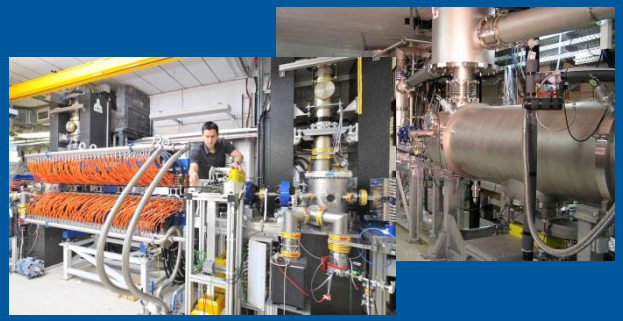
Beam Arrival Time Monitoring at CW Accelerators

Michael Kuntzsch



Partner von DRESDEN concept exzellenz-dresden.de

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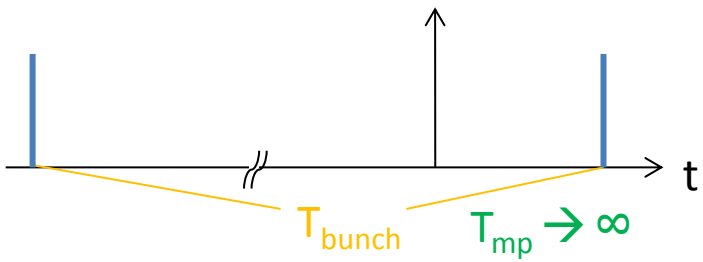
HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

What means CW?

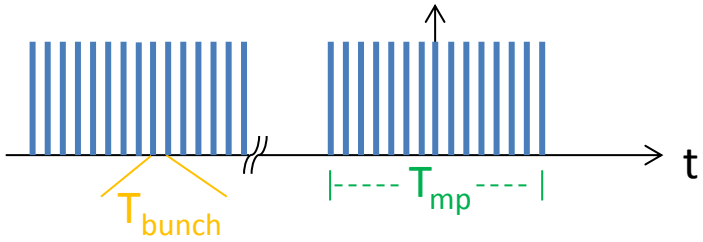
ELBE.



Single Shot / Low repetition rate

(e.g. LCLS, up to 120 Hz)

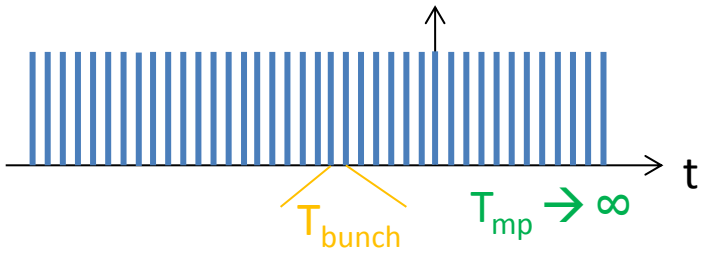
- low repetition rate
- low measurement bandwidth (Nyquist) → 60 Hz



Macro Pulsed

(e.g. FLASH, 1 MHz @ 800µs, T_{mp} = 100ms)

- high repetition rate
- bandwidth limited by macro pulse length T_{mp}



(quasi-) CW

(e.g. ELBE, up to 13 MHz; LCLS II; …)

- high repetition rate
- bandwidth only limited by bunch rate (Nyquist) → 6.5 MHz

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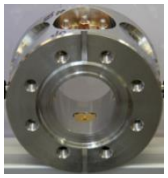
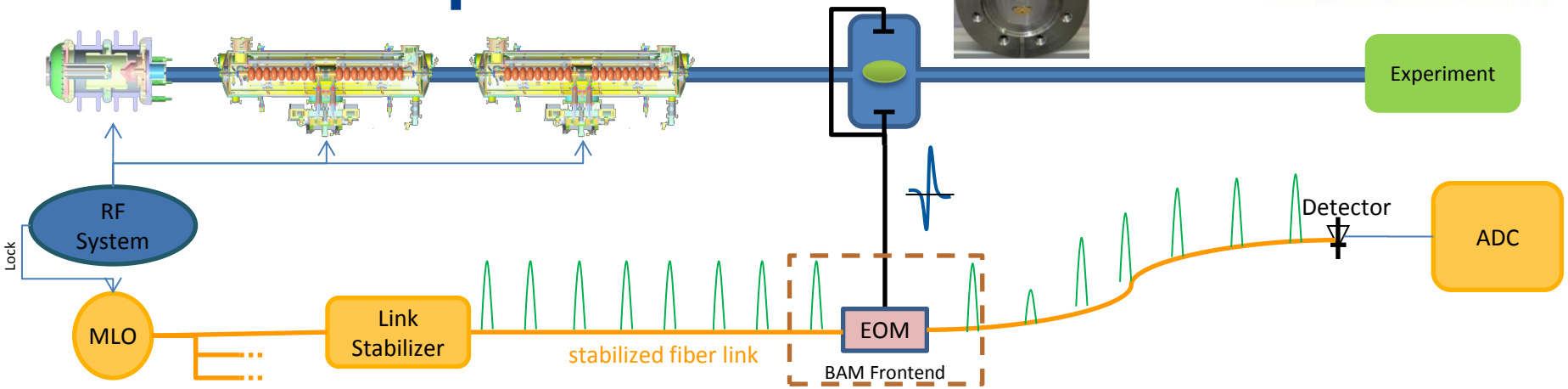
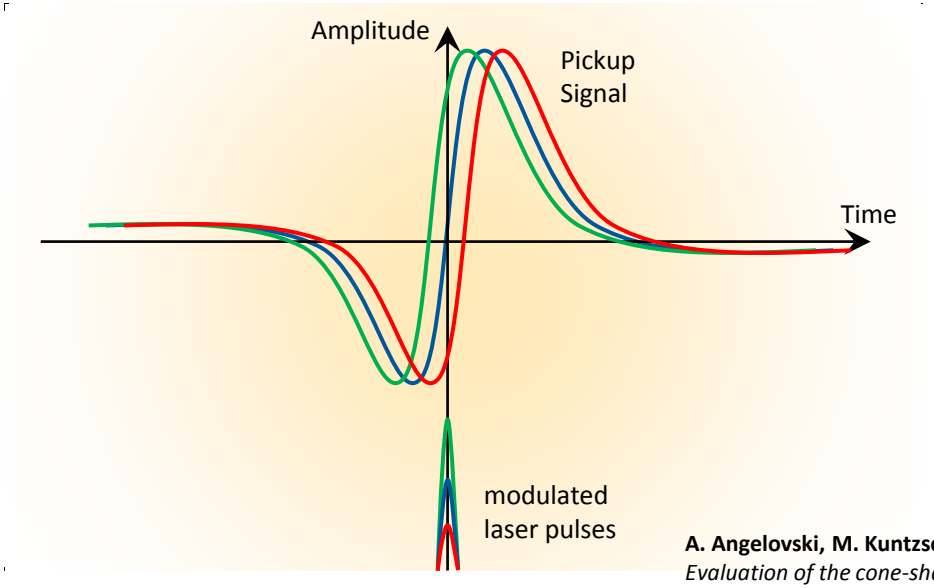
BAM - Setup

ELBE.







Bunch Arrival Time Monitor (BAM)

- timing information coded to laser pulse amplitude
- bunch arrival time w.r.t. optical master clock
- single bunch resolution
- up to 40 GHz sensor bandwidth

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A. Angelovski, M. Kuntzsch, M.K. Czwalinna, et al.:
Evaluation of the cone-shaped pickup performance for low charge sub-10 fs arrival-time measurements at free electron laser facilities.
Physical Review Special Topics - Accelerators and Beams 18 (2015), S. 012801.

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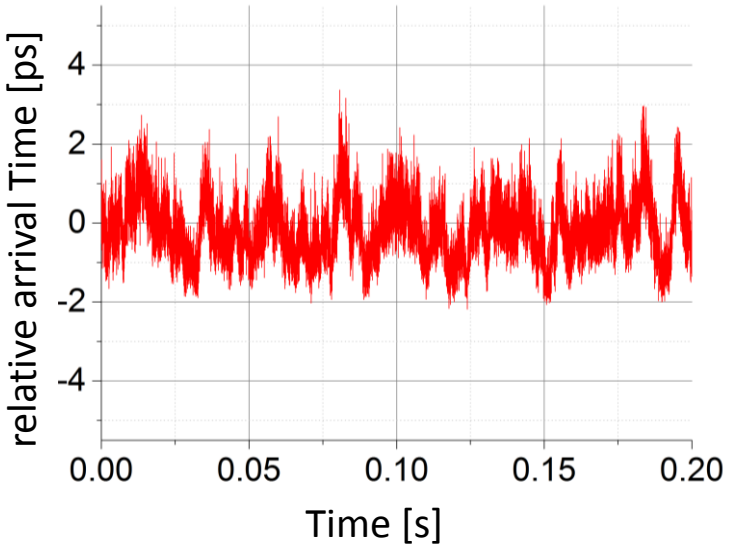
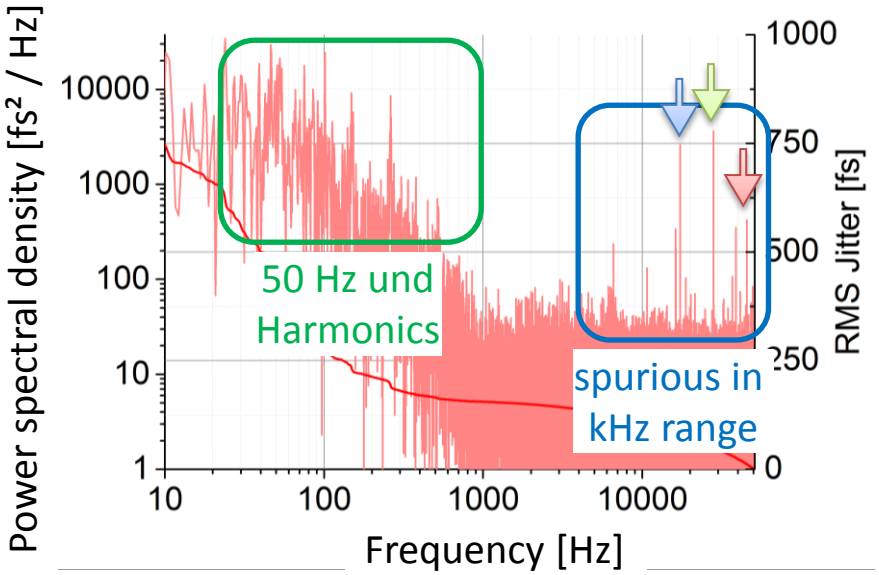
Noise Analysis

ELBE.

- Identification of noise sources by their specific frequency
  - 50 Hz and Harmonics from power supplies
  - spurious at in kHz-range



FFT



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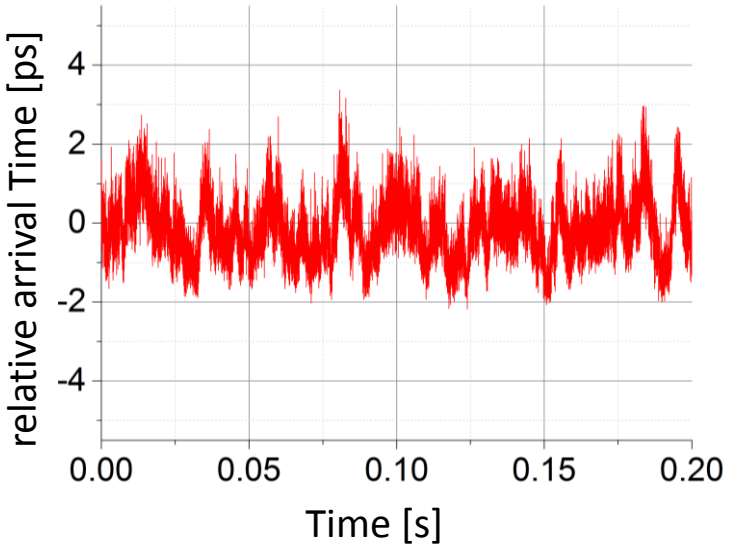

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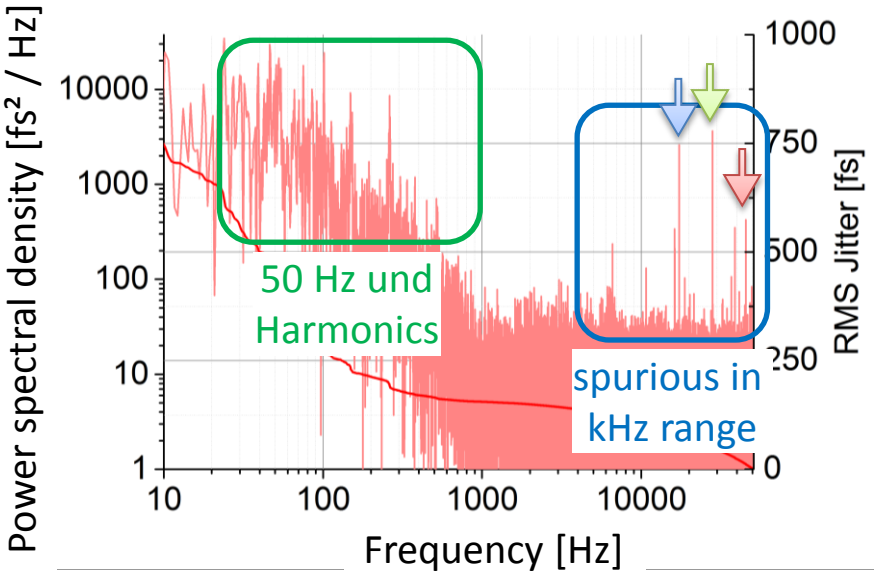
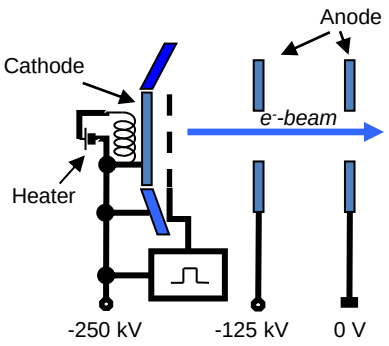
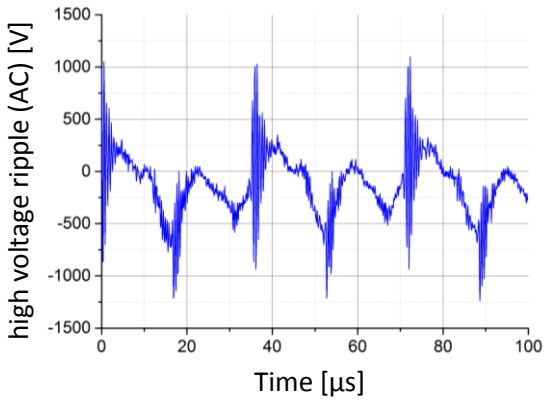


➢ periodic variation of high voltage





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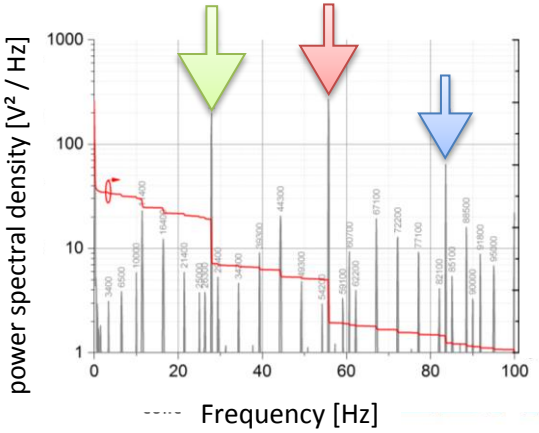

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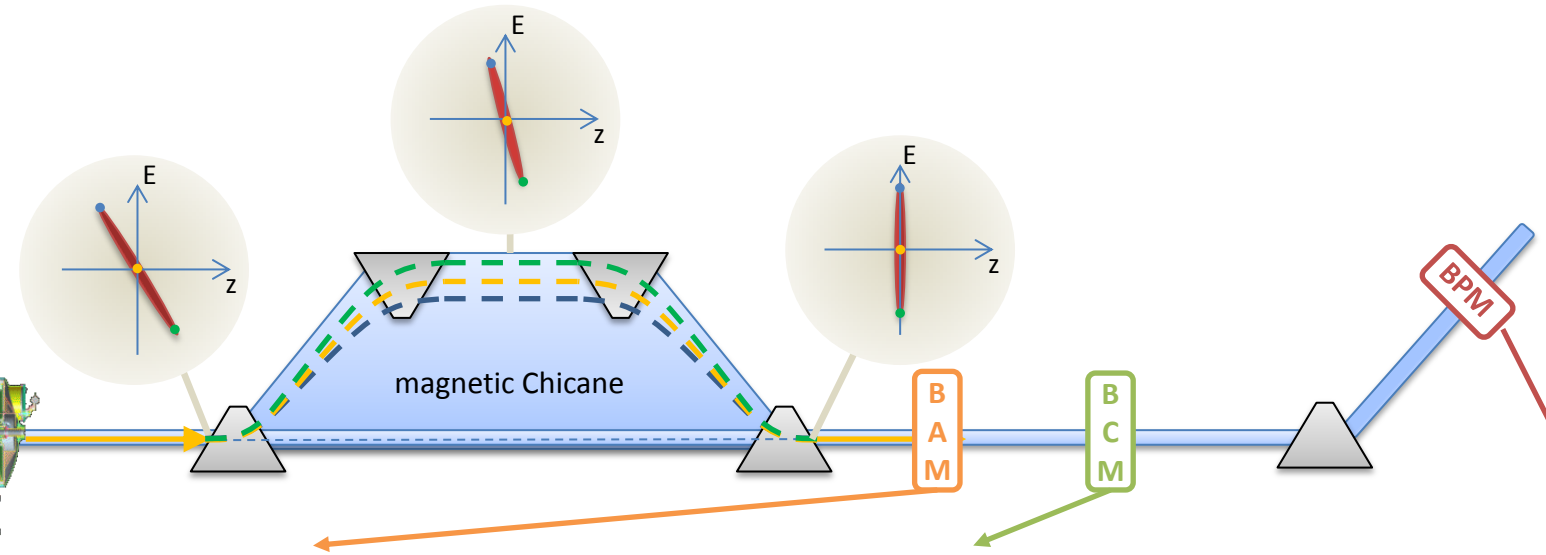
Compression dependence

ELBE.



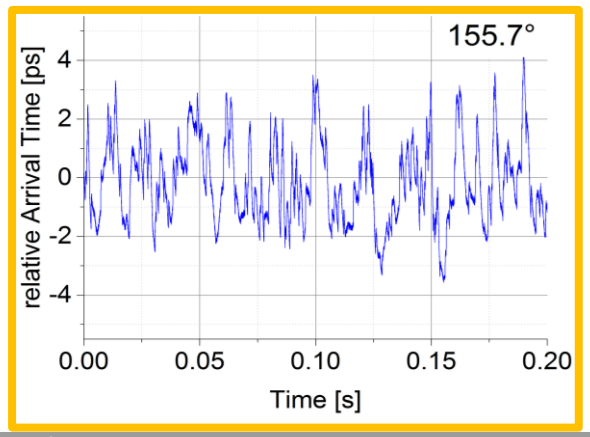
– Arrival time –
Bunch Arrival-Time Monitor

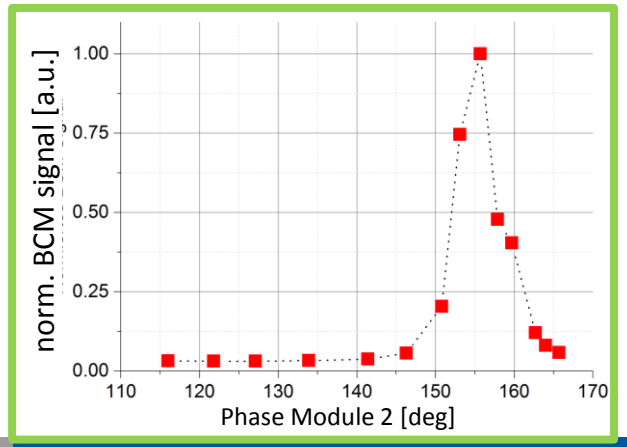
– Bunch length –
Bunch Compression Monitor

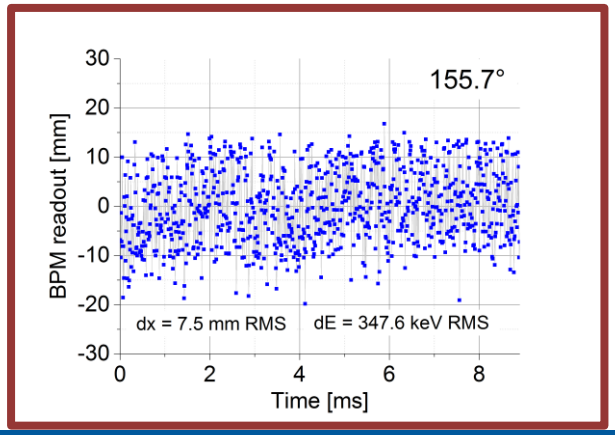
$$U_{\mathrm{det}} = f(\frac{1}{\sigma_z^2})$$

– Energy monitoring –
Beam Position Monitor

$$dx \sim dE_{electron}$$







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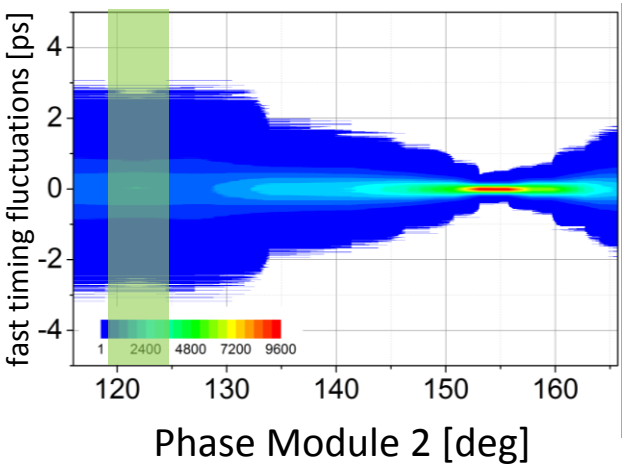
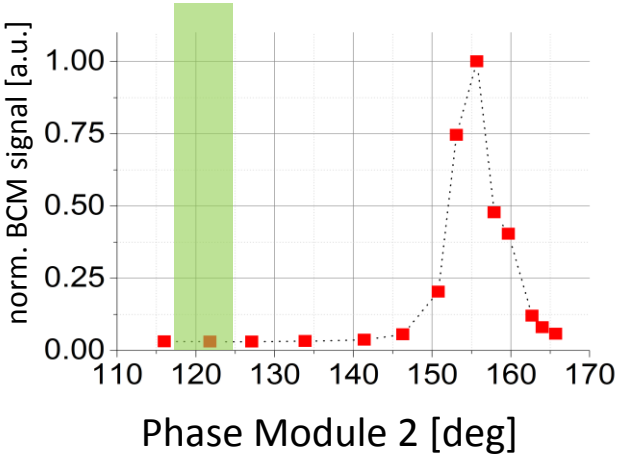
Compression dependence

ELBE.

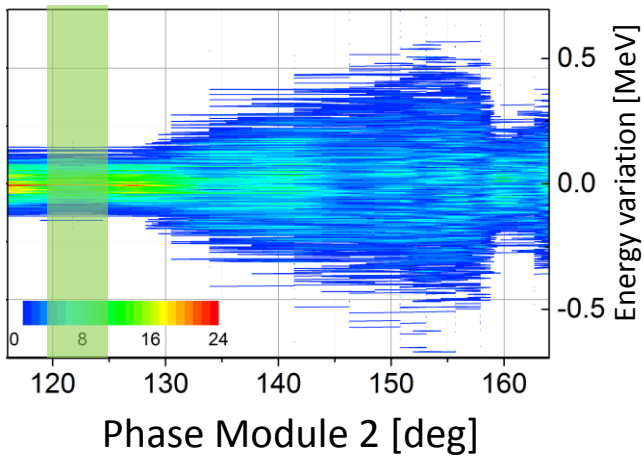
– Arrival time fluctuations –



– Pulse length –



– Energy variation –



- Transformation of arrival-time jitter into energy jitter correlated to compression state

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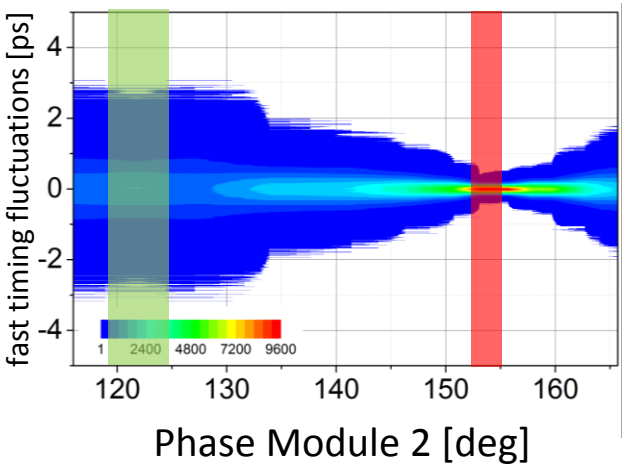
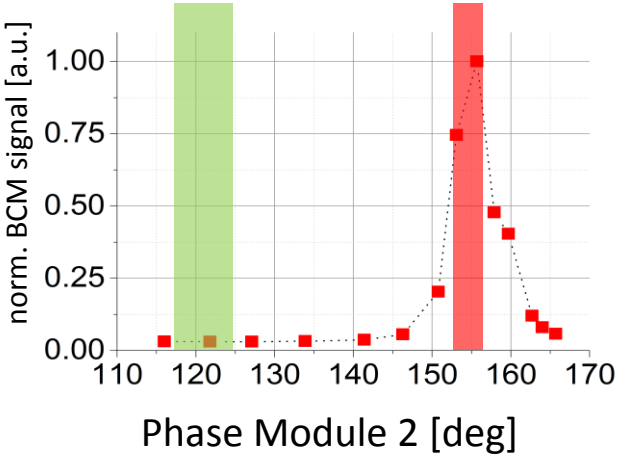
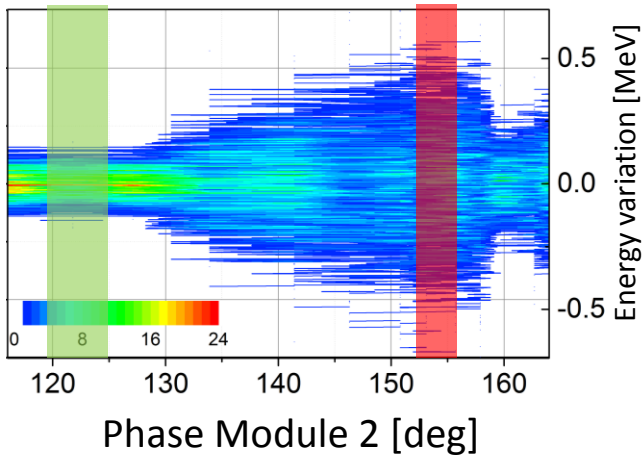


– Pulse length –



– Energy variation –



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Compression dependence

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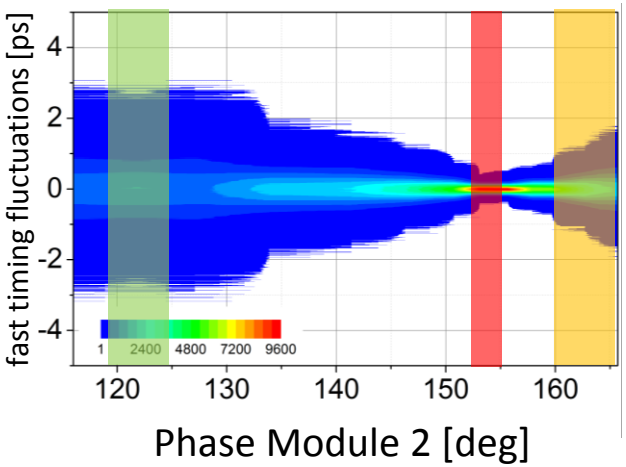
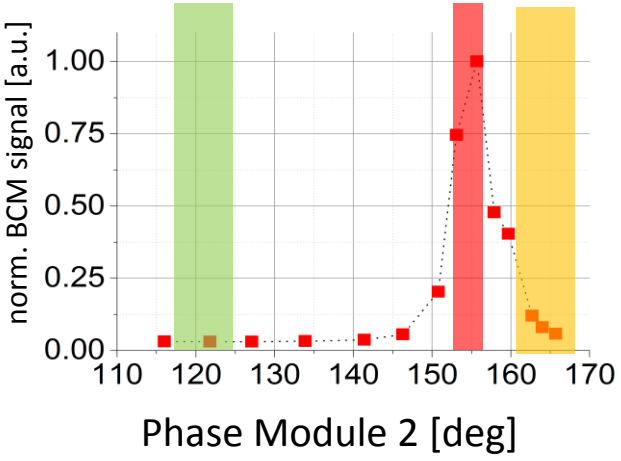
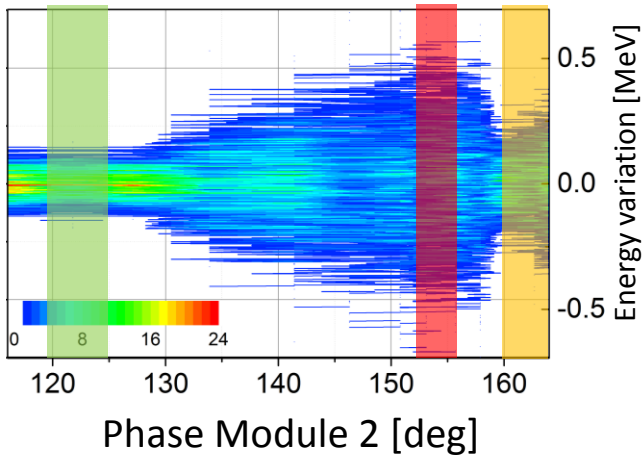


– Pulse length –



– Energy variation –



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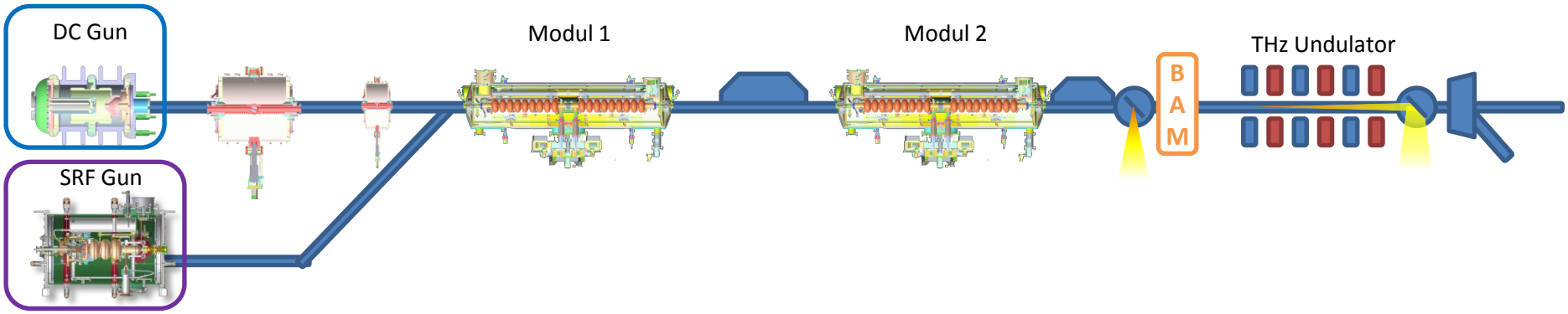
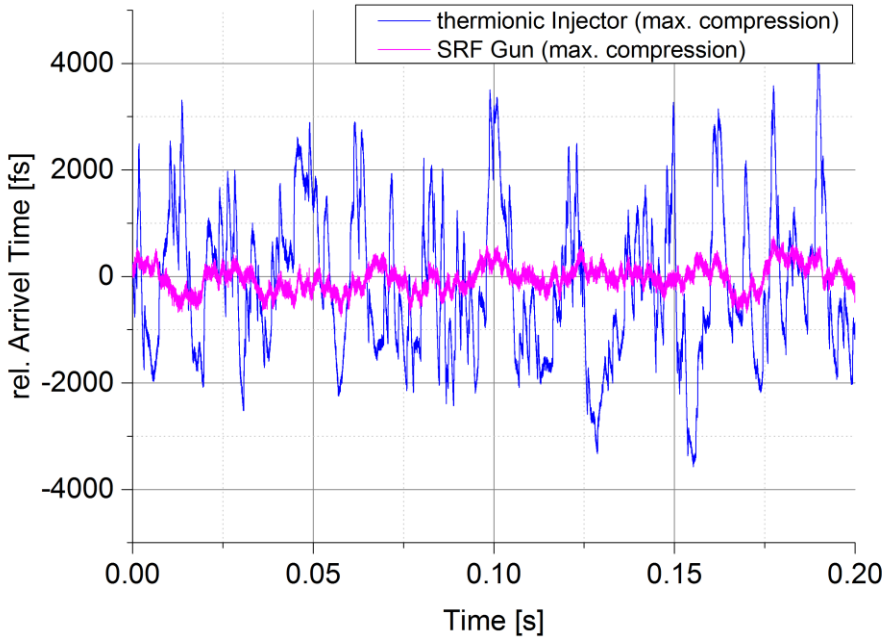
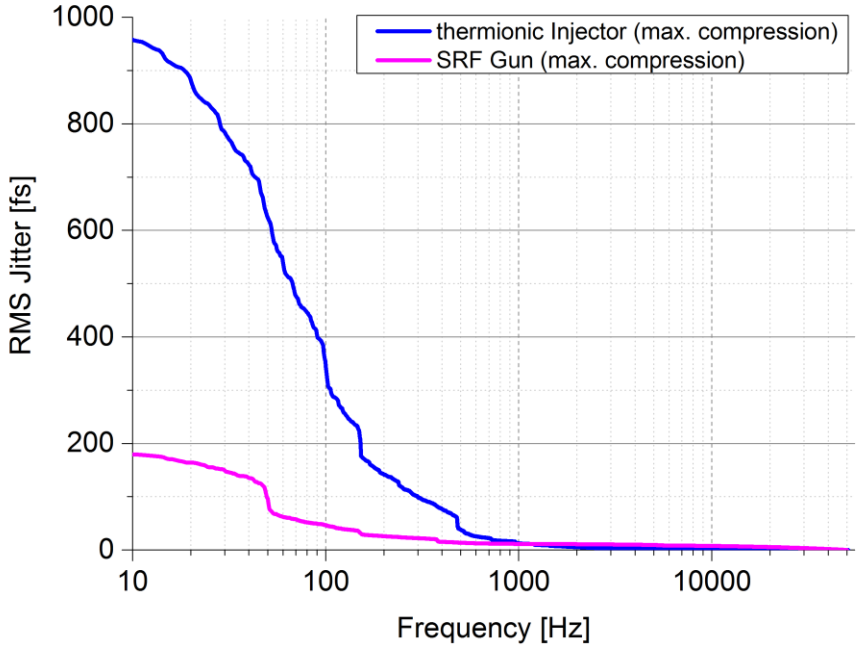
DC-Gun vs. SRF-Gun

ELBE.







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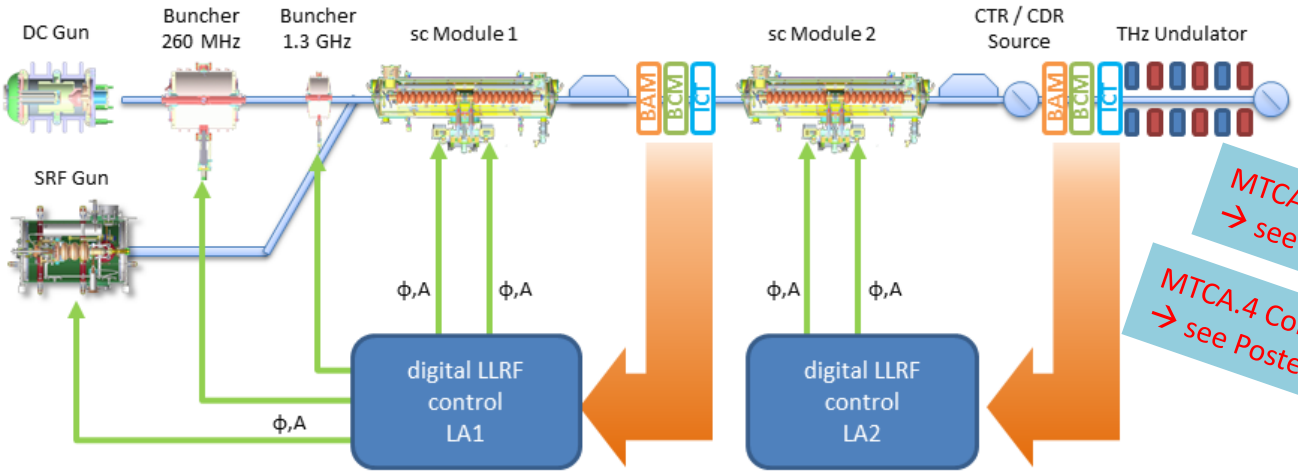
Outlook – beam based feedback

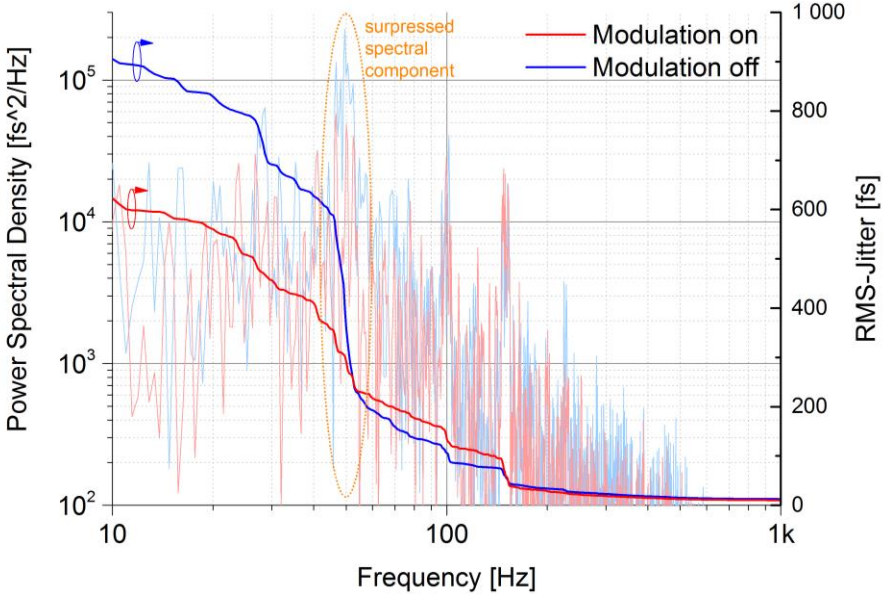
- suppression of residual Jitter based on BAM and BCM data



MTCA.4-based LLRF at ELBE
→ see Poster Igor Rutkowski

MTCA.4 Control System Integration
→ see Poster Reinhard Steinbrück

- first (simple) test
  - suppression of **50-Hz**-component (feedforward)
  - from **300 fs RMS** to **20 fs RMS**



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Summary

- CW-Mode-Diagnostics
  - enables noise analysis with large spectral range
  - reveals high frequency and low frequency noise components
  - transformation of jitter components visible

- at ELBE
  - translation of injector instabilities on electron beam jitter
  - performance evaluation of both injectors
  - beam-based feedback needed to improve stability
  - first successful test with analogue controllers
  - µTCA.4 digital LLRF control + feedbacks are in preparation

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ELBE.

Thank you.

Acknowledgements

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DESY LbSynch Team, especially H. Schlarb, M. Czwalinna, C. Sydlo, M. Felber

S. Vilcins, J. Kruse

A. Angelovski, A. Penirschke

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Backup

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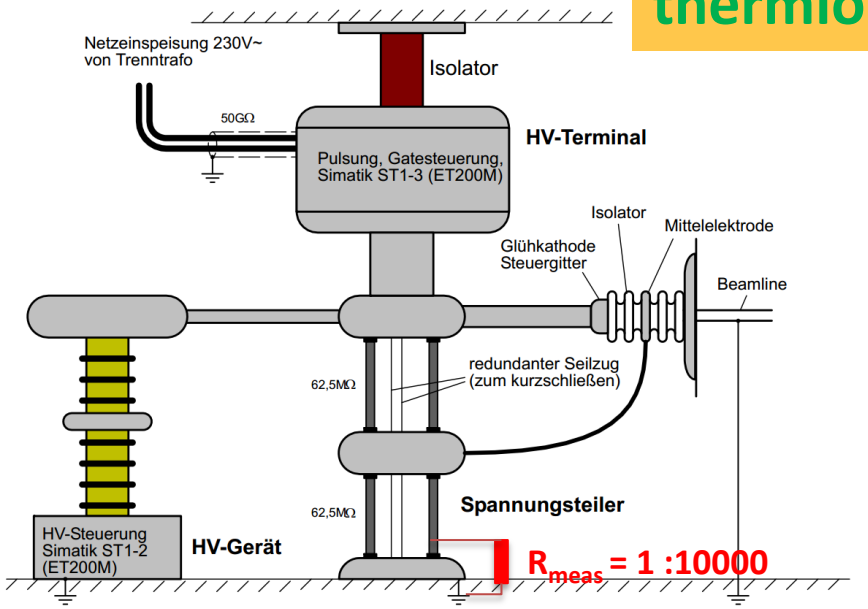
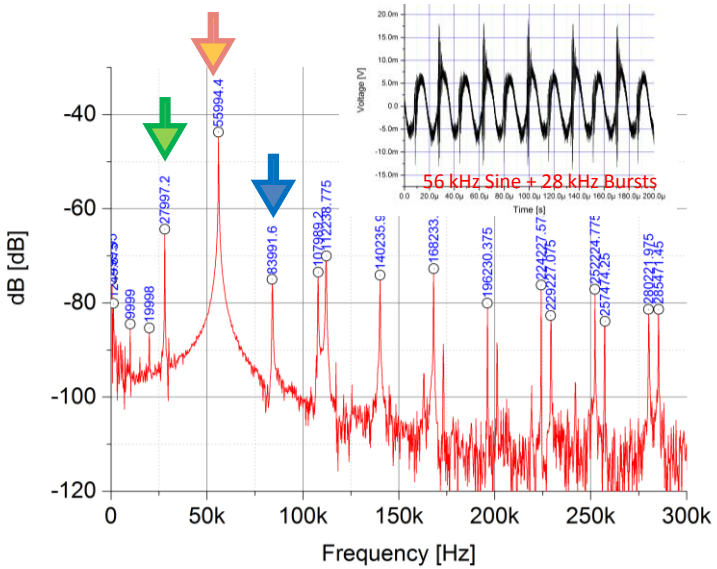
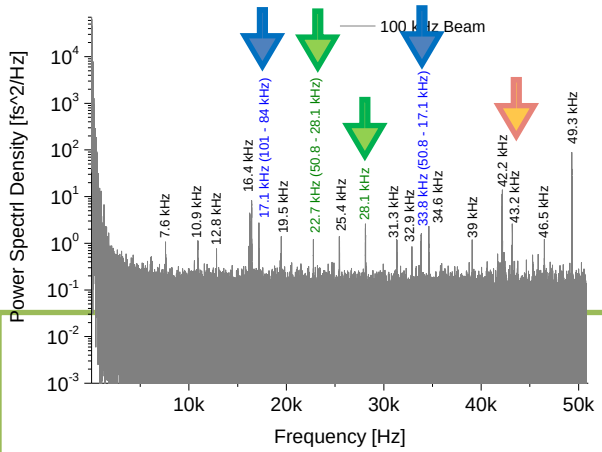
thermionic Injector



Gun HV Ripple



BAM



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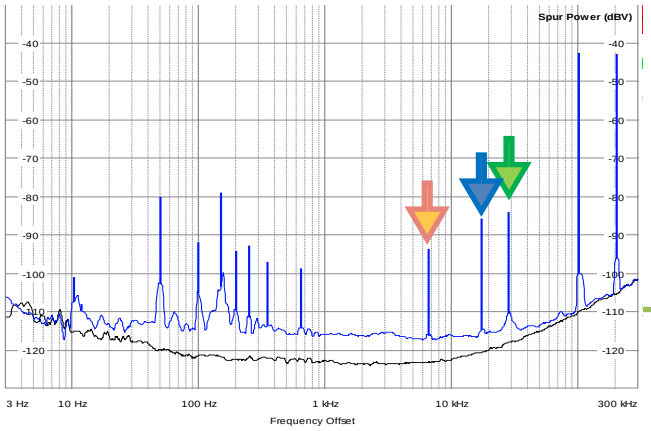
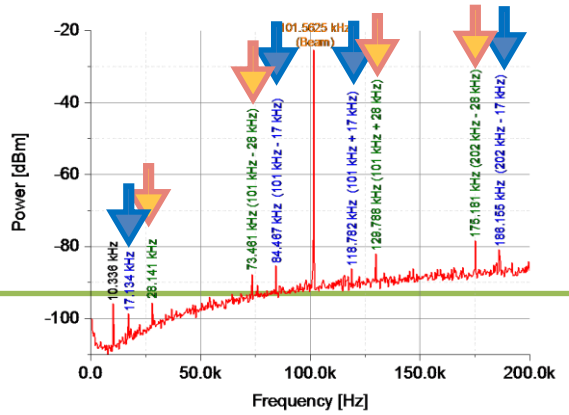
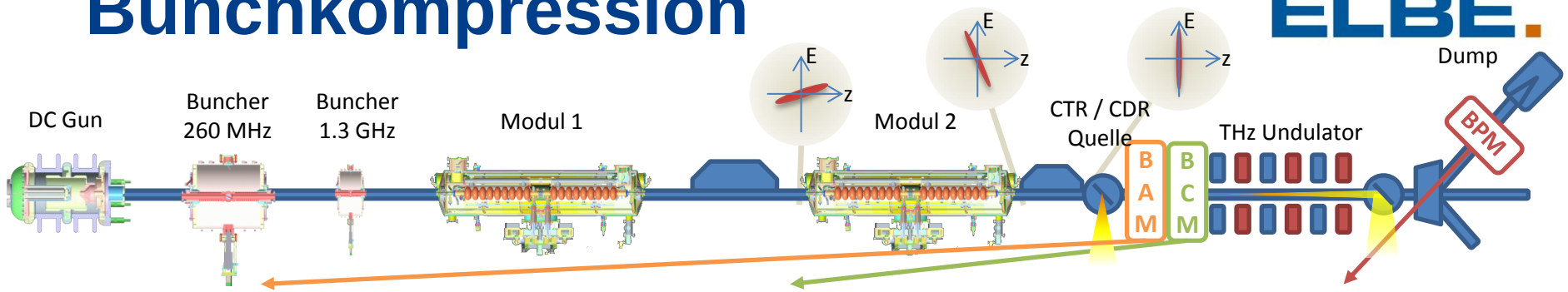


BPM

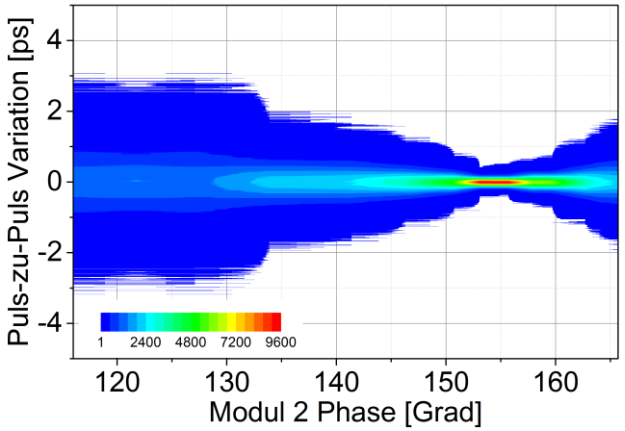


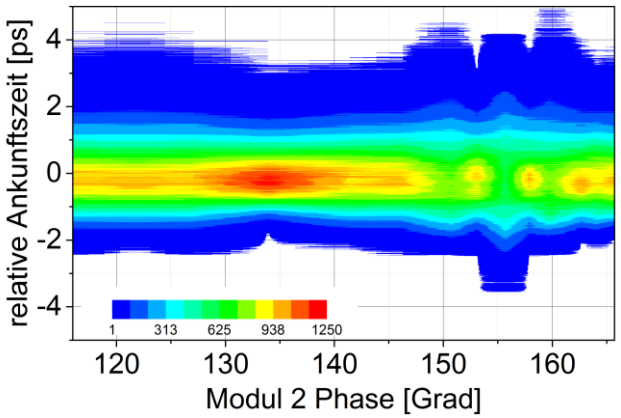
Bunchkompression

ELBE.

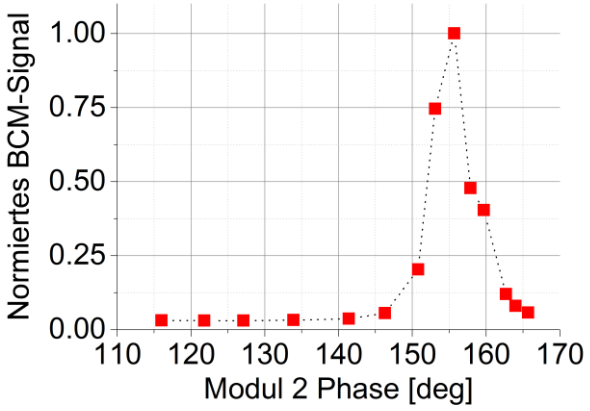


– Ankunftszeitmessung –
Bunch Arrival-Time Monitor

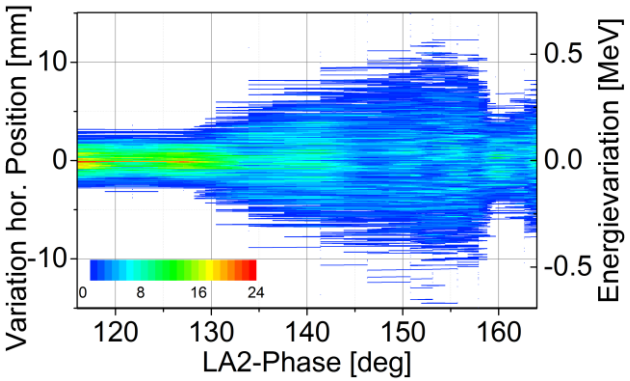




– qualitative Pulslängenmessung –
Bunch Compression Monitor



– energieabhängige Lagemessung –
Beam Position Monitor



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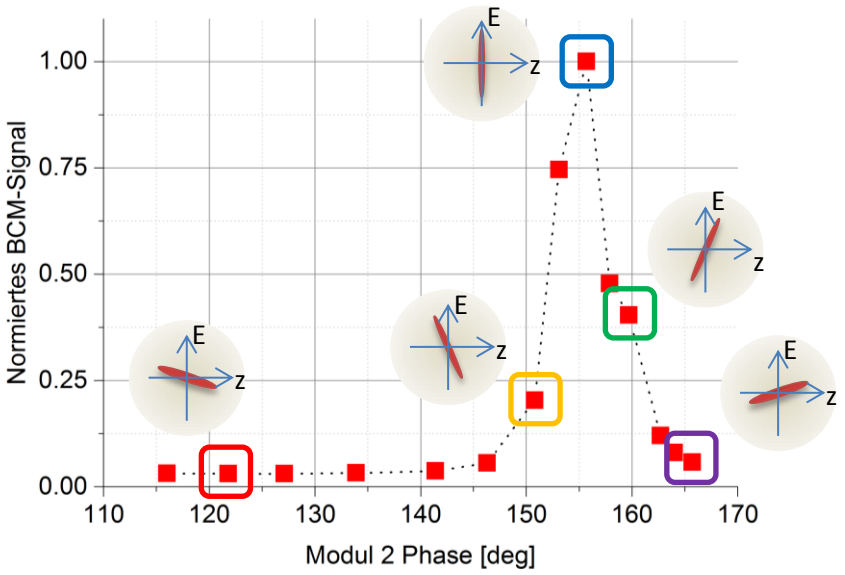
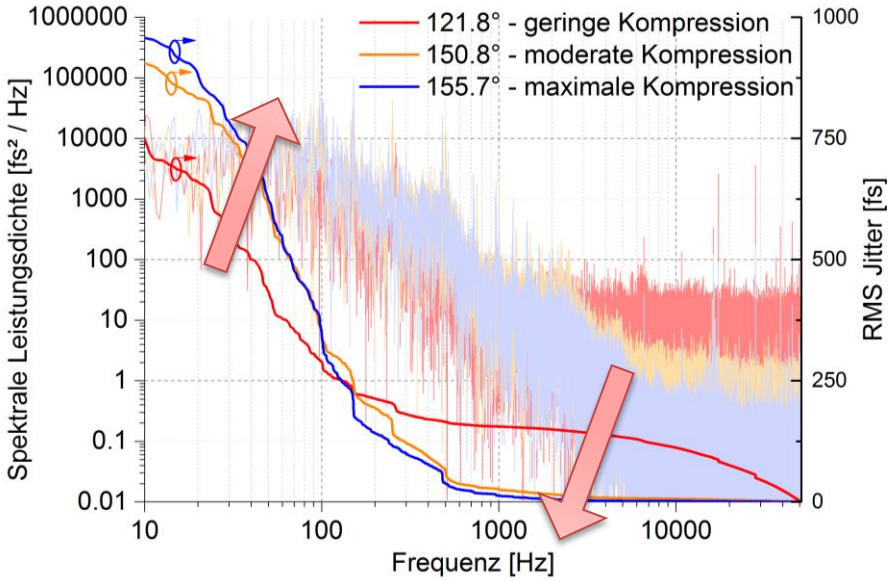
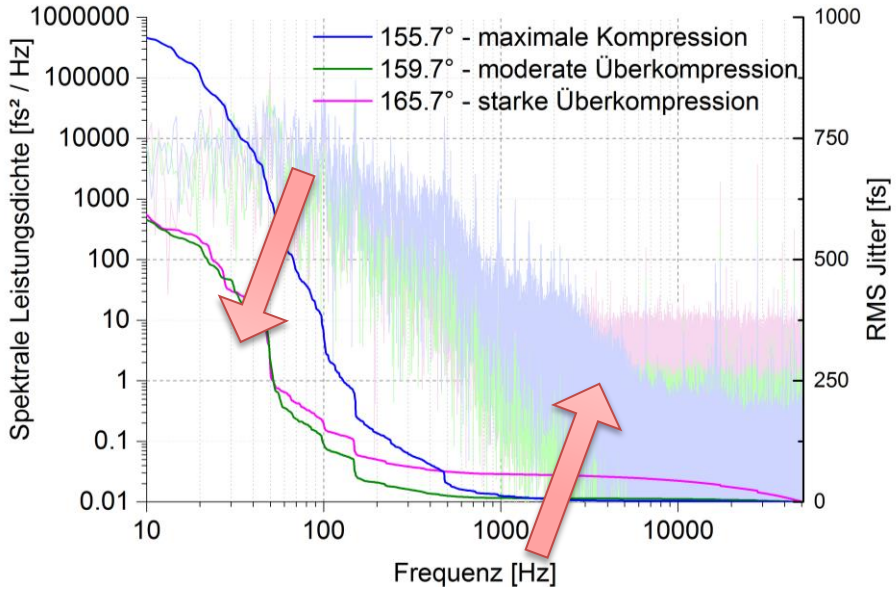
Kompressionsabhängigkeit

- bei steigender Kompression
  - Unterdrückung hochfrequenter Rauschanteile
    - Quelle vornehmlich Injektor
  - Anstieg niederfrequenter Rauschanteile
    - eingebracht durch Modul 2
- bei Überkompression inverses Verhalten







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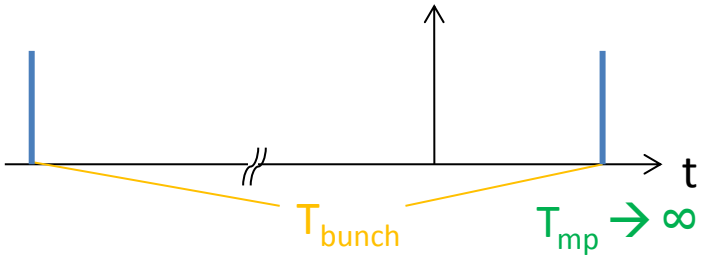
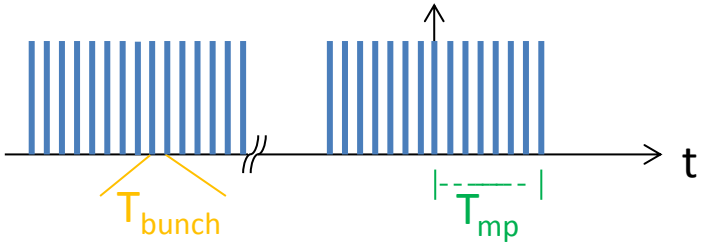
What means (quasi-) CW?

ELBE.

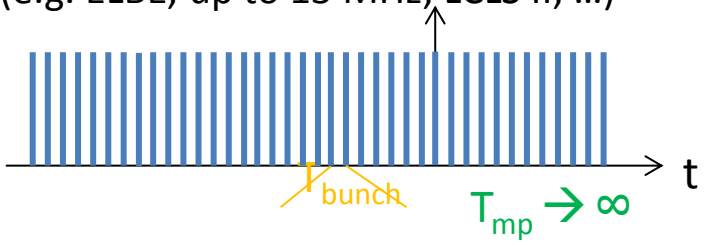
Single Shot / Low repetition rate
(e.g. LCLS, up to 120 Hz)



Macro pulse
(e.g. FLASH, 1 MHz @ 800µs, T_{mp} = 100ms)

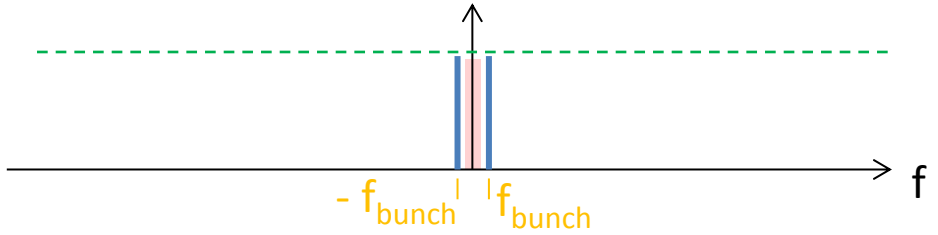


(quasi-) CW
(e.g. ELBE, up to 13 MHz; LCLS II; …)

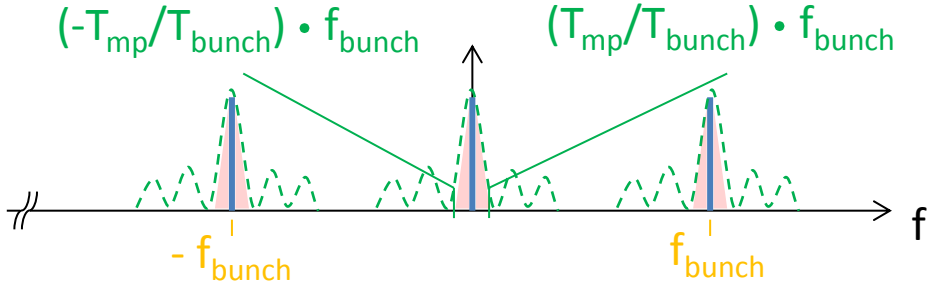


FFT

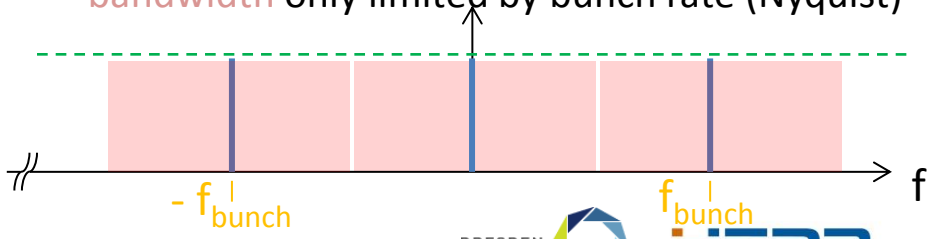
- low statistics
- low measurement bandwidth (Nyquist)



- high repetition rate
- bandwidth limited by macro pulse length T_{mp}



- high repetition rate
- bandwidth only limited by bunch rate (Nyquist)



DRESDEN concept

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