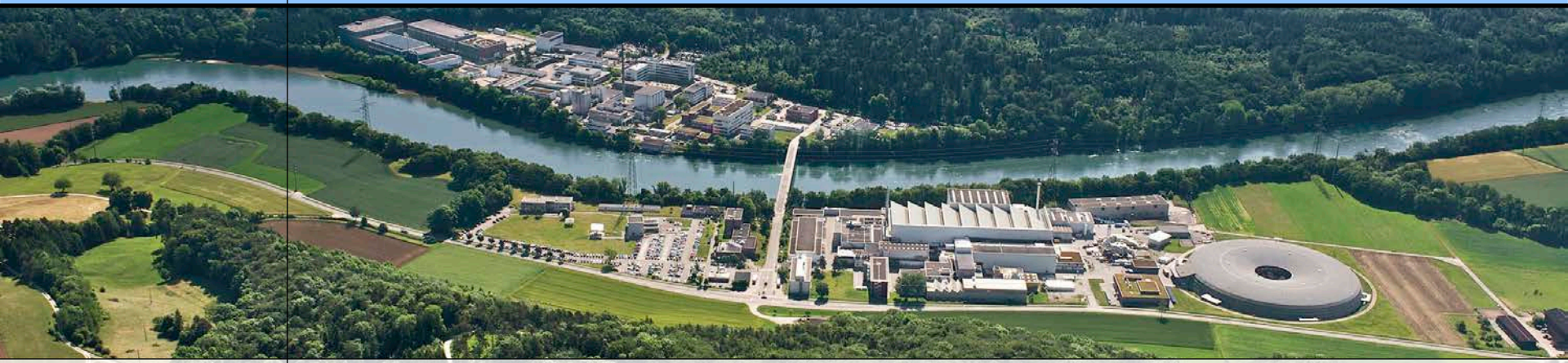
PAUL SCHERRER INSTITUT

PSI



Wir schaffen Wissen – heute für morgen

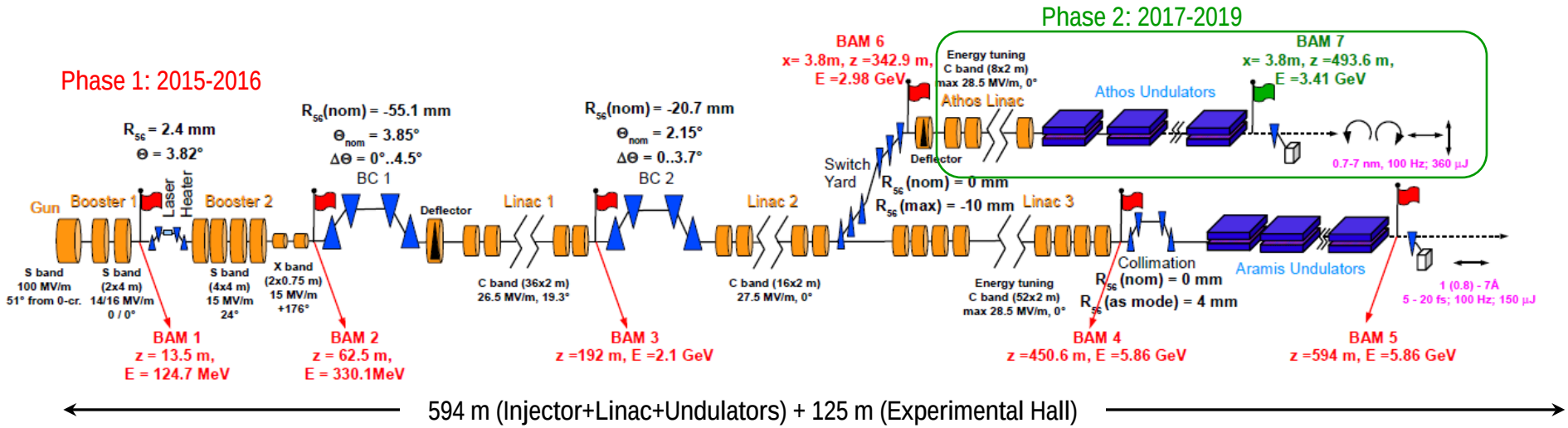
Paul Scherrer Institut

Vladimir Arsov, M. Dehler, S. Hunziker, M. Kaiser, V. Schlott

First Results from the Bunch Arrival-Time Monitor at the SwissFEL Test Injector

- Specification & Requirements
- Conceptual Design
- Prototype Results
- Summary and outlook

Layout and Parameters of SwissFEL

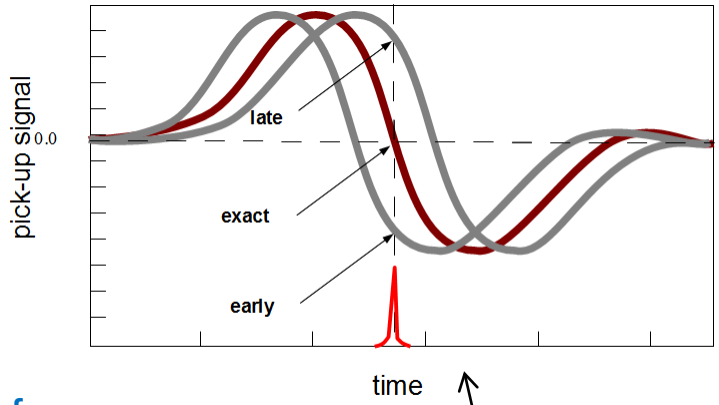


Design parameters of the two beamlines

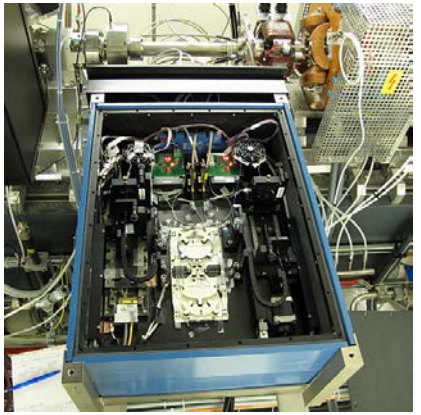
- Charge: 10 .. 200 pC
- Beam energy for 1 Å: 5.8 GeV
- Core slice emmittance: 0.18 .. 0.43 mm.mrad
- Energy spread: 250 .. 25000 keV (rms)
- Peak current at undulator: 1.6 .. 15 kA
- Bunch length: 0.3 .. 25 fs (rms)
- Bunch compression factor: 125 .. 5000
- Repetition rate: 100 Hz, 2 bunches @ 28 ns

- Wavelengths: 1 .. 7 Å (linear polarization)
  0.1 .. 7 Å (linear/circular polarization)
- Pulse lengths: 0.06 .. 20 fs
- Peak brightness: $< 1.3 \cdot 10^{33}$ phot/s·mm^2·mrad^2·0.1%BW

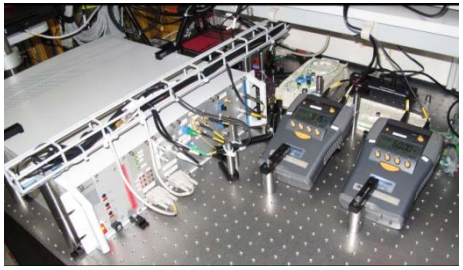
BAM Detection Principle

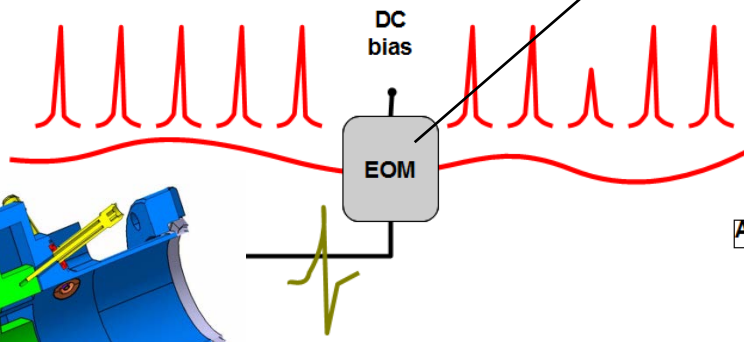


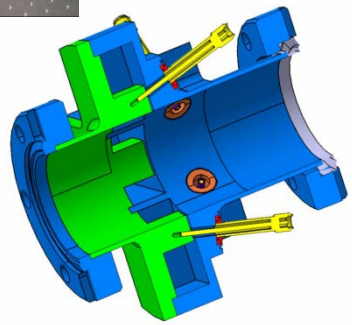
Opto-mechanical and RF-front-end in the accelerator tunnel

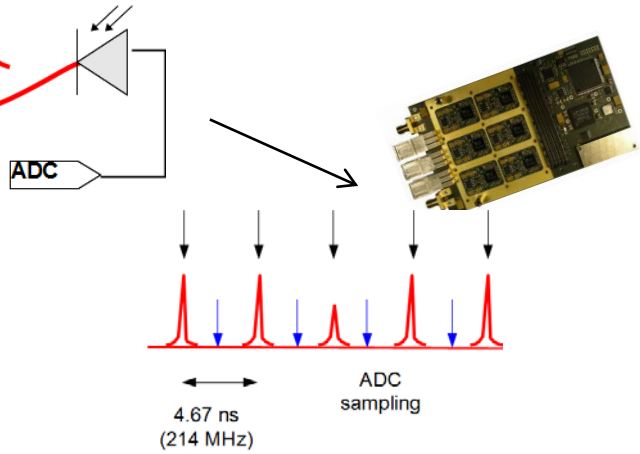


Stable (pulsed) optical reference







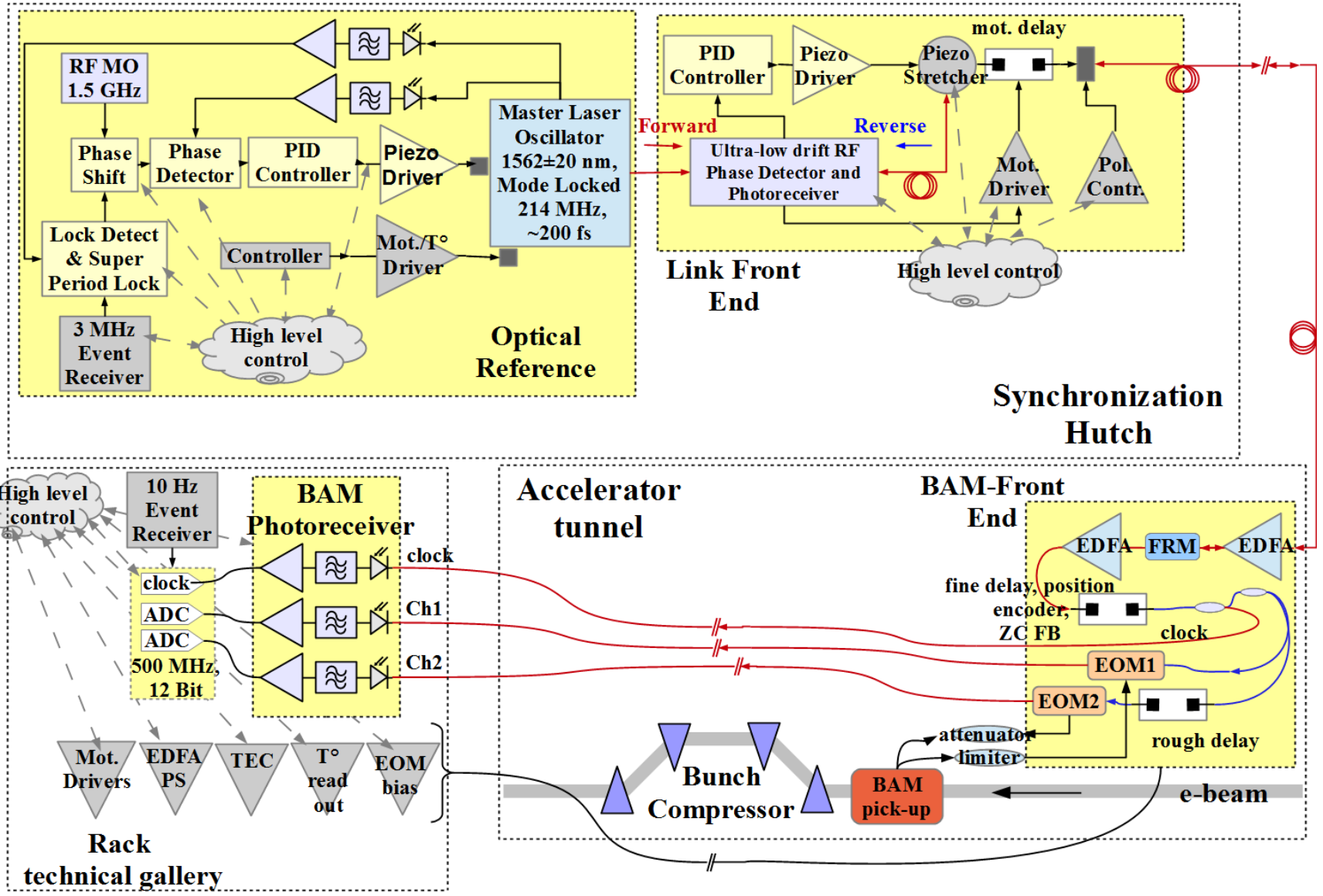


Pickup in the accelerator tunnel

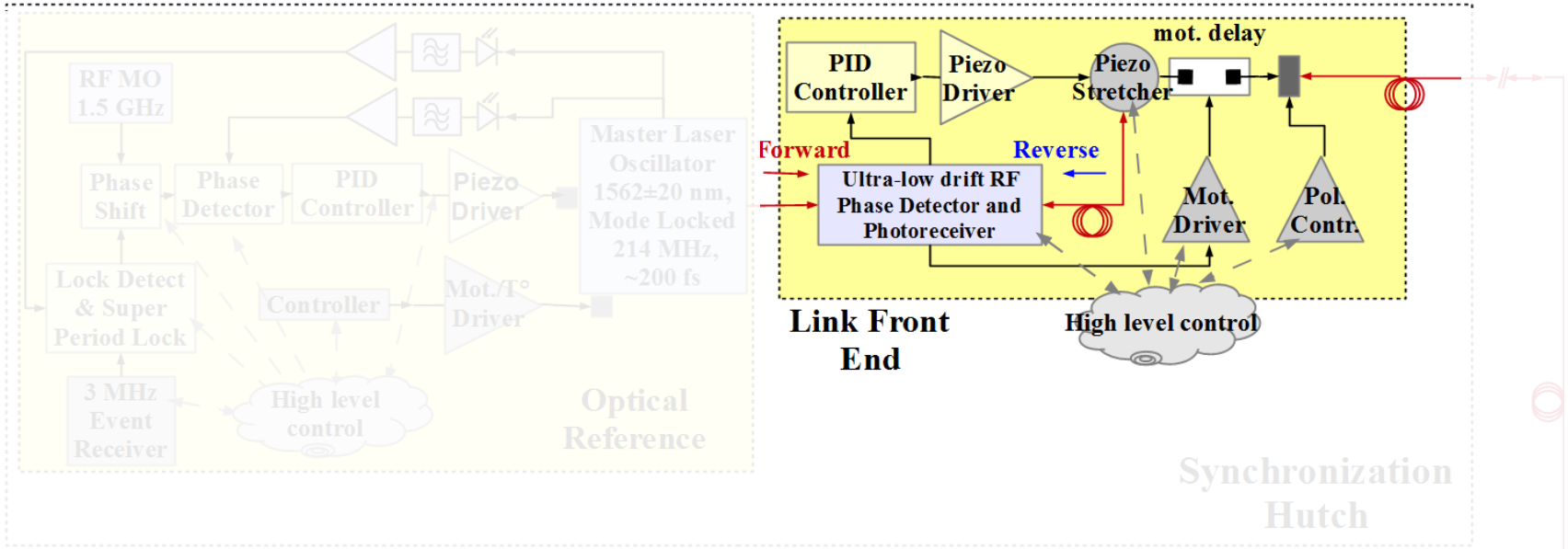
Data Acquisition (e.g. GPAC ADC12FL) in the technical gallery

*Florian Löhl, DESY-THESIS-2009-031, March 2009

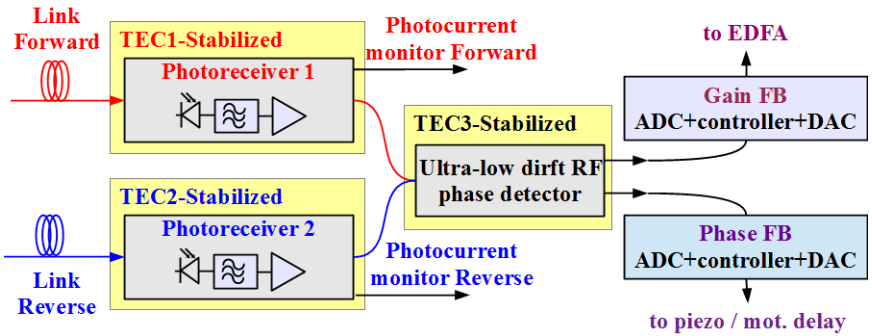
Layout of the Optical Synchronization and BAM



Highly Stable RF-Based Phase Detection



Highly Stable RF-Based Phase Detection



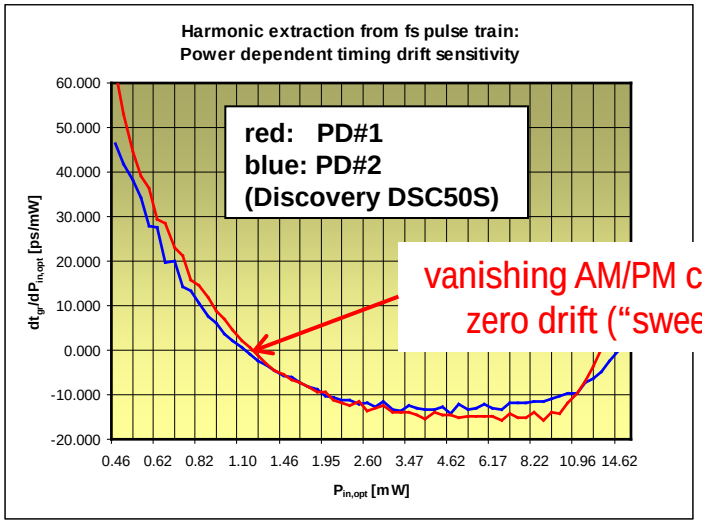
Design and realization: S. Hunziker

Optimized Detector and Photodiode Performance

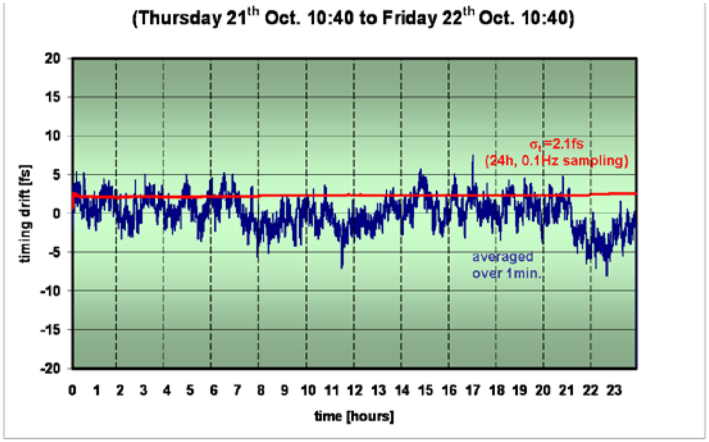
- Peltier-stabilized phase detector (stability < 0.01° C)
- Use of T° - insensitive cables
- Fused fiber-optic power splitter with equal length arms
- Specially selected and T° stabilized PDs
- PD Operation at vanishing AM/PM conversion (sweet spot)
- Amplitude stability (forward/reverse) kept < 0.1 dB
- T° stabilized amplifiers, ceramic BP filters

Phase control: mot. delay line (330 ps) / fiber stretcher
(19 fs/V → compensates 3.4° / 12.2% RH)

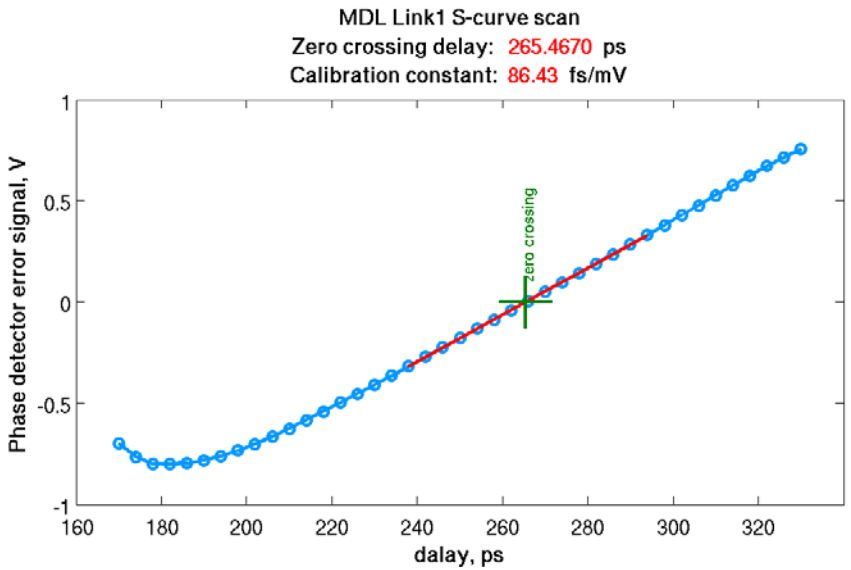
Amplitude control: EDFA 1 in the BAM-Box



Laboratory test HF signal (no BAM, no EDFA): < 10 fs pk-pk stability



Highly Stable RF-Based Phase Detection



Phase detector error signal slope: 86 fs/mV

Link power stability (forward):

Mean: 2.05 V

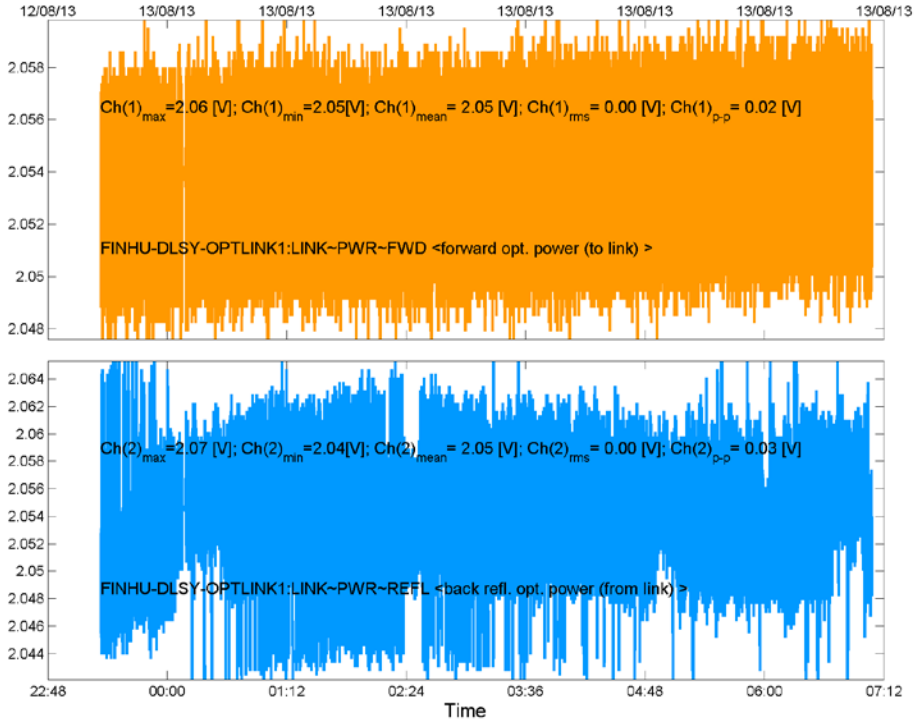
Ripple pk-pk: 15.6 mV

Link power stability (reverse):

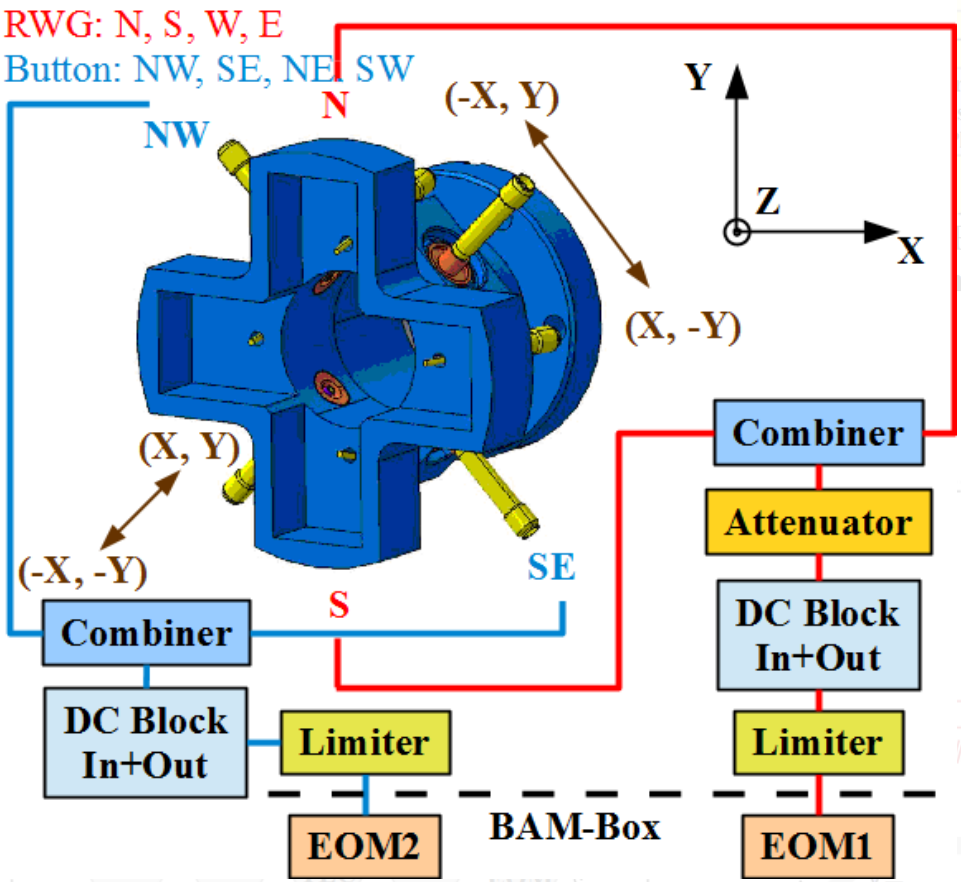
Mean: 2.05 V

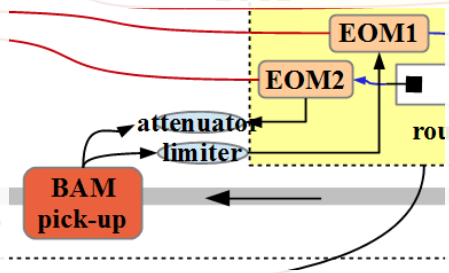
Ripple pk-pk: 27.6 mV

Amplitude FB monitor signals

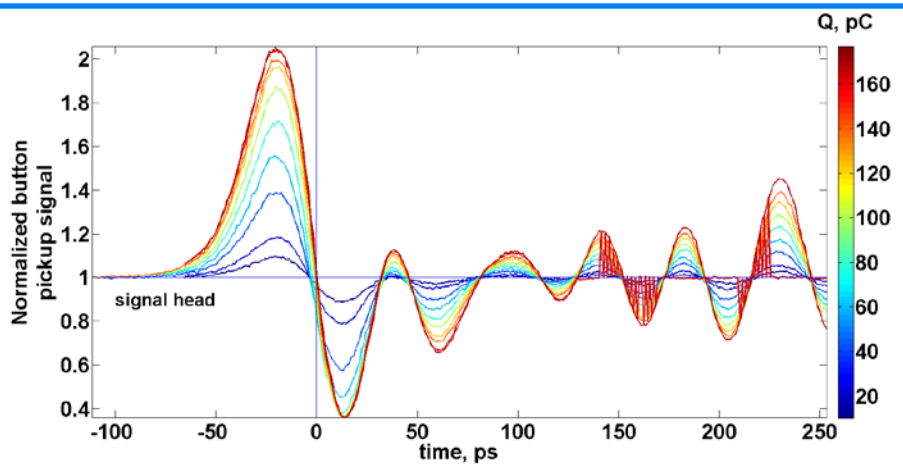


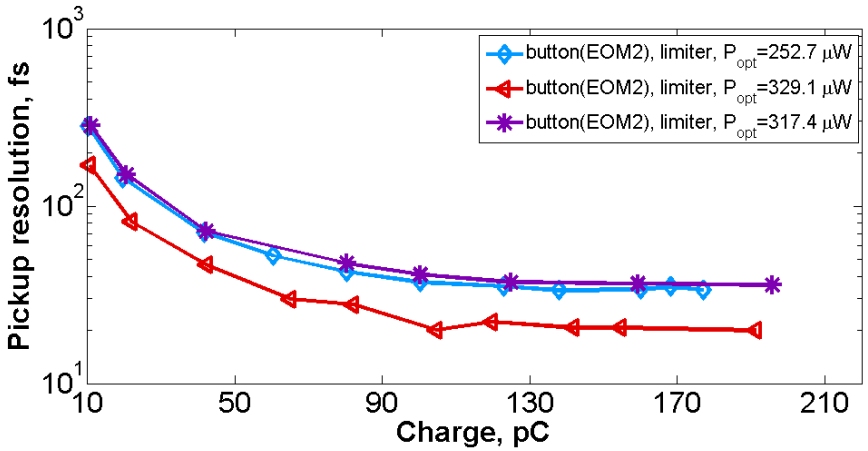
BAM-Pickups


RWG: N, S, W, E
Button: NW, SE, NE, SW
N
NW
(-X, Y)
Y
Z
X
(X, -Y)
(X, Y)
(-X, -Y)
SE
S
Combiner
Attenuator
DC Block
In+Out
Combiner
DC Block
In+Out
Limiter
Limiter
EOM2
BAM-Box
EOM1


EOM1
EOM2
attenuator
limiter
BAM
pick-up

BAM Button Pickup: charge dependence



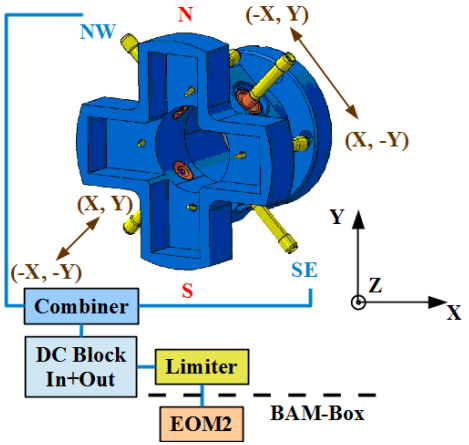


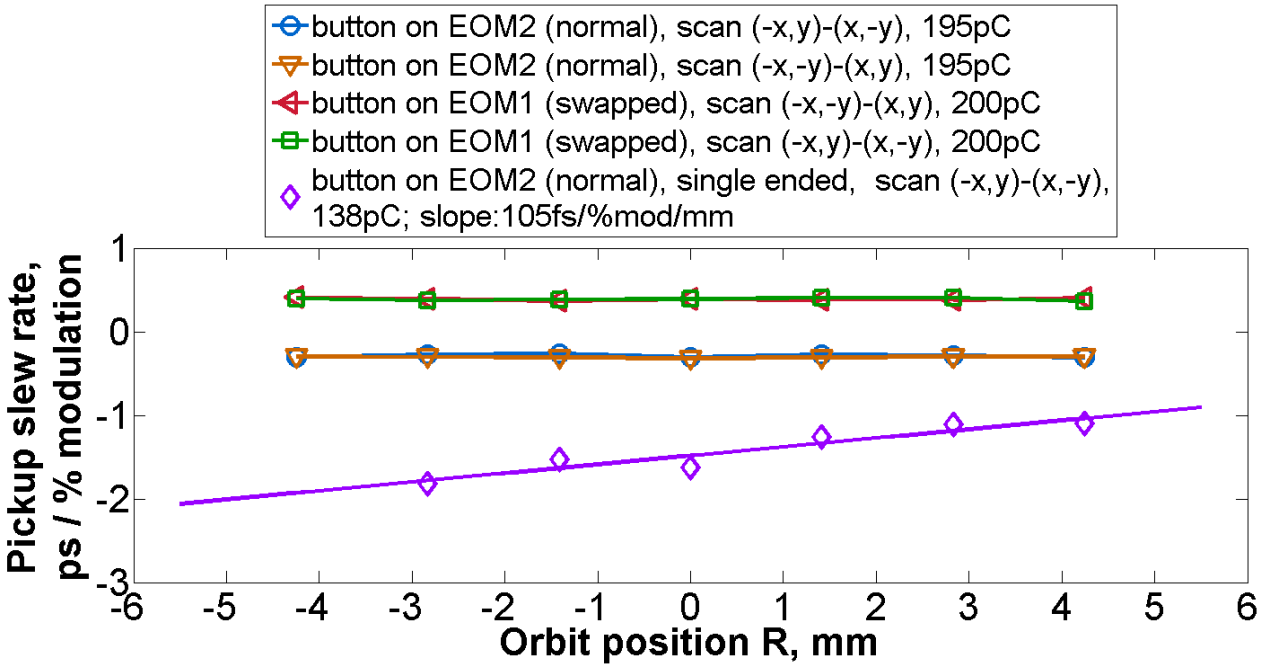
The Resolution is limited through:

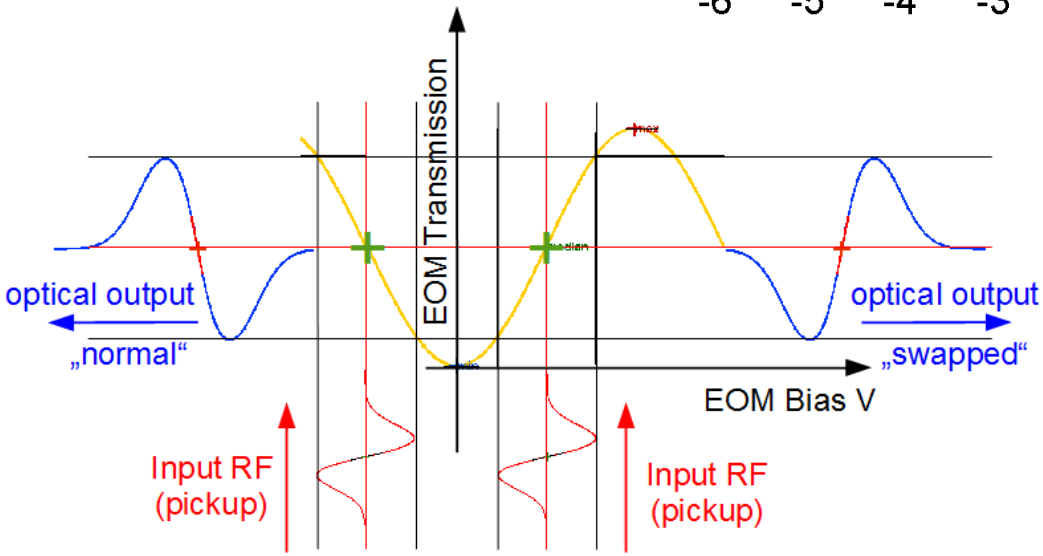
- Bandwidth of the pickup feedthrough (DC..20GHz, Meggit PN853872)
- Bandwidth of the EOMs (12 GHz)
- ADC resolution (12 bit), AC-Coupling
- Missing Signal Conditioning Front-end (DC-Offset)

BAM Button Pickup: orbit dependence

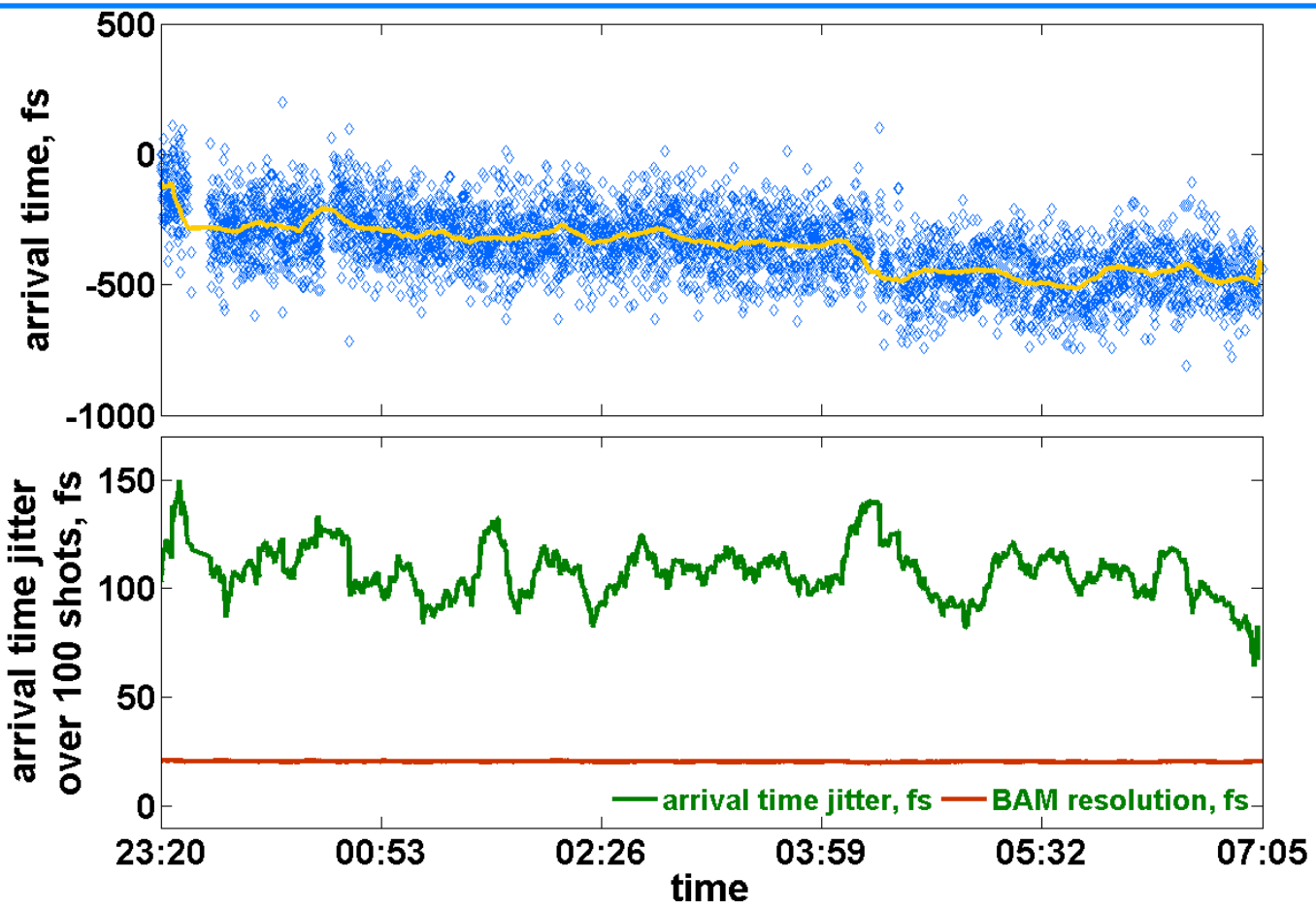
Button: NW – SE
Cables to combiner: group delay compensated, ~50 fs accuracy







BAM: drift measurement



beam parameters (average):	130 pC, 245 MeV, ~3 ps
BAM resolution (average):	20 fs
Bunch arrival-time drift:	410 fs
Jitter:	110 fs (rms); 150 fs (peak)

BAM: gun phase scan

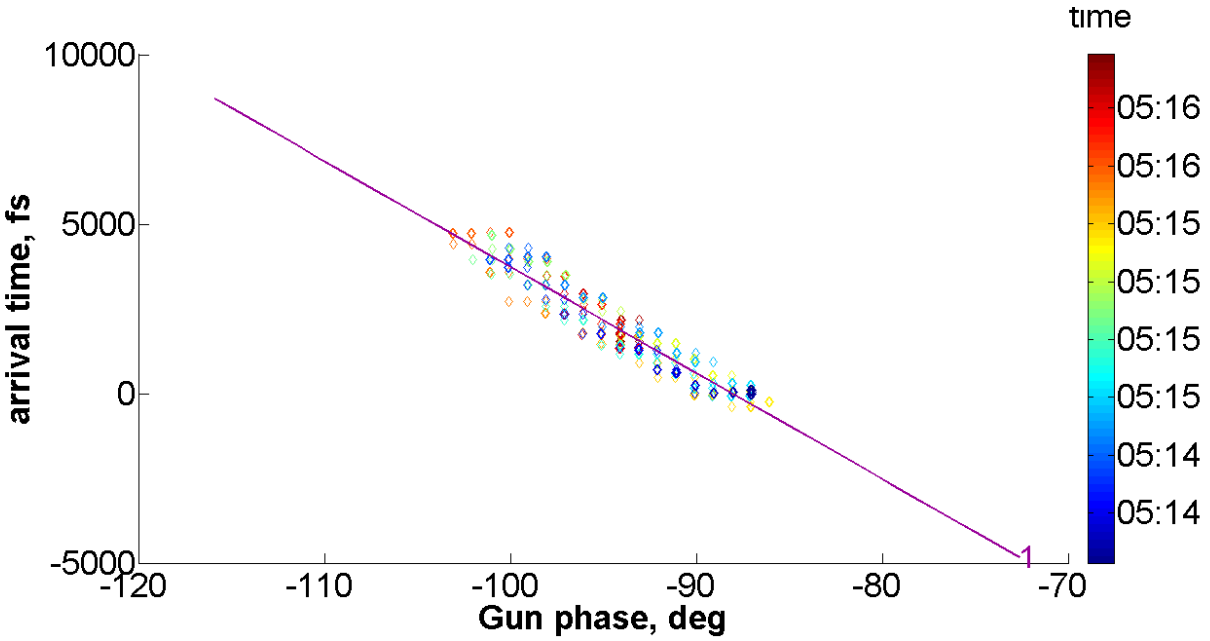
Bunch Arrival-Time Downstream the Bunch Compressor:

$$\Delta t_{beam} = G_{laser} \cdot \Delta t_{laser} + G_{gun} \cdot \Delta t_{gun} + O_2\left(G_{ACC} \cdot \Delta t_{ACC}\right)$$

$$G_{gun} = \frac{dt_{beam}}{dt_{gun}} = 2\pi f^{(S)} \frac{dt_{beam}}{d\varphi_{gun}}$$

$$f^{(S)} \approx 3GHz$$

$$\frac{dt_{beam}}{d\varphi_{gun}} = 310\ fs/\deg$$



⇒ Gun phase contribution: ~34%

Summary and Outlook

Milestones:
- 1 BAM operational downstream BC ☑
- 2 bunch operation ☐
- Resolution, charge: 10 pc: <10 fs ☐

Implementation of one BAM-Box upstream BC :
- 40 GHz Cables and Components
- 40 GHz EOMs

Implementation of 40 GHz pickups:
- Reduced ringing
- Operation below the cut-off of the X-Band

Improved Readout:
- GPAC 16 FL, 160 MHz, 16 bit,
- Increased sample length;
- DC coupling
- signal conditioning DAC (in progress)

Thank you for your attention!