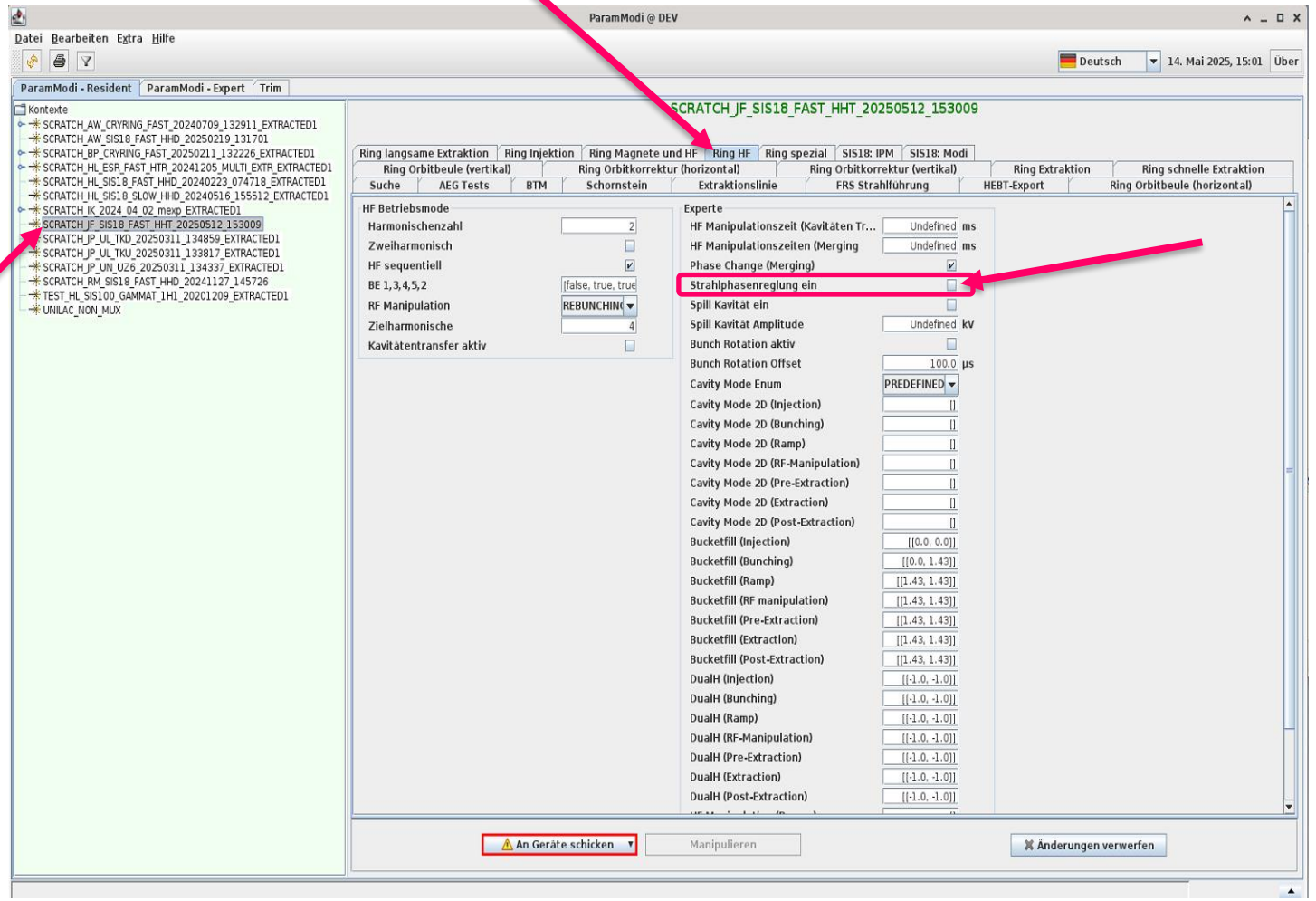
Demo of BPC phase modulation on 1MHz RF-signal

Beam Phase Control acting on Group-DDS Phase Reference

Getting Access to BPC in ParamModi

- select pattern
  (machine cycle / virt.acc.)
- use Tab <Ring HF>
- switch Option <Strahlphasenregelung>

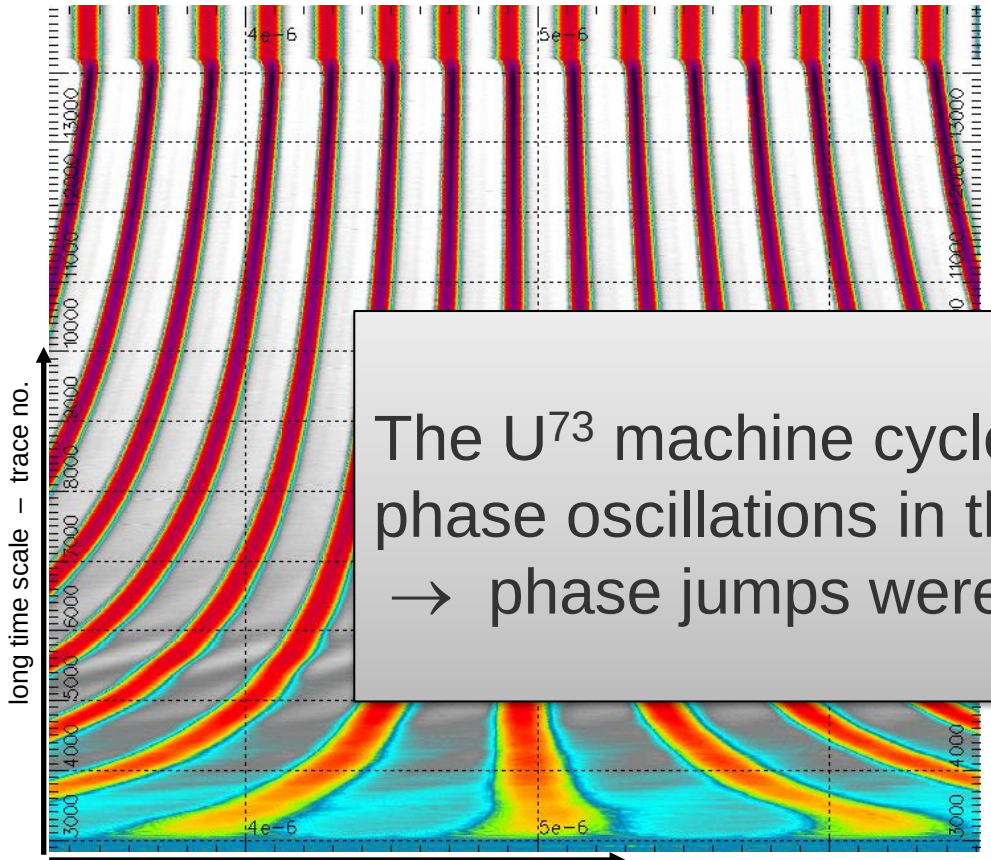
- check values for Bucketfill (U_{rf})



FCT Scope Acquisition

- Data Set 1 (well adjusted machine cycle)

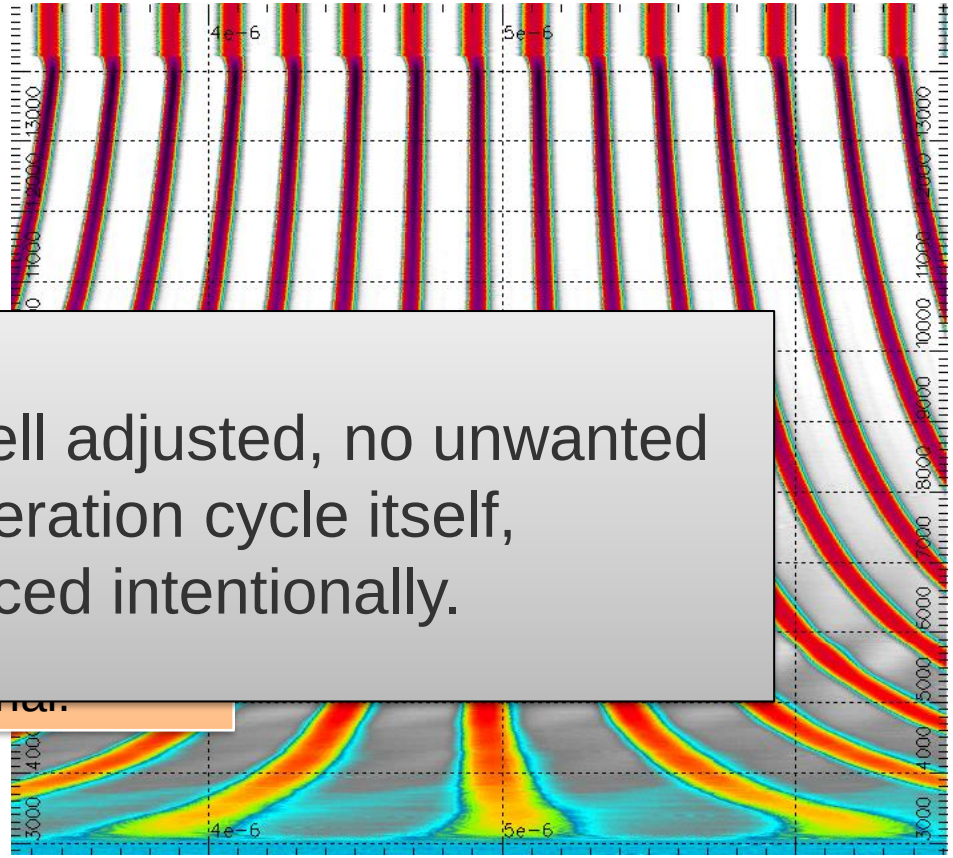
BPC off



time base 3.5µs @250MHz

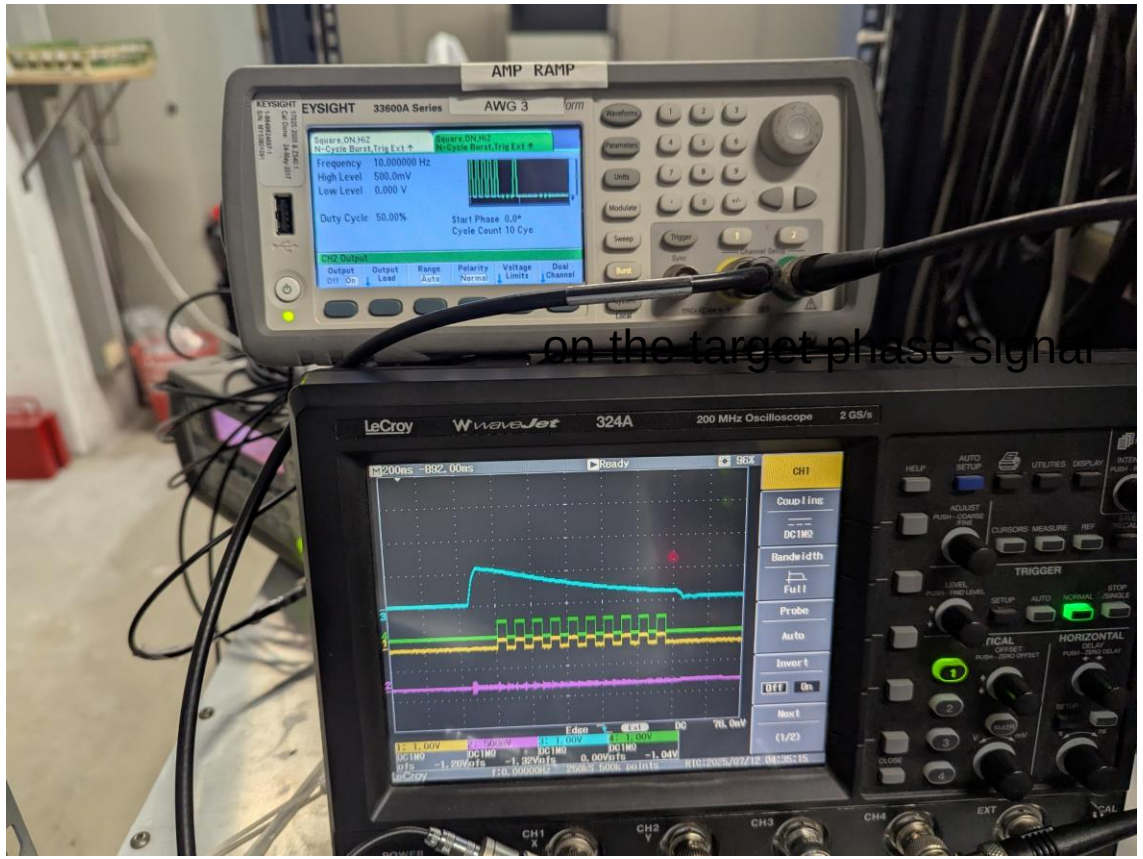
- Data Set 8 (BPC has no effect on proper cycles)

BPC on



The U^{73} machine cycle was well adjusted, no unwanted phase oscillations in the acceleration cycle itself,
→ phase jumps were introduced intentionally.

Exciting Bunch Phase Oscillations



on the target phase signal

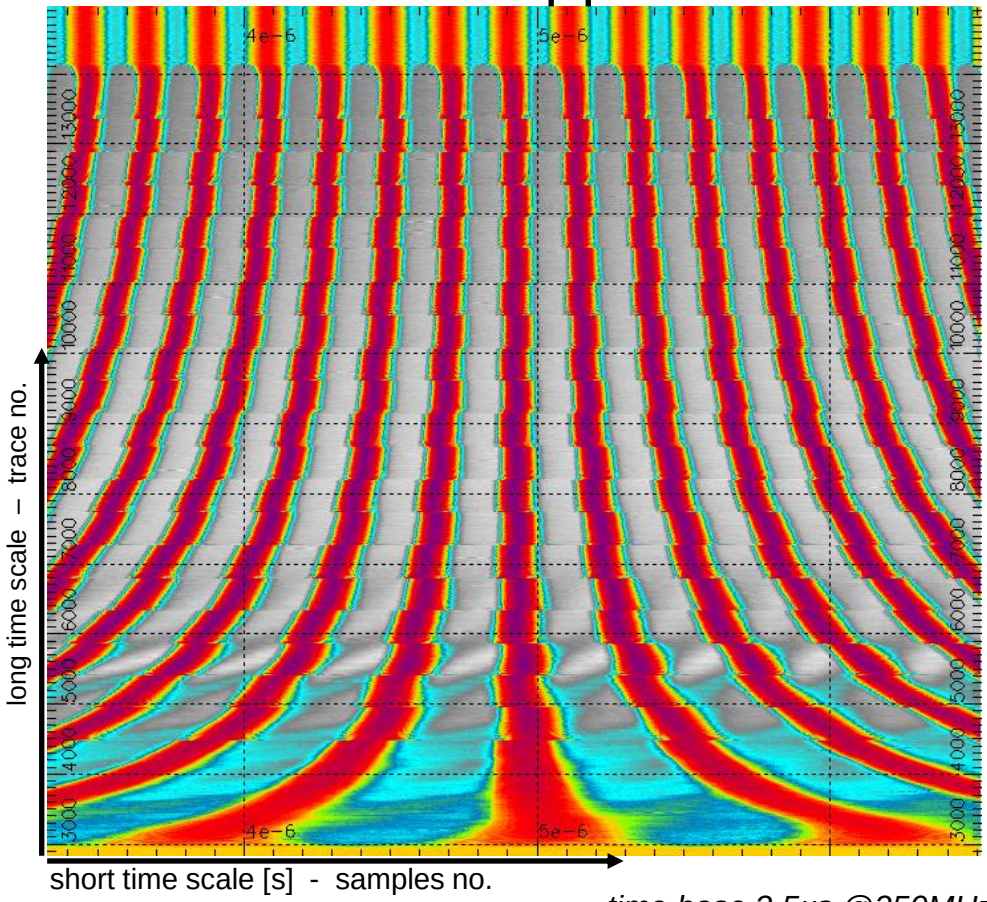
phase variations on target phase ramp

Fast phase displacements were added for both cavities on the target phase signal from CCS Data Supply.

FCT Scope Acquisition

- Data Set 5

BPC off

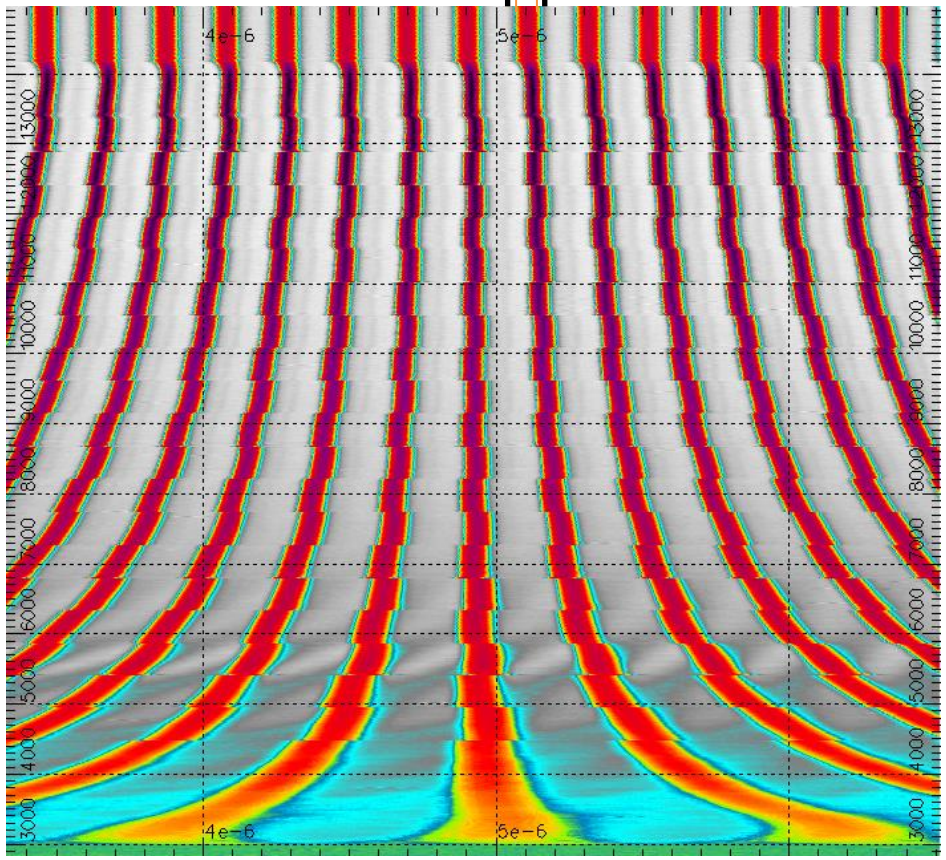


time base 3.5µs @250MHz

- Data Set 4

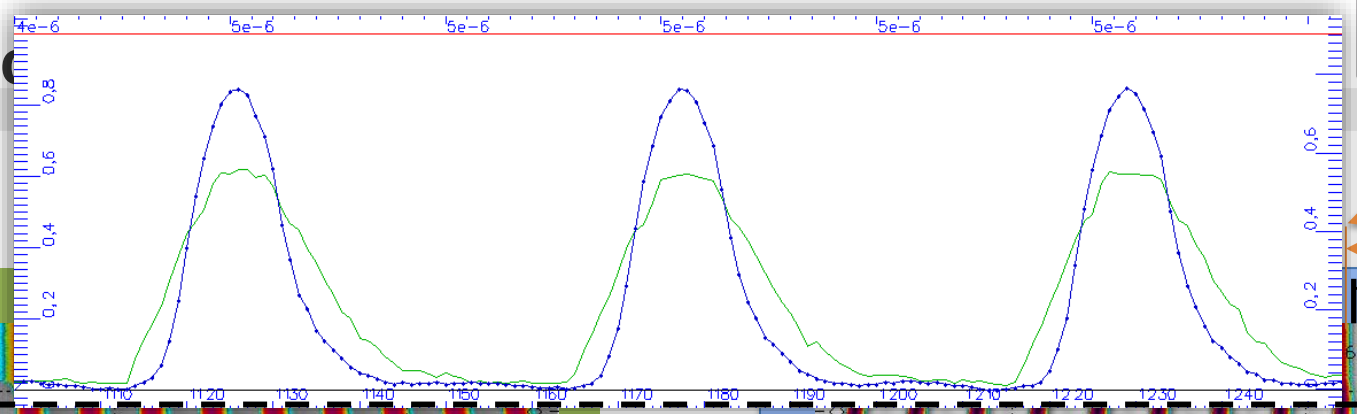
BPC on

BPC helps with phase space preservation.



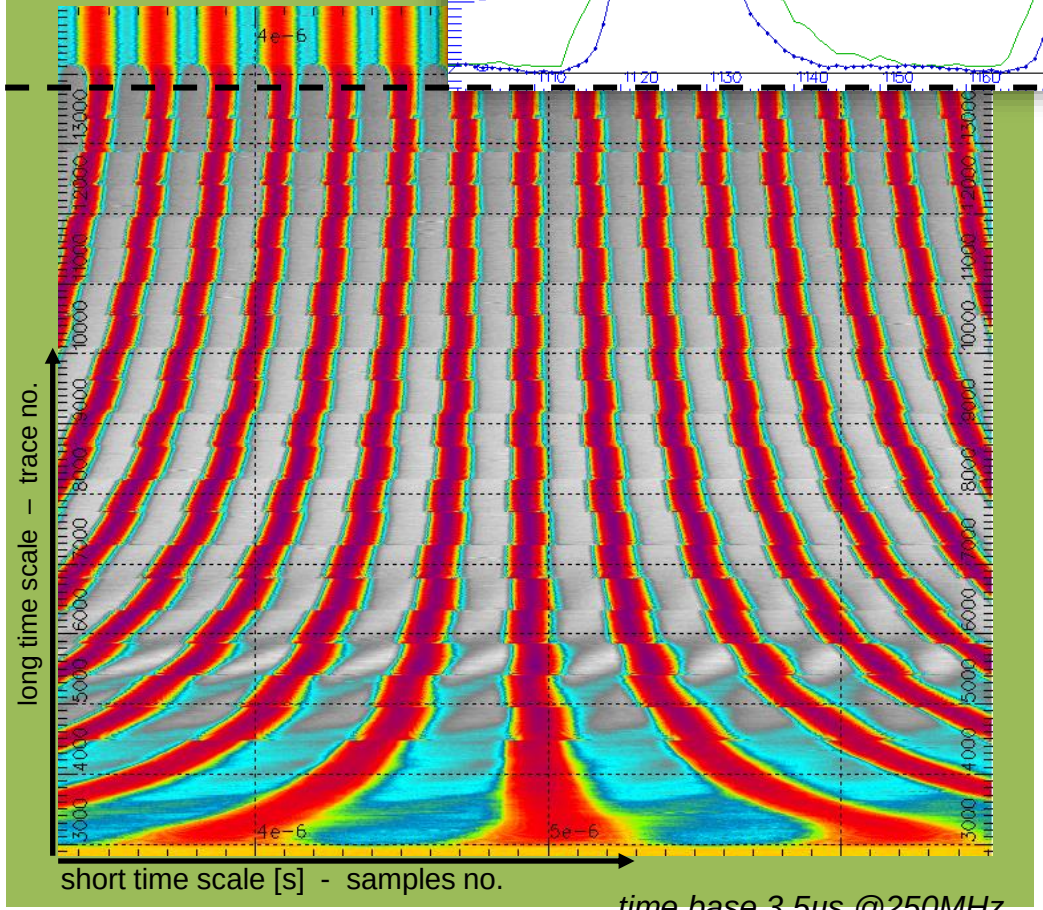
FCT Scope Ac

- Data Set 5

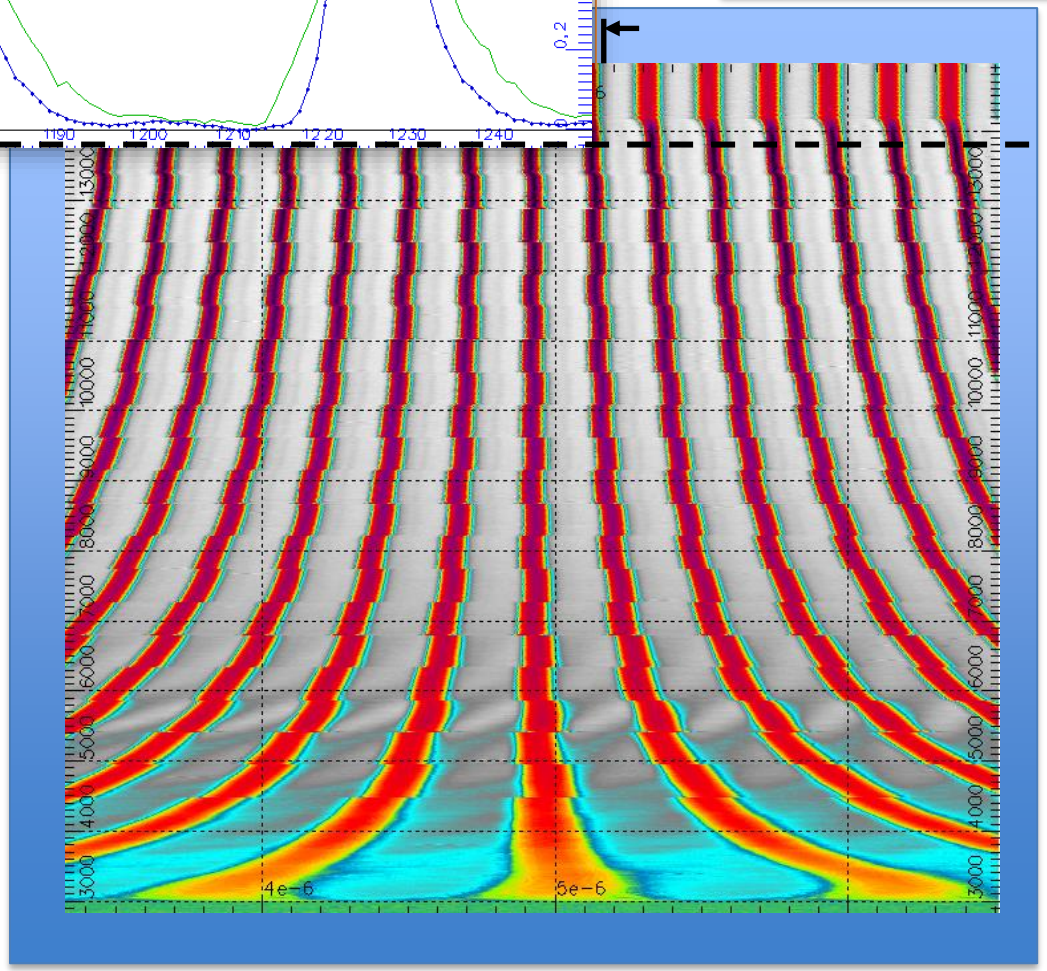


BPC helps with phase space preservation.

BPC off



time base 3.5µs @250MHz



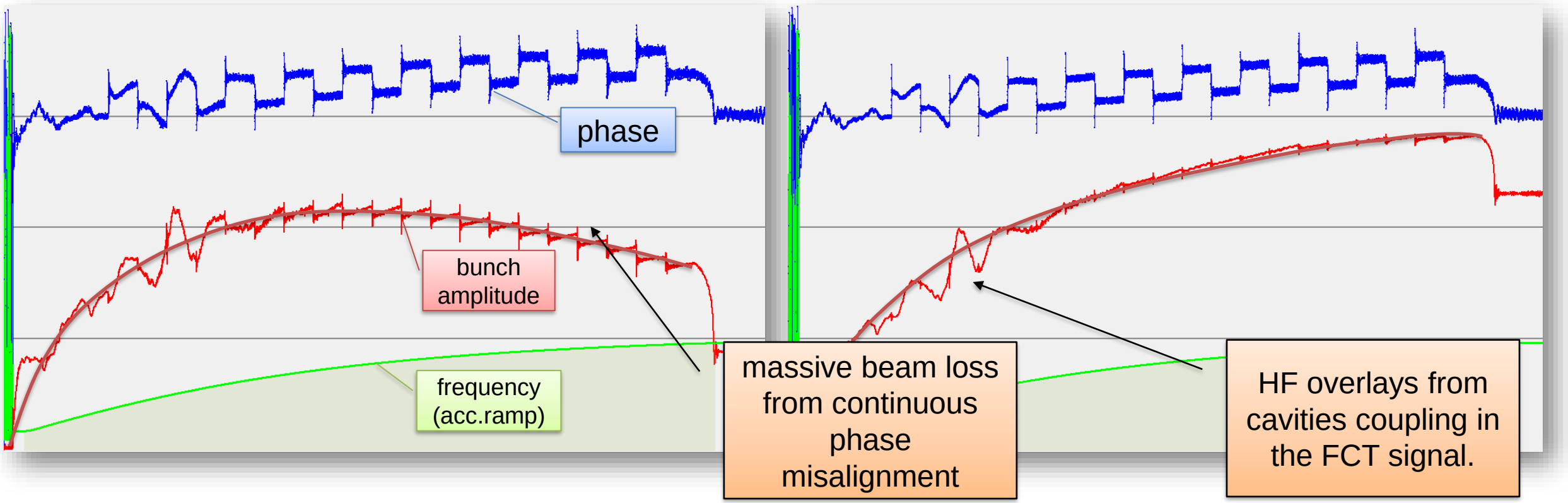
Offline Scope Data Spectral Analysis

- Data Set 5

BPC off

- Data Set 4

BPC on

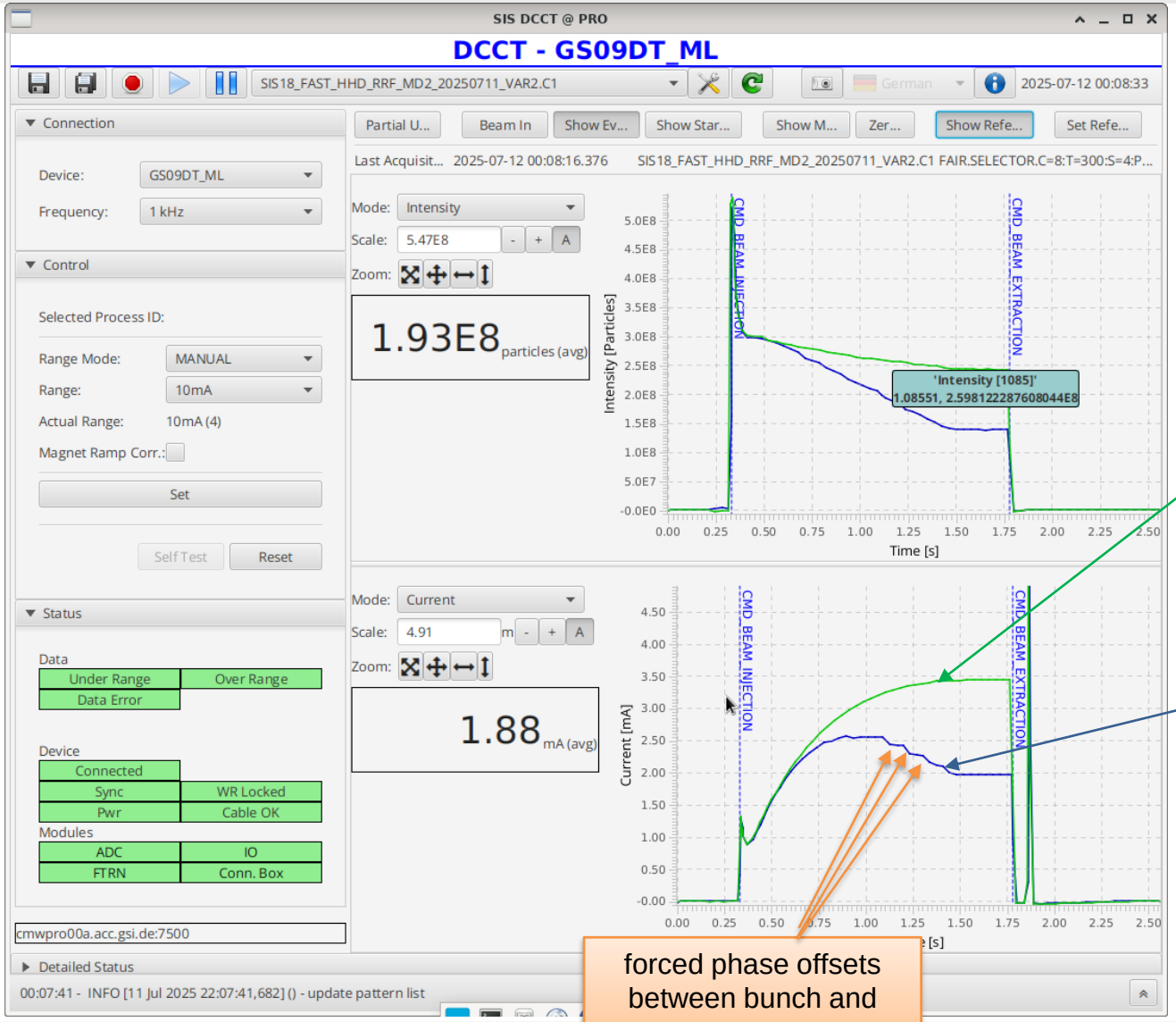


It is obvious that the BPC helps to keep the ion beam on track, thereby reducing beam loss.

Observations on Beam Current Monitor (DC-Trafo)

The influence of the BPC on the ion beam can be easily evaluated using the online DC-transformer monitor.

The DC-Trafo was used to evaluate current BPC-configuration during the experiment.



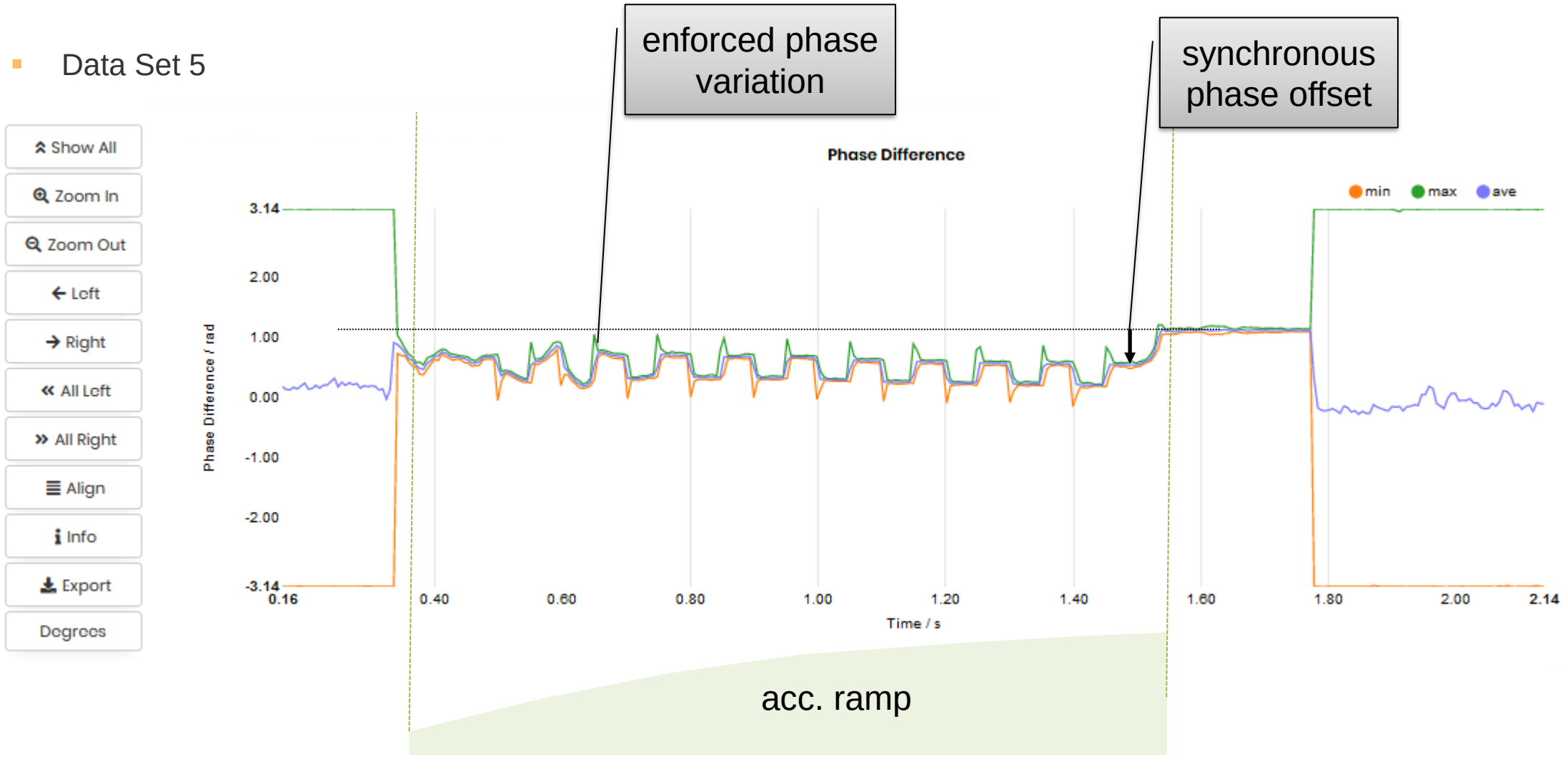
BPC on

BPC off

forced phase offsets between bunch and cavity frequency

Deeper Analysis using DSP Phase Recordings

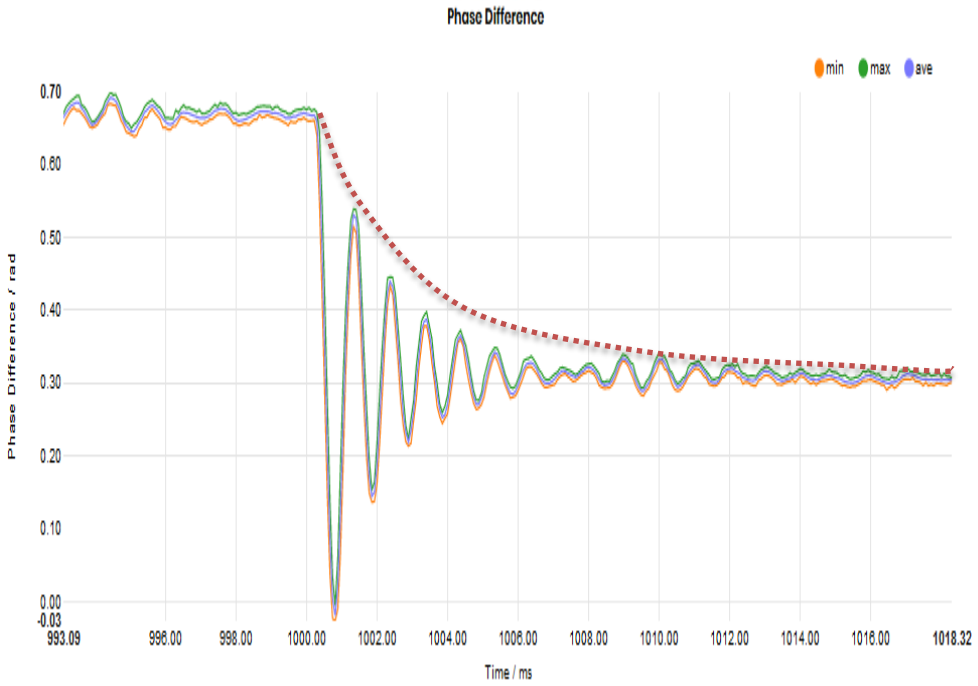
- Data Set 5



DSP Phase Difference Recordings (Details)

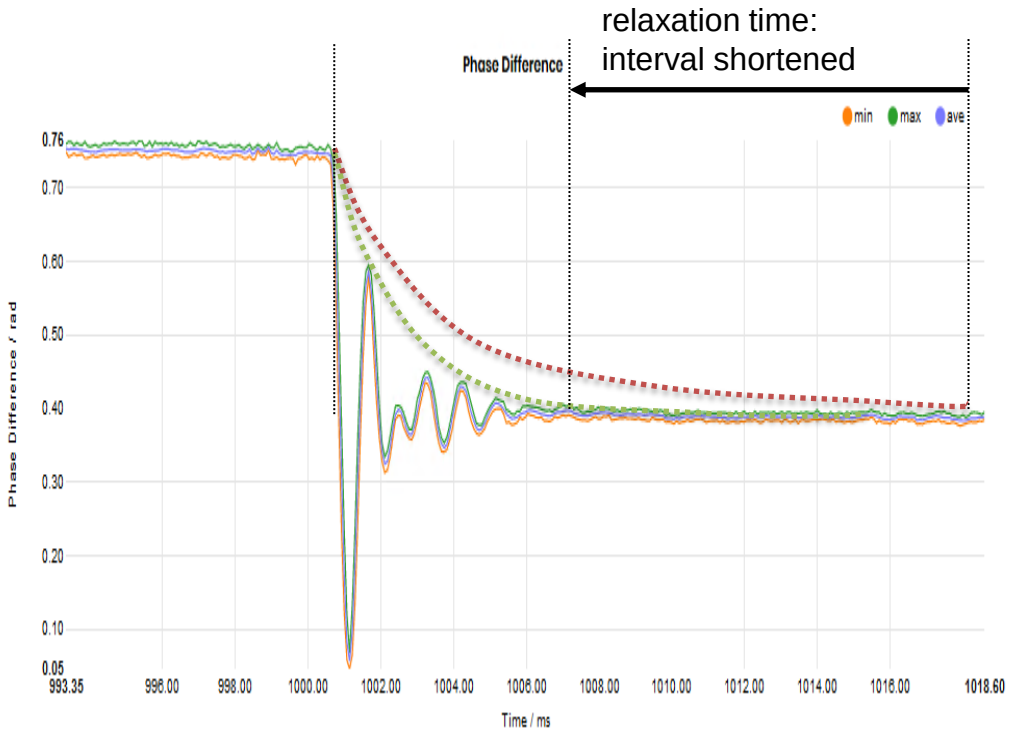
- Data Set 5

  BPC off



- Data Set 4

  BPC on



EXP 241: first time Test BPC in ESR (23.5.2025)

Participants

- Steering and Evaluation

B. Zipfel - Coordination & Preparation, FCT-Color plots

D. Lens - Coordination **HKR,** & LSA

H. Klingbeil - Evaluation DC-Trafo, FCT-Signal & Acq-PC

G. Thomin - Configuration, Acquisition und Analysis DSP-Systems BPC/ESR-BE1/SISBE1&BE2

- Preparation and Configuration Hardware und Data Acquisition and Control

D. Penza - Data Acquisition Group-DDS Data ESR (Scope Data)

J. Wegmann - Data Acquisition Group-DDS Data SIS18 (Scope Data)

D. Ziegelmann & K.Groß - Data Acquisition Data Supply (Yokogawa1 SIS)

C.Thielmann - Data Acquisition Data Supply (Yokogawa2 ESR)

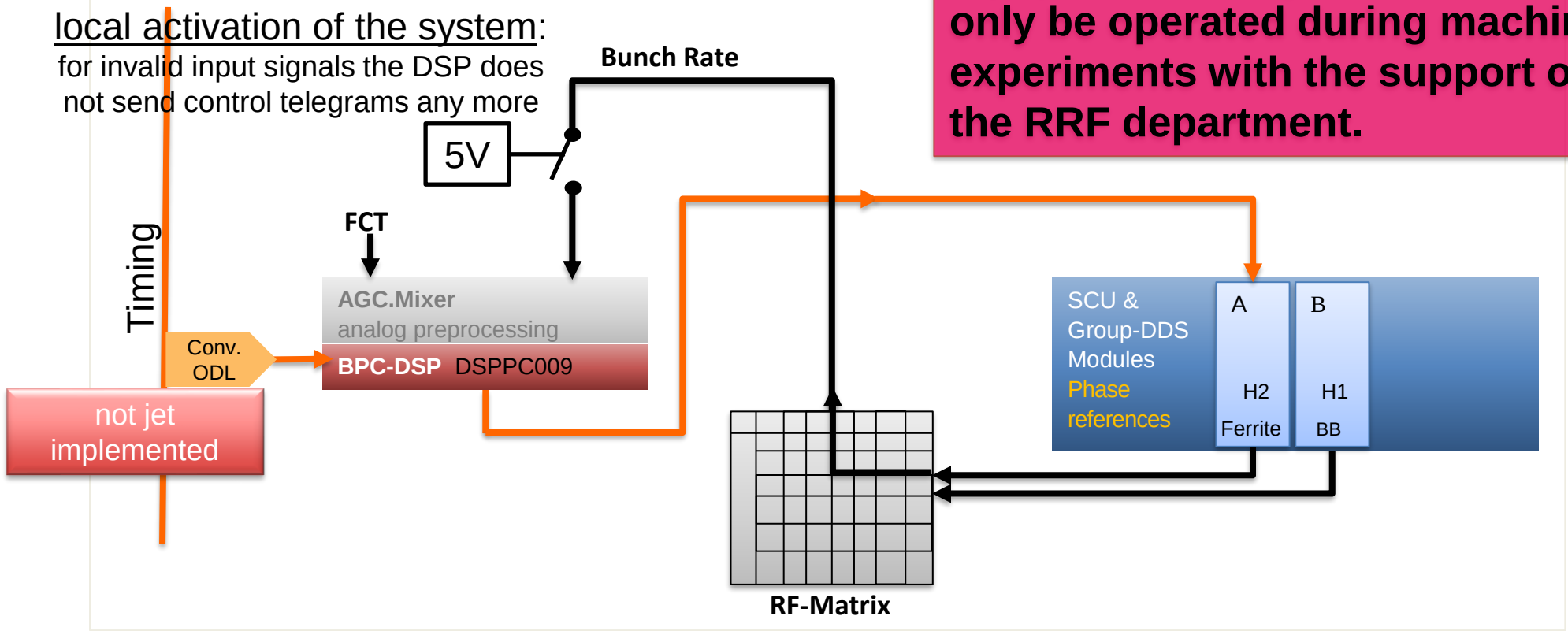
M. Hardieck - Hardware Implementation and Preparation

C. Wetzel - HKR

Simplified Topology and Special Modification for ESR

- BPC at ESR

Disclaimer: due to incomplete equipment, the system in ESR can only be operated during machine experiments with the support of the RRF department.



DSP recording FCT-Signal

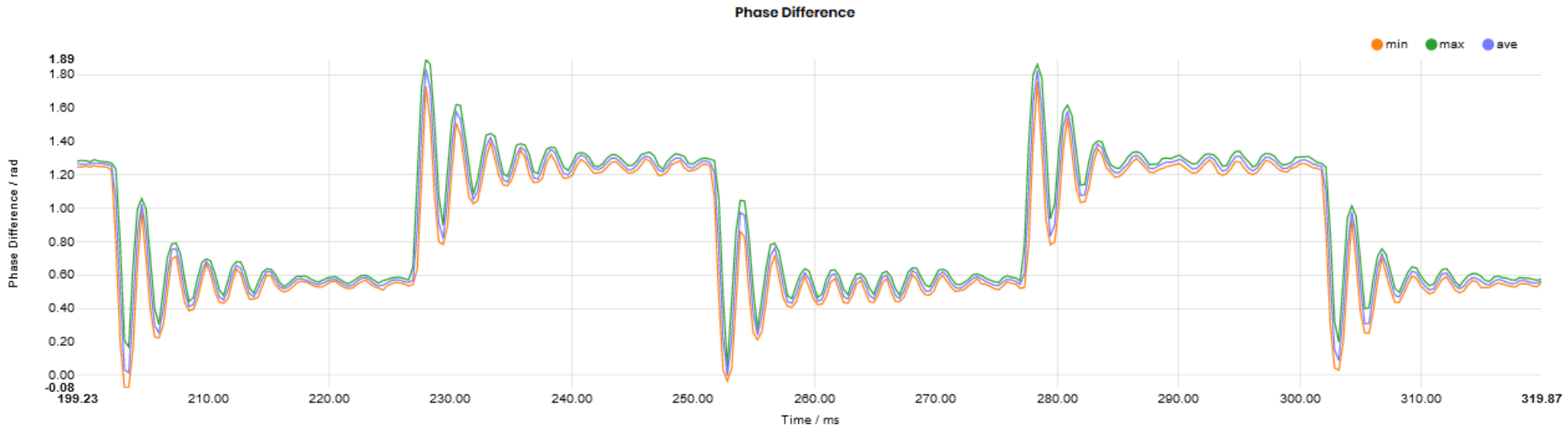
LSA Pattern: SIS18_FAST_ESR_RRF_MD_202505 (Ions: C^{12})

Data Set 1026

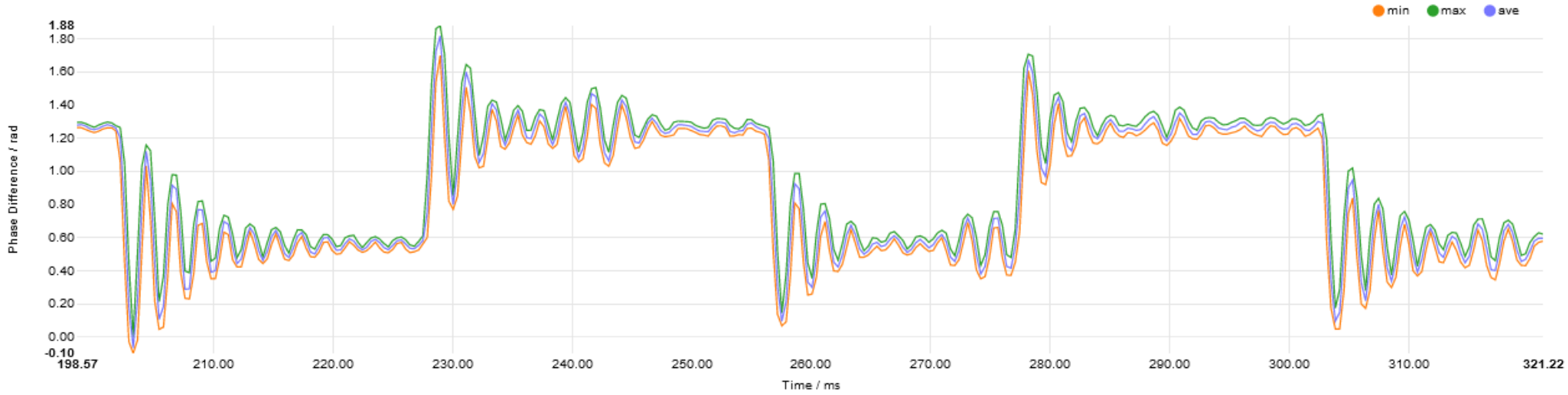
Effect of the ESR-BPC

- Data Set 1026
  BPC on

  Parameters:
  passband factor
  f=469
  gain factor
  kp=-6



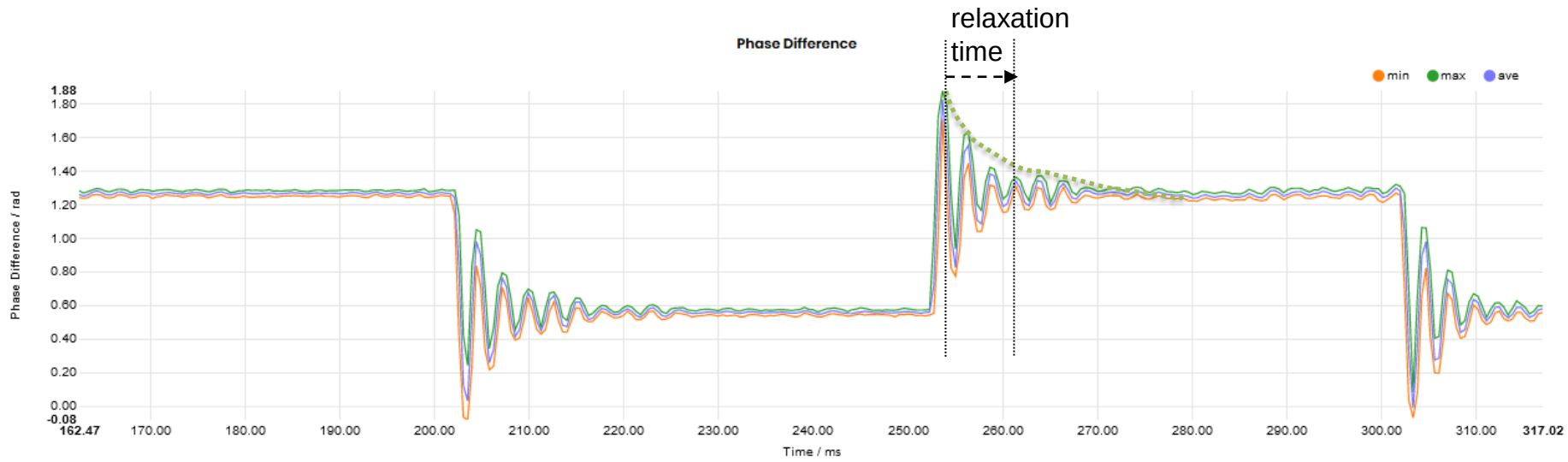
- Data Set 1025
  BPC off



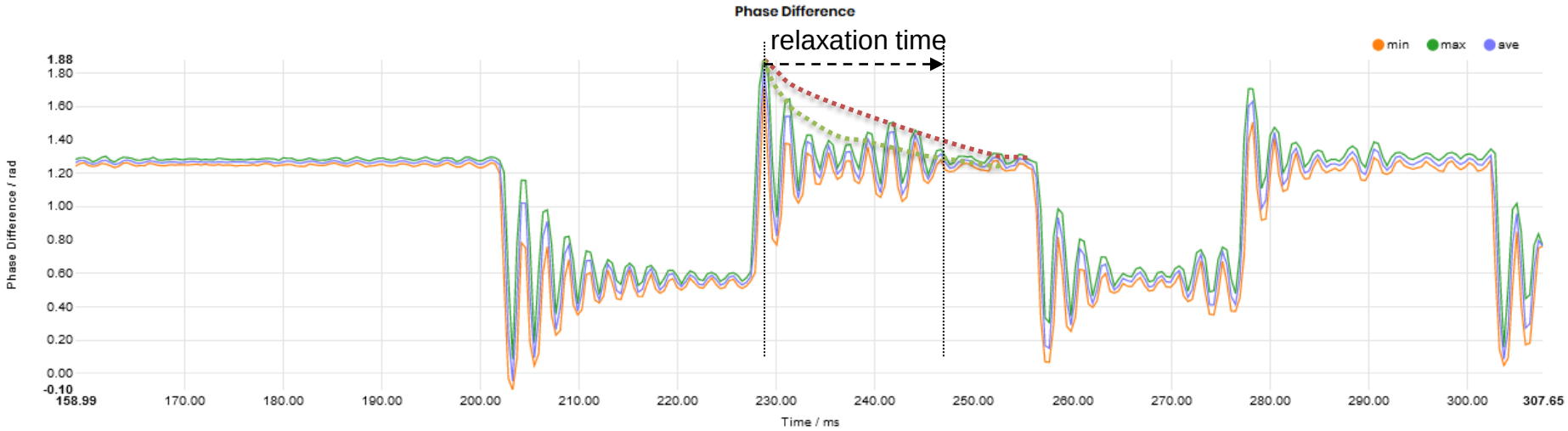
Best Parameter set for ESR-BPC

- Data Set 10
  BPC on

  Parameters:
  passband factor
  f=450
  gain factor
  kp=-1.84



- Data Set 1025
  BPC off



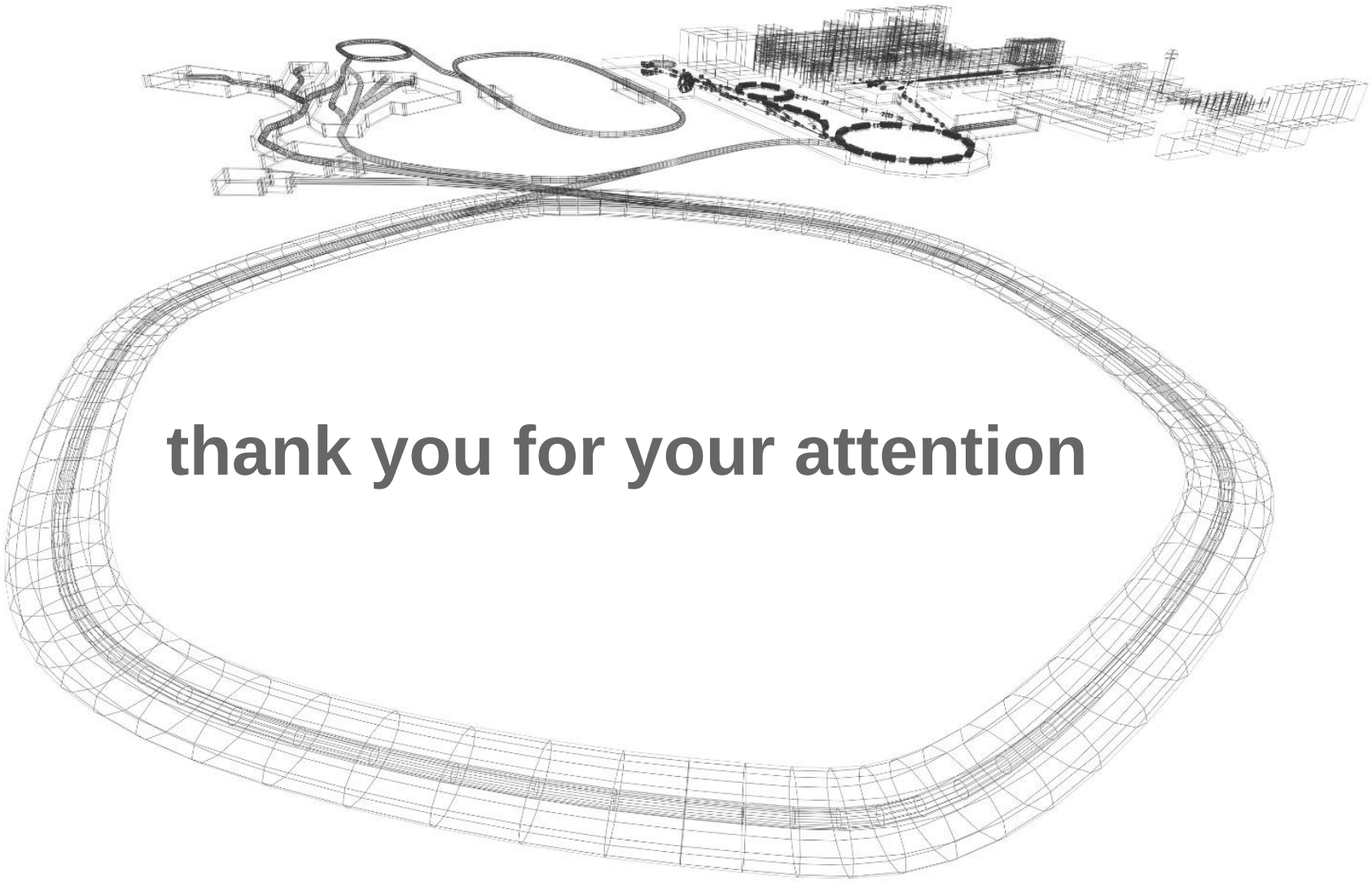
Summary & Outlook

- BPC implemented so far and ready for operation and activation via ParamModi
  - New: BPC now useable for GSI-experts
  - New: SIS18 System is integrated in CCS in combination with ferrite cavities
  - New: System was tested in single and parallel operation of BE1 and BE2
  - New: ESR hardware is installed and the first run was done successfully with BE1

- Restrictions and ongoing work
  - SIS18 works only with Ferrite Cavities (regularly h=4)
  - Stepwise integration is in work (for MA-Cavities and RF-matrix control via FESA)
  - for ESR the integration in control system is not yet implemented

Feel free to use the new functionality in SIS18 and gain experience

- In case of problems or any unexpected behavior or the system is ineffective, please contact the RRF department. (B. Zipfel, D. Lens, M. Hardieck, G. Thomin, ...)



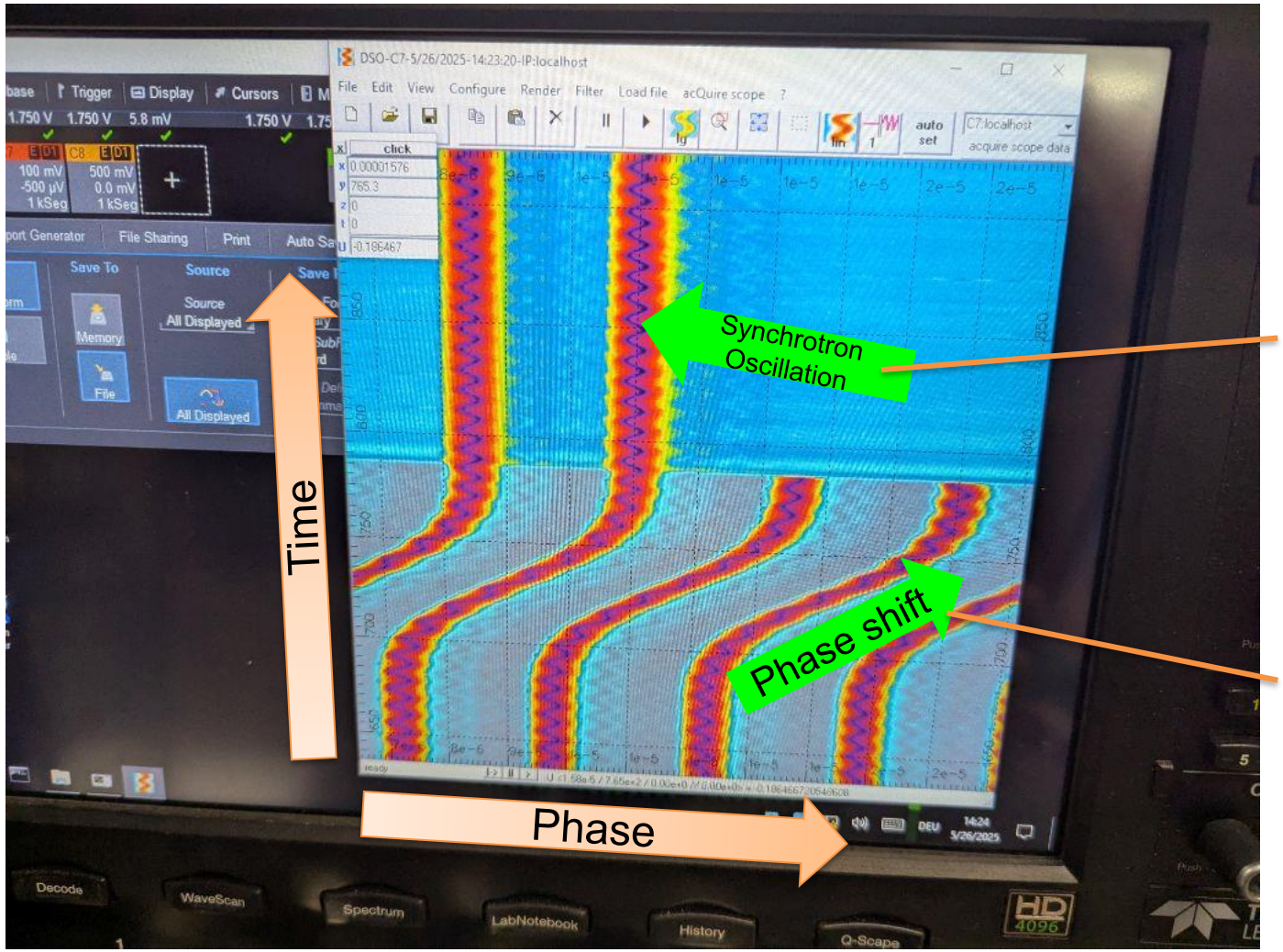
thank you for your attention

Additional Transparencies

- additional slides for explanation purposes following

Intentional Phase shift and undesired Oscillations

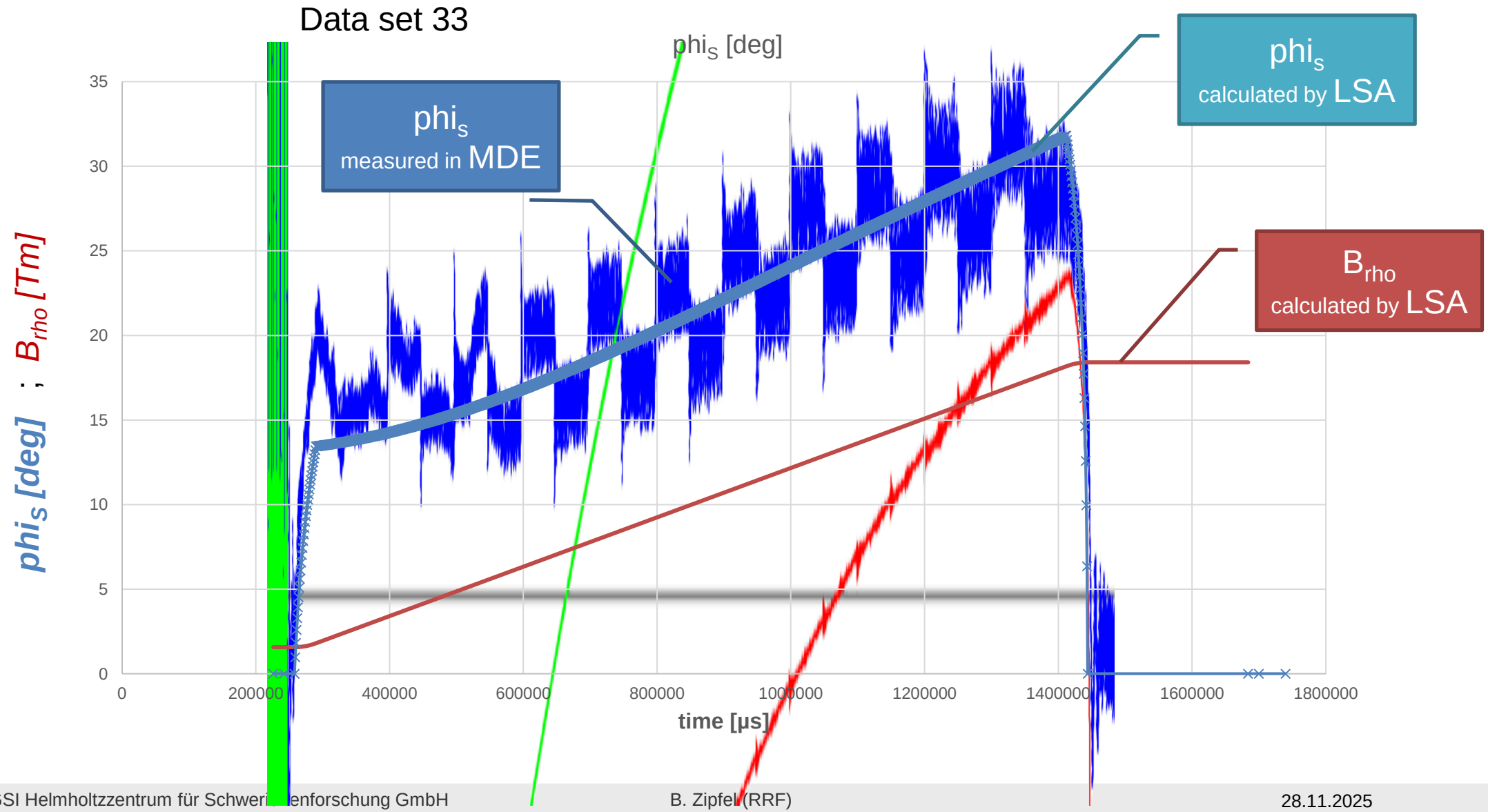
MDE 26.May 2025
Bunch to Bucket
SIS18 to ESR



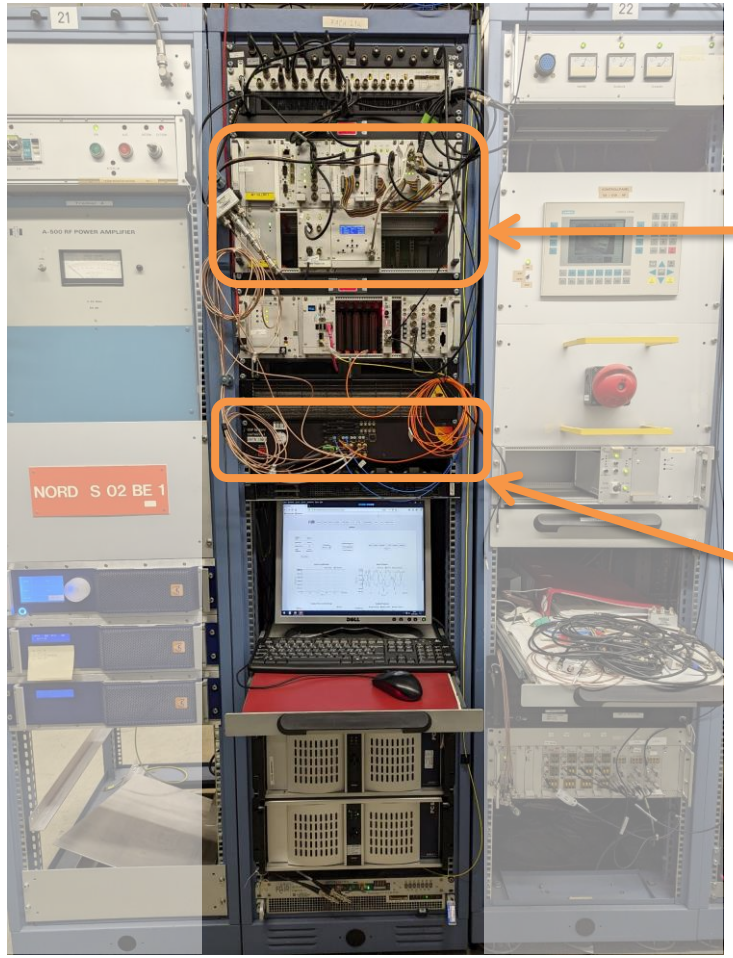
Parasitic Synchrotron Oscillations

Phase shift induced by B2B

Accellerating Phase (synchronous phase)



Hardware DSP System 2.Generation



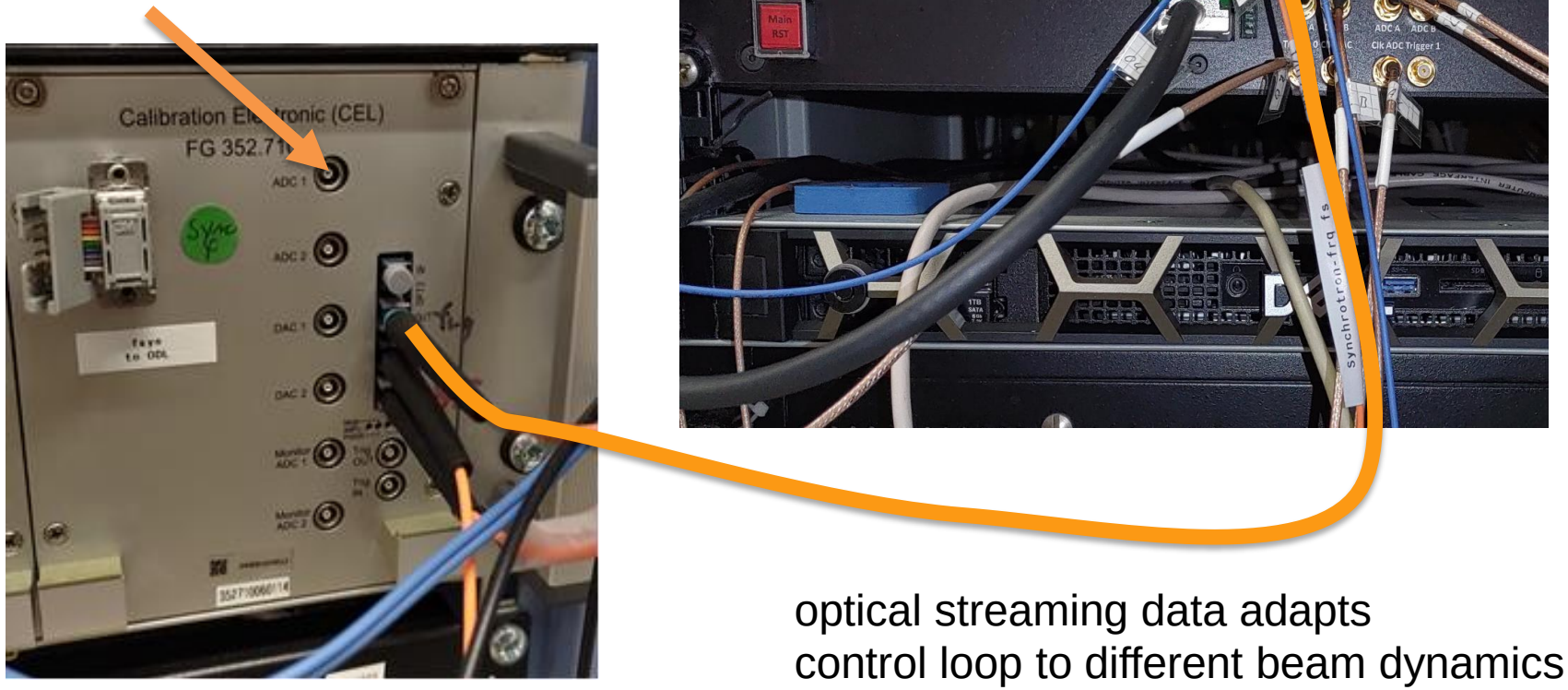
Tried and tested mixing ensemble

2. Gen DSP-System

the Dual-DSP-Hardware provides several analog RF-in/out and optical in/out for streaming data like measurements, ramped parameter and control signals

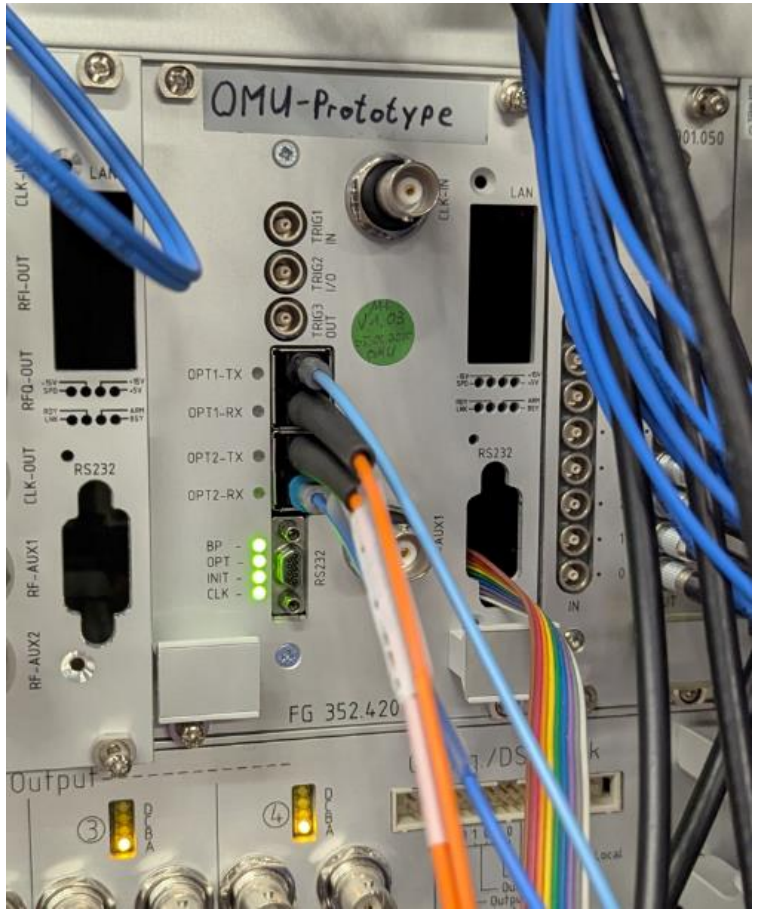
Sychrotron Frequency
Ramped Parameter

- CEL-Modul used to convert analog ramped output to
  digital optical streaming data



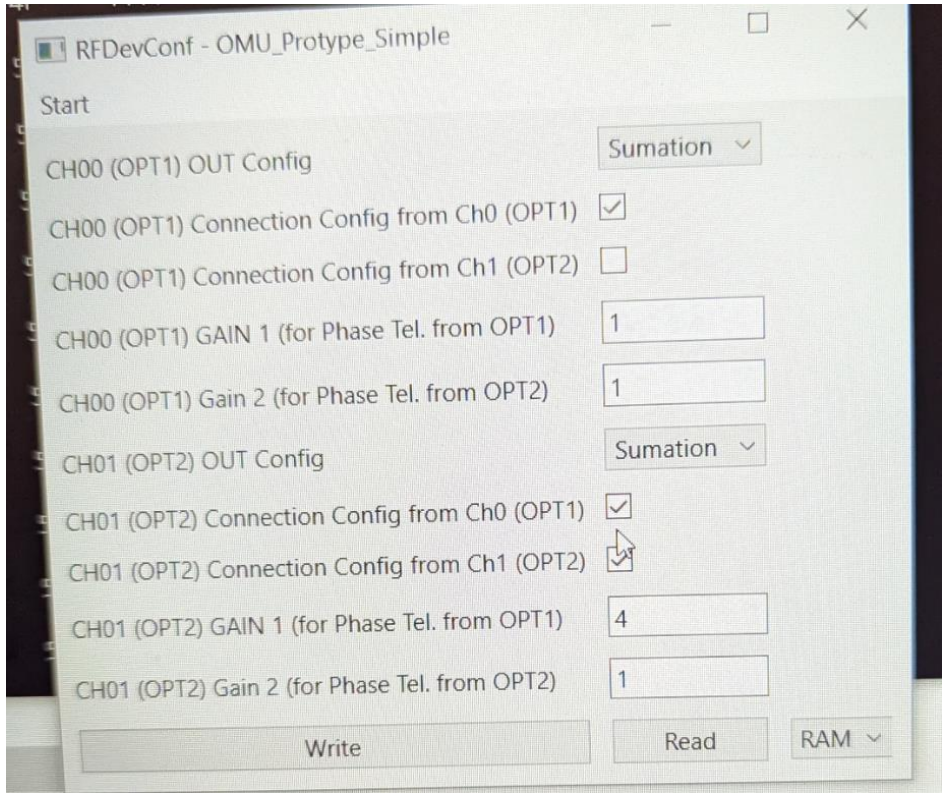
optical streaming data adapts
control loop to different beam dynamics
at injection, acceleration and flattop

Multiplexer Protype



FIB3 Hardware

Stream Multiplexing Configuration



OMU Firmware and Software (M. Hardieck)