Compact ultra-high precision beam phase monitor system

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DESY[1], Hamburg University[2]

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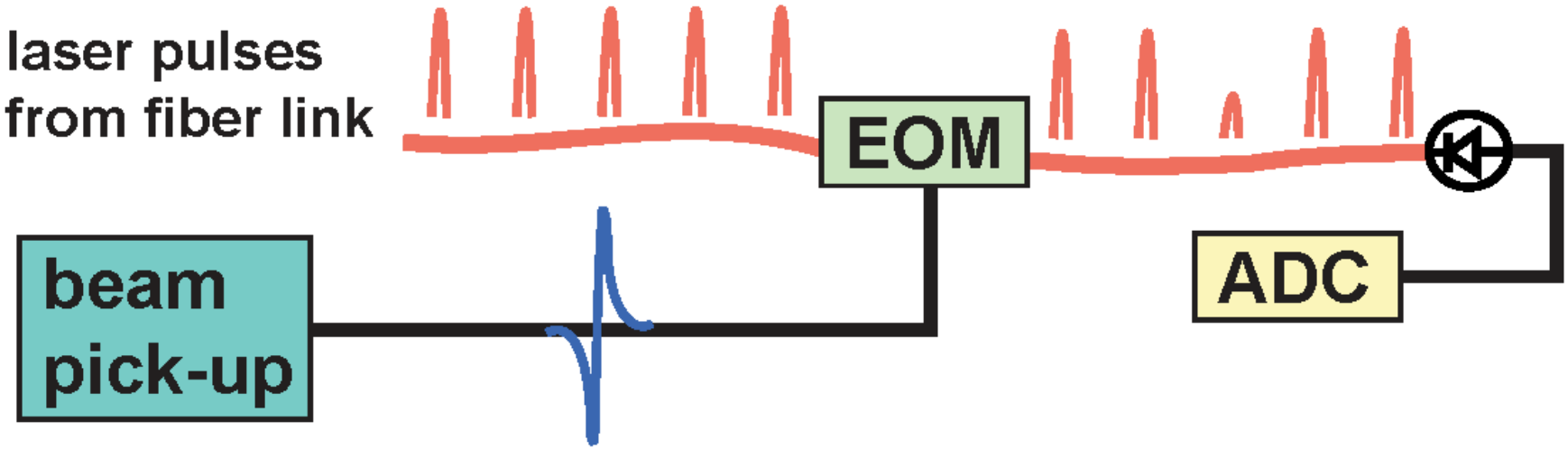
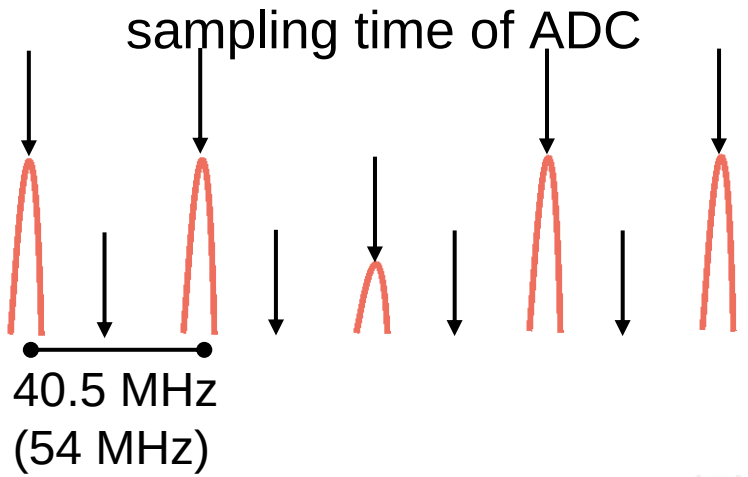
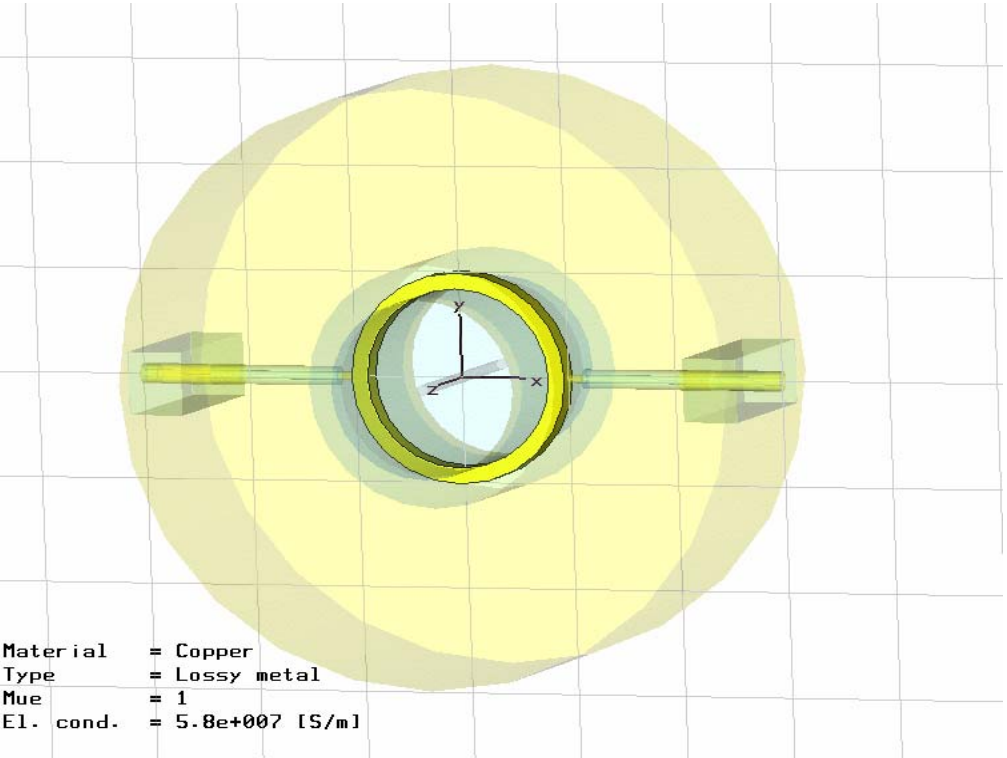
Principle of the Beam Phase Monitor



The timing information of the electron bunch is transferred into an amplitude modulation. This modulation is measured with a photo detector and sampled by a fast ADC.

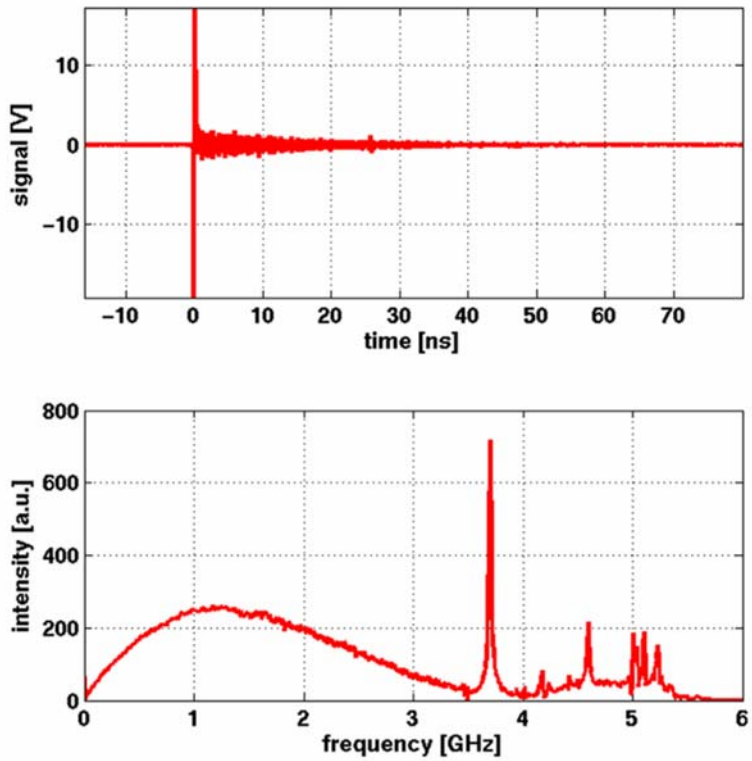


Beam Pick-up

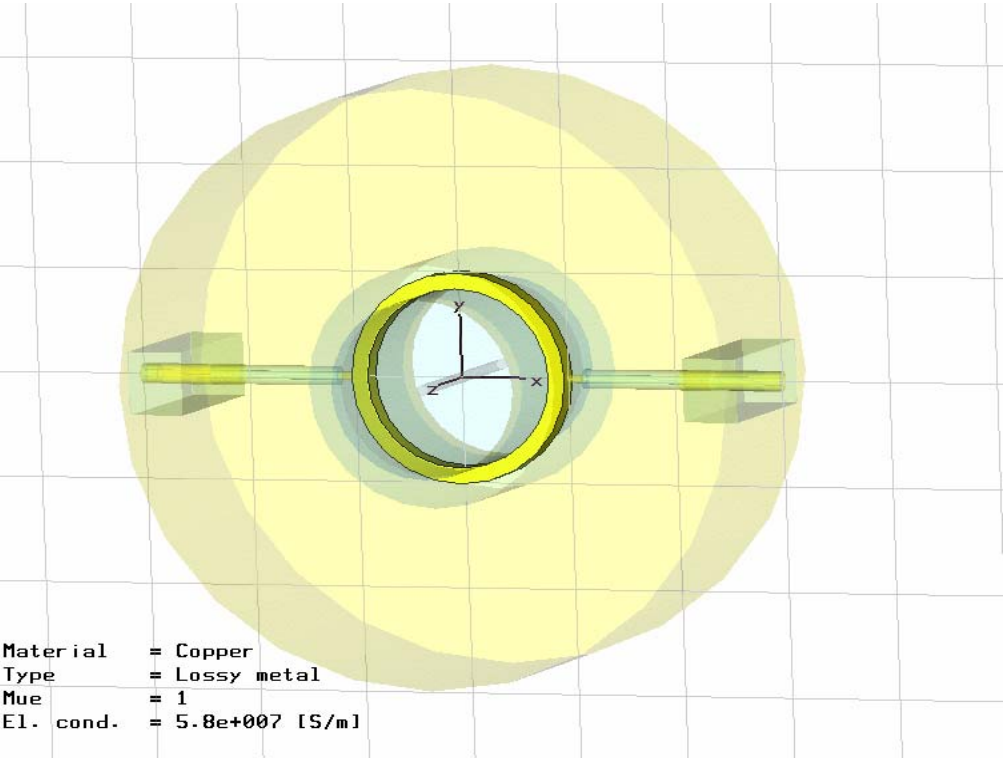


Courtesy of MDI, DESY

Beam pick-up signal in EO-hutch:



Beam Pick-up



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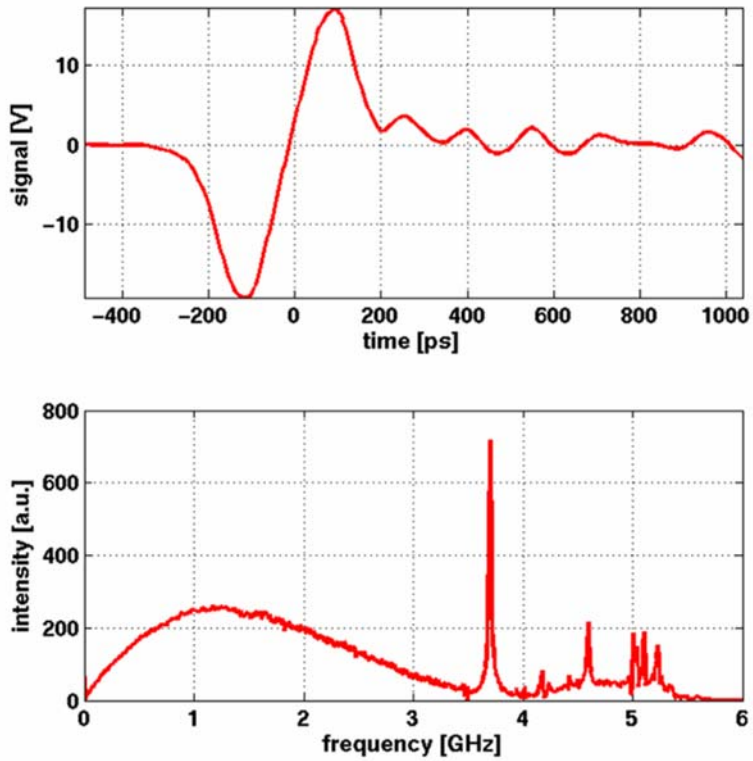
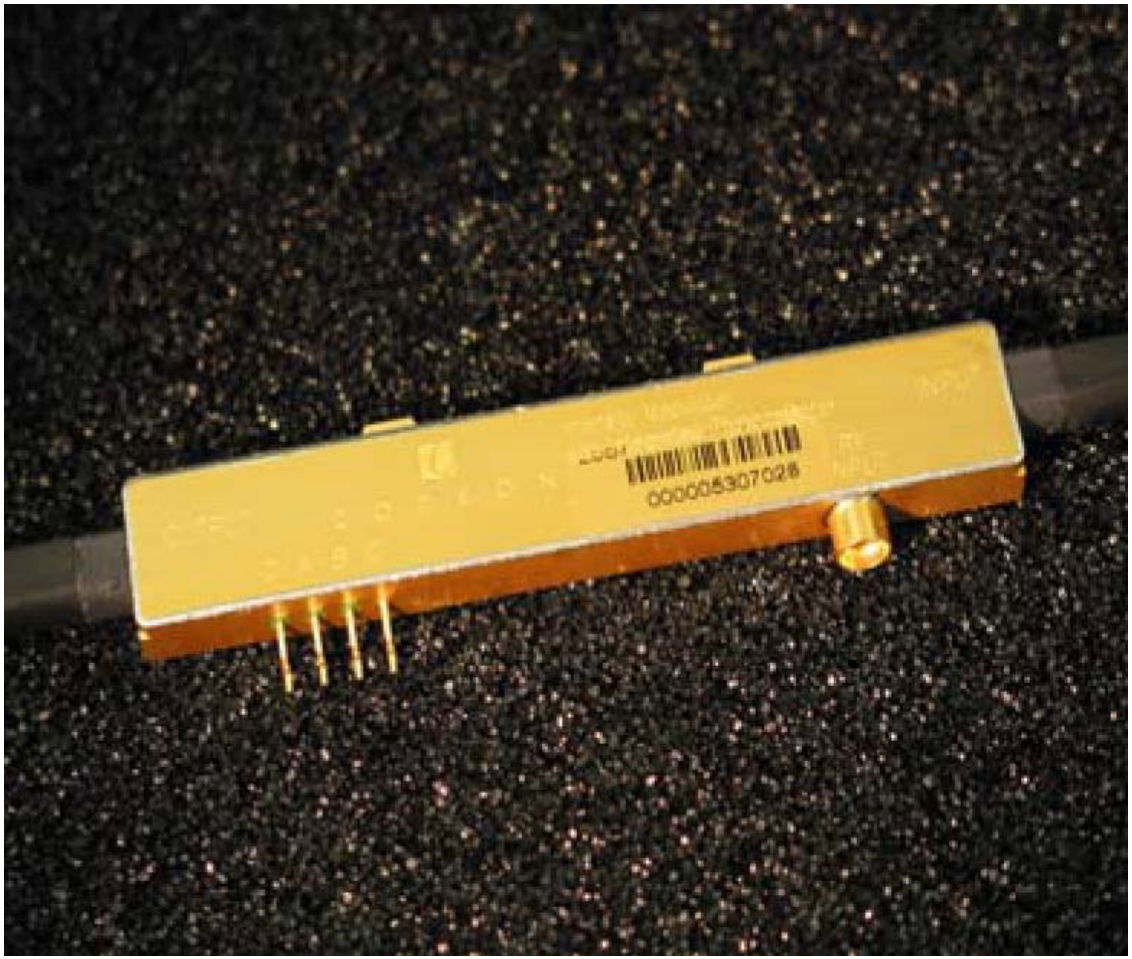


Electro-Optical-Modulator (EOM)



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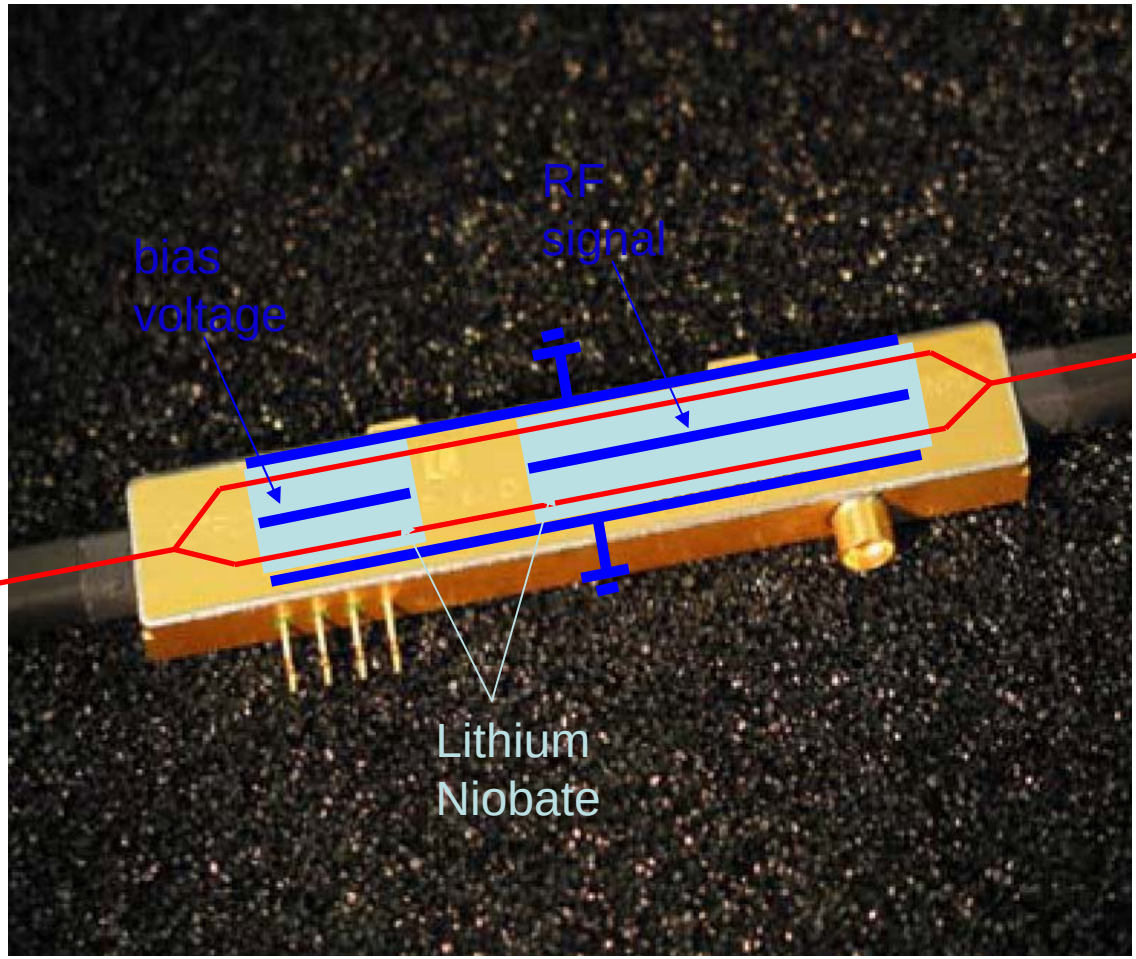
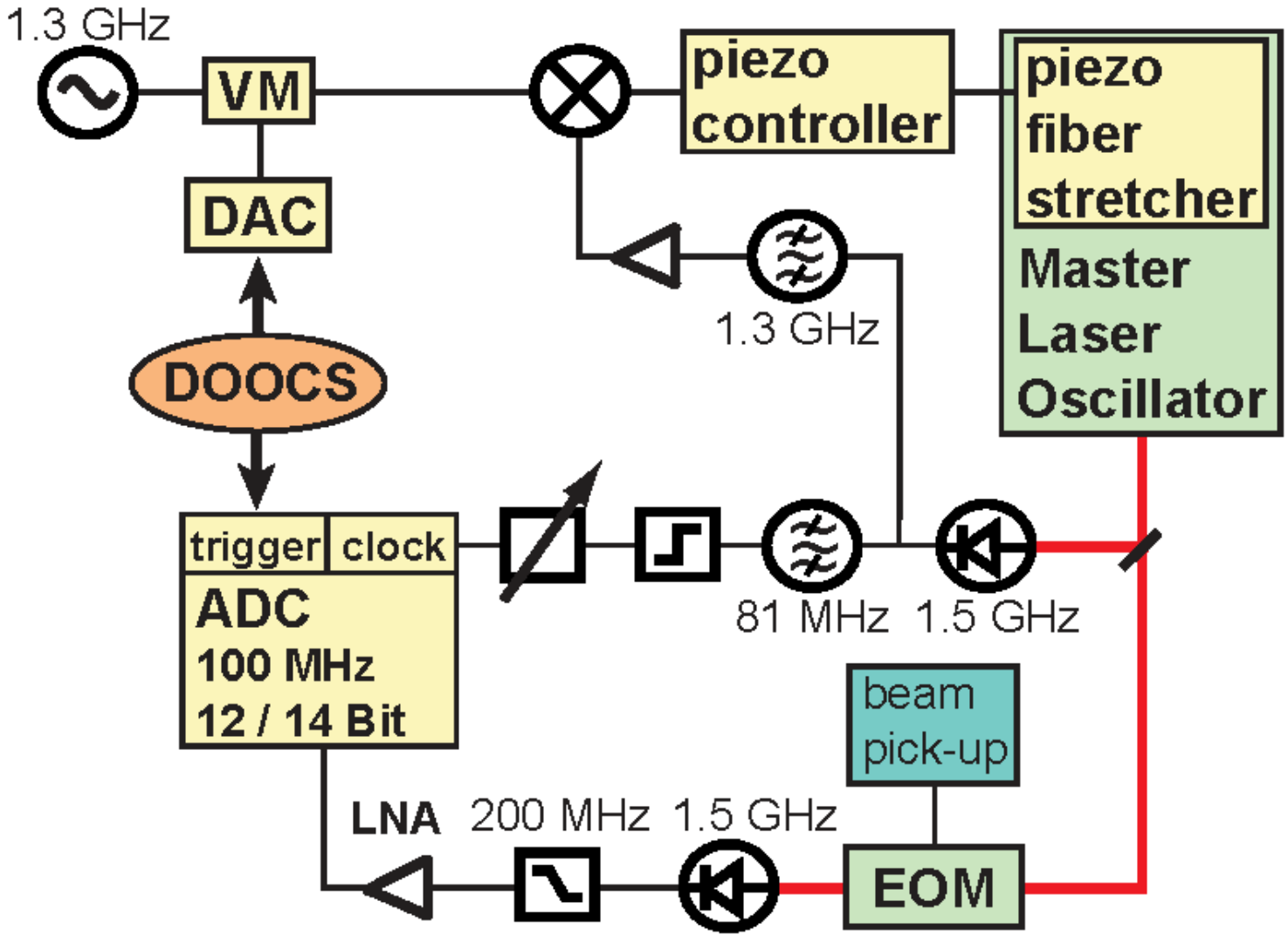
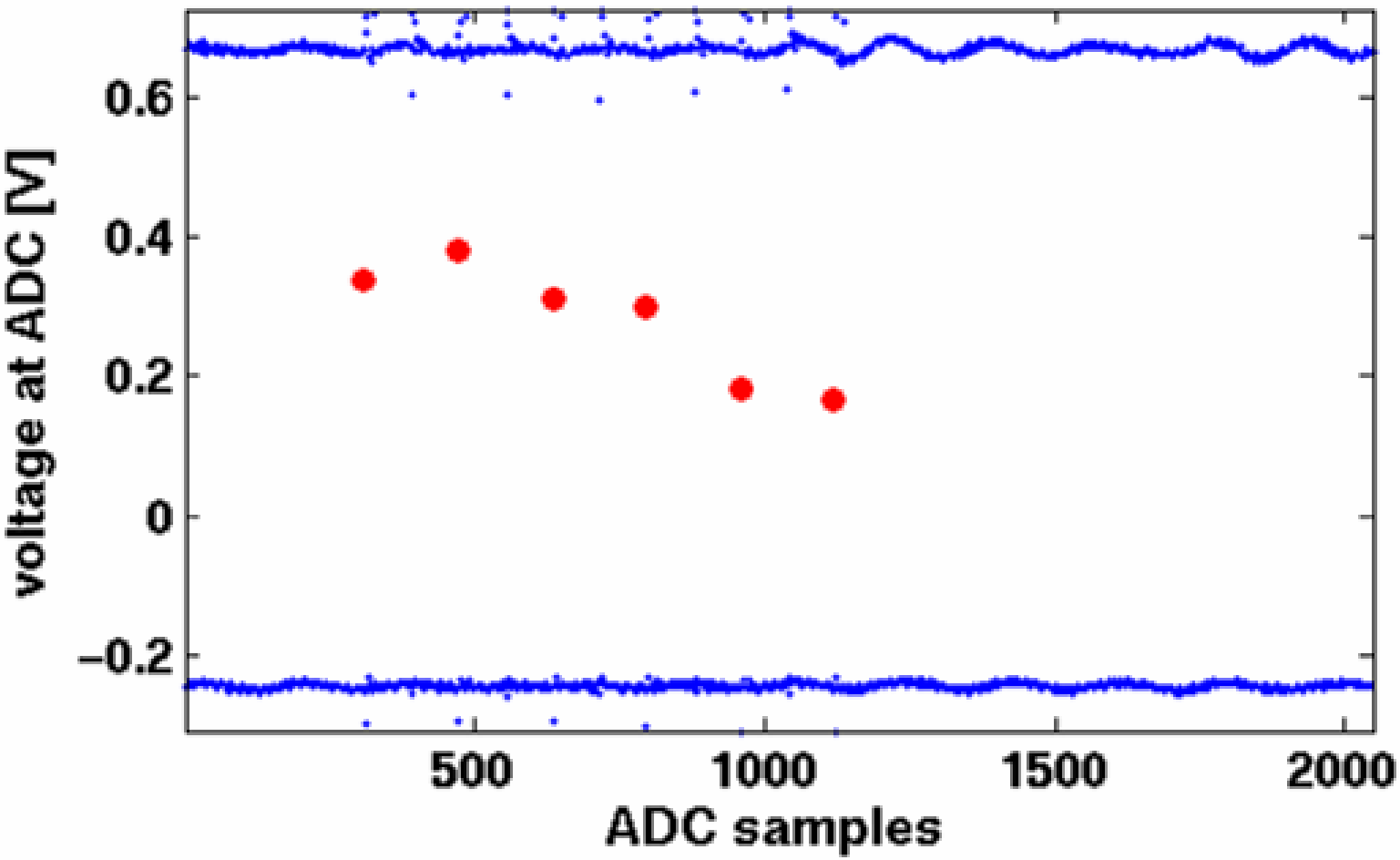


Commercially available with bandwidths up to 40 GHz
(we use a 10 GHz version)

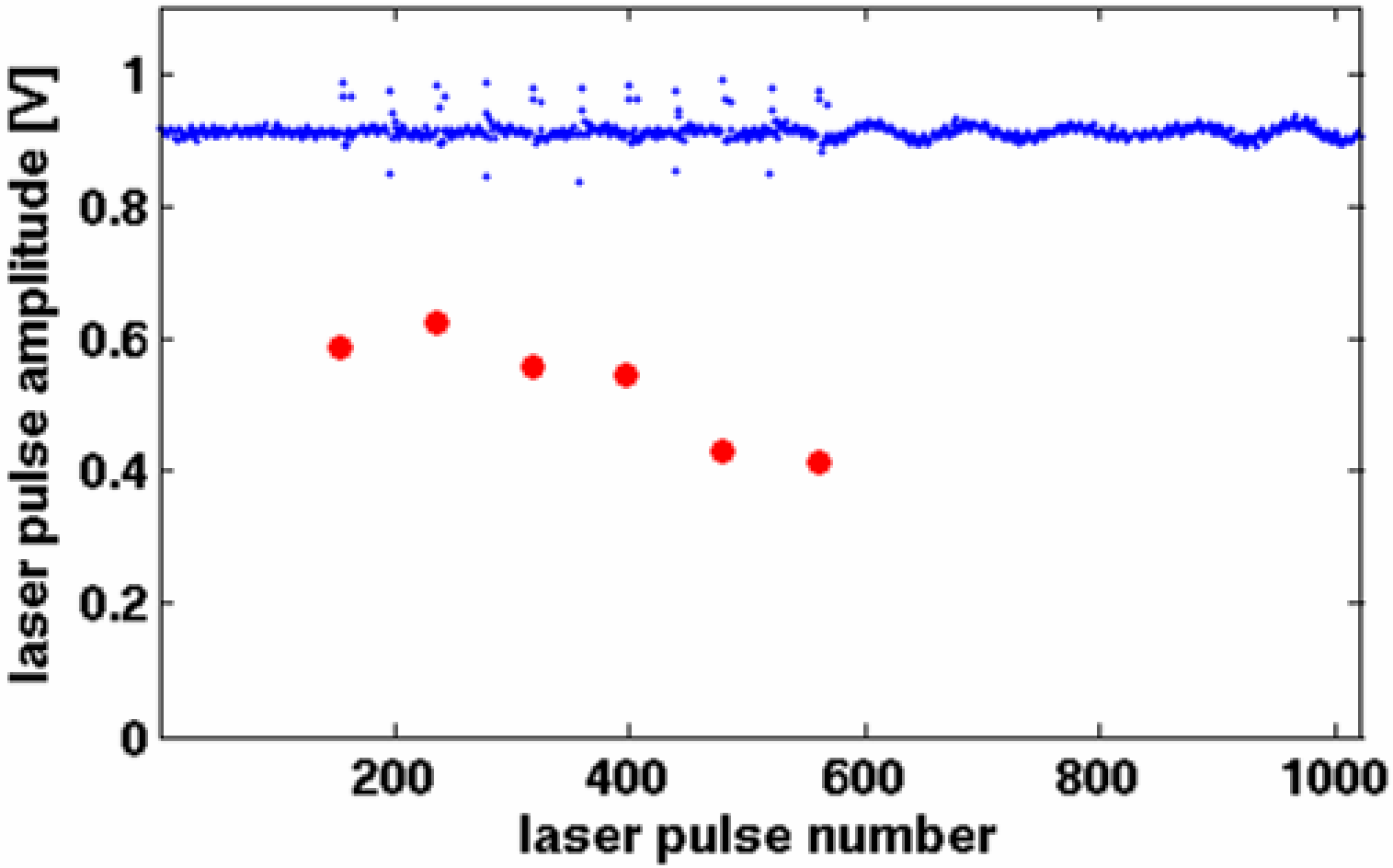
Systematic Layout of the Phase-Monitor System



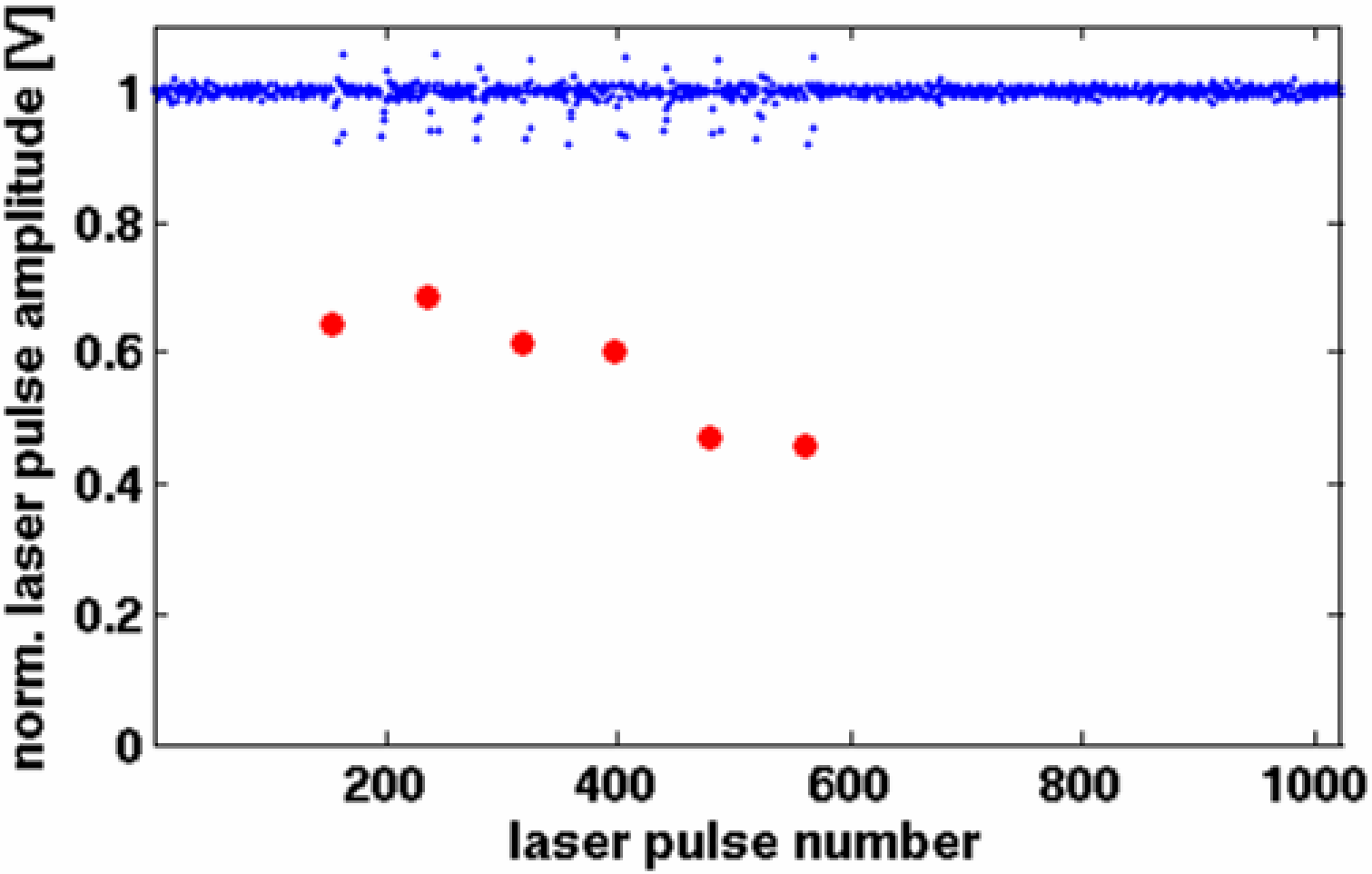
First Results:
Raw Data of Phase Monitor Measurement



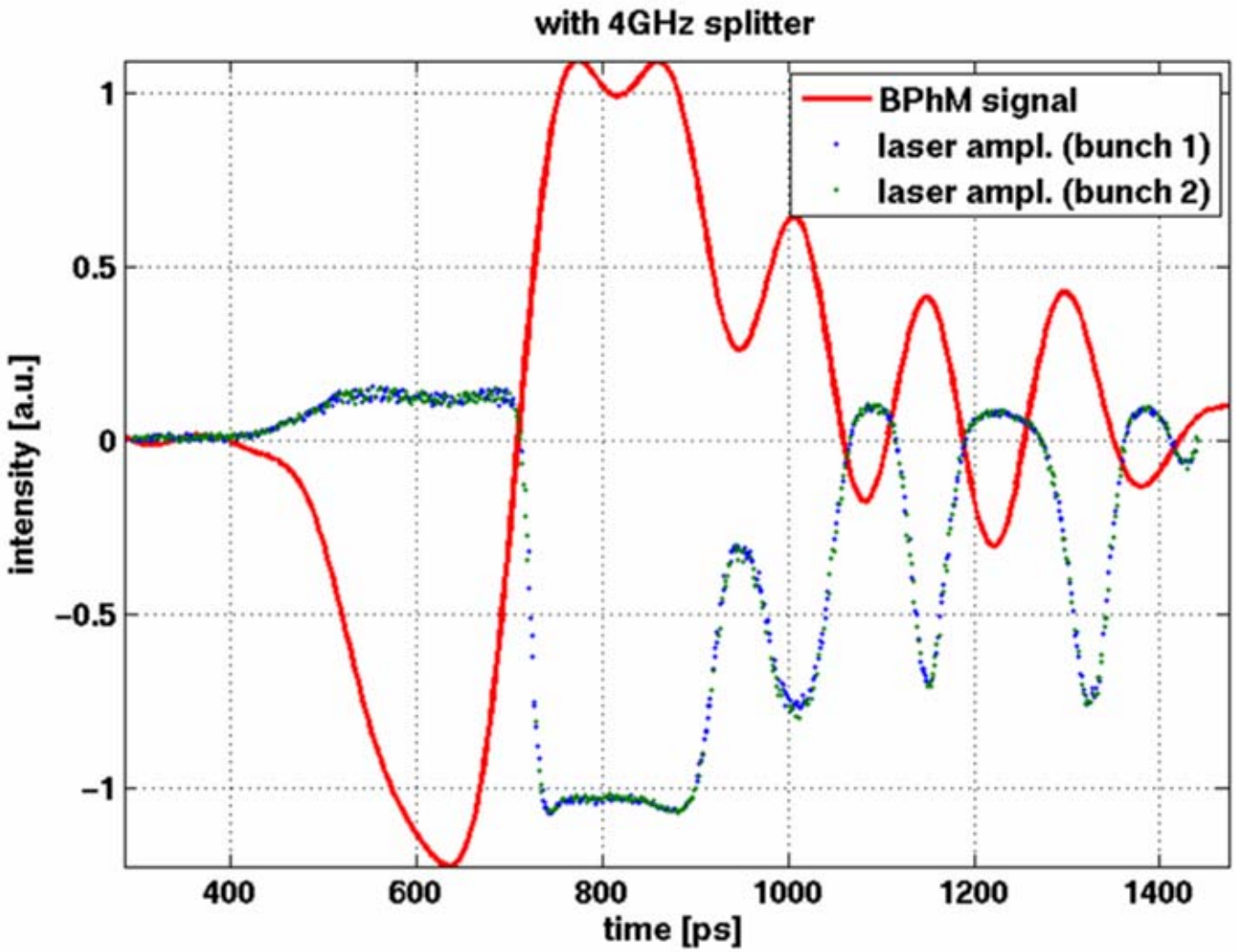
First Results: Amplitude of Laser Pulses



First Results:
Amplitude of Laser Pulses (normalized)



First Results:
Scan of Laser Pulse over Beam Pick-up Signal



First Results:
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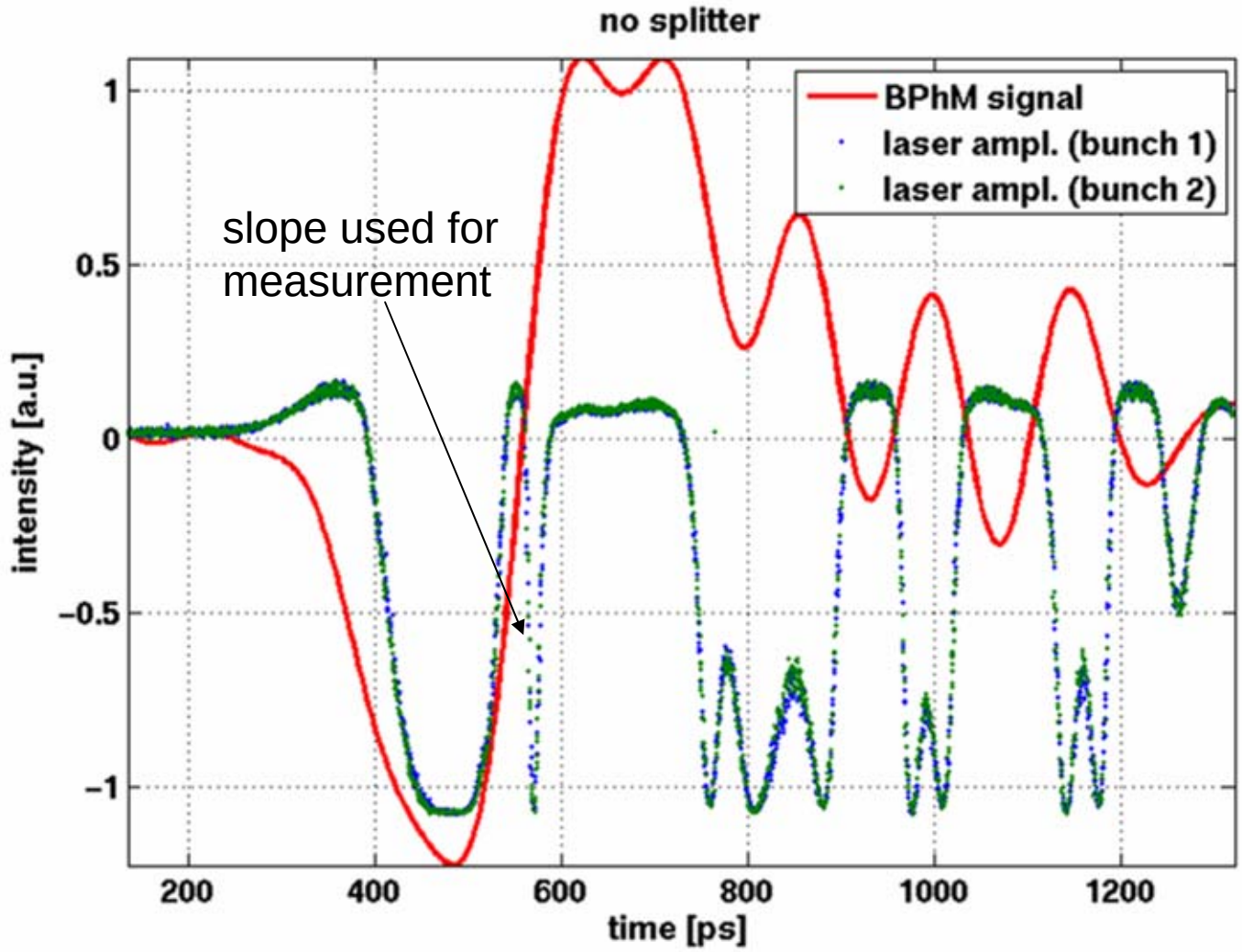
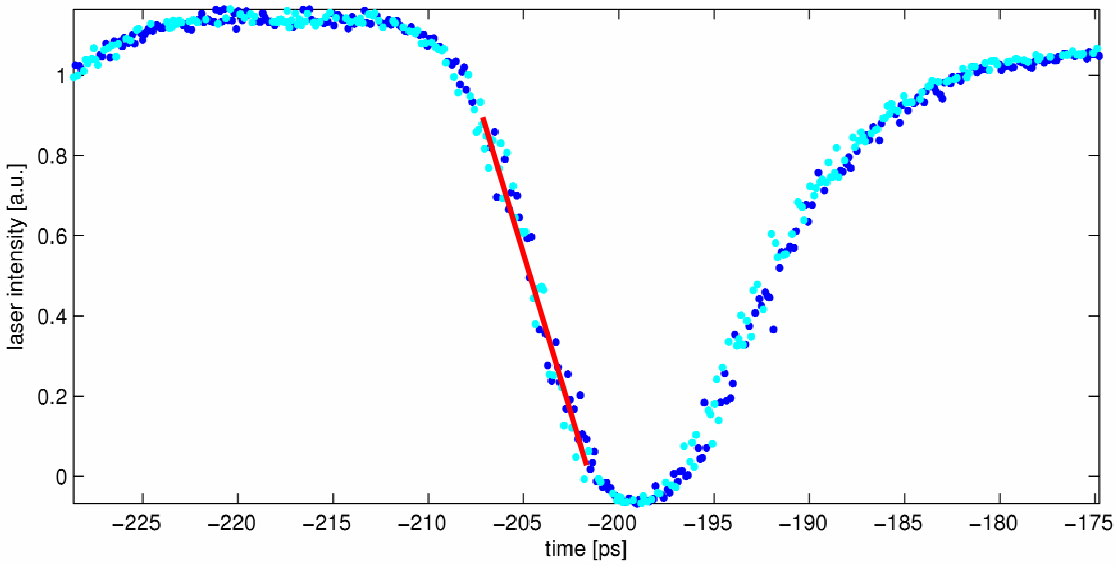


First Results: Calibration and Resolution of the System



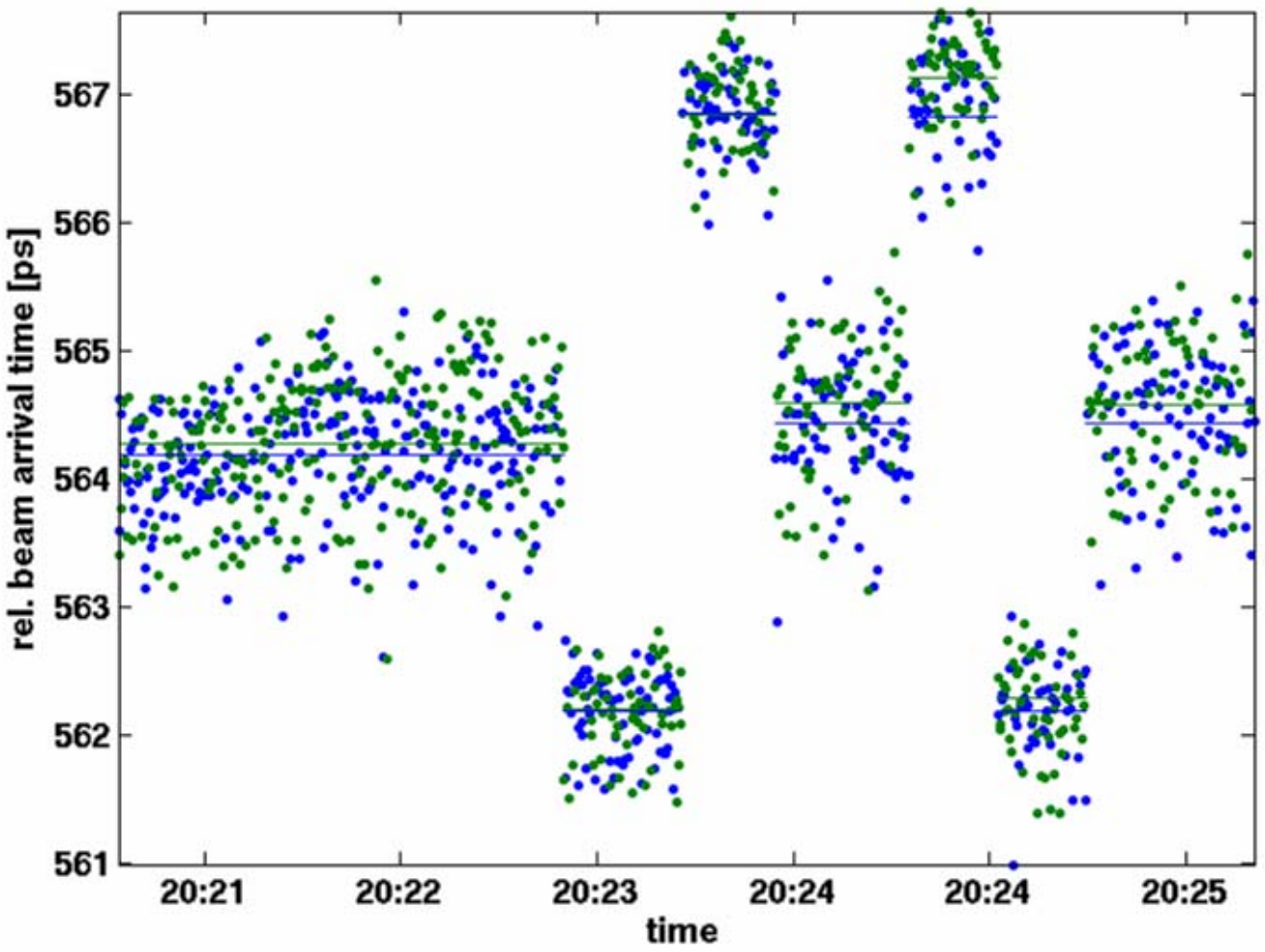
The resolution can be estimated from the slope of the phase monitor signal and the amplitude noise of the unmodulated laser pulses:

Best results:

slope ~ 7.1 ps / unit
rms(laser amplitude) ~ 0.425 %

➢ rms resolution ~ 30 fs

First Results:
Rel. Beam Arrival Time for Different ACC1 Gradients



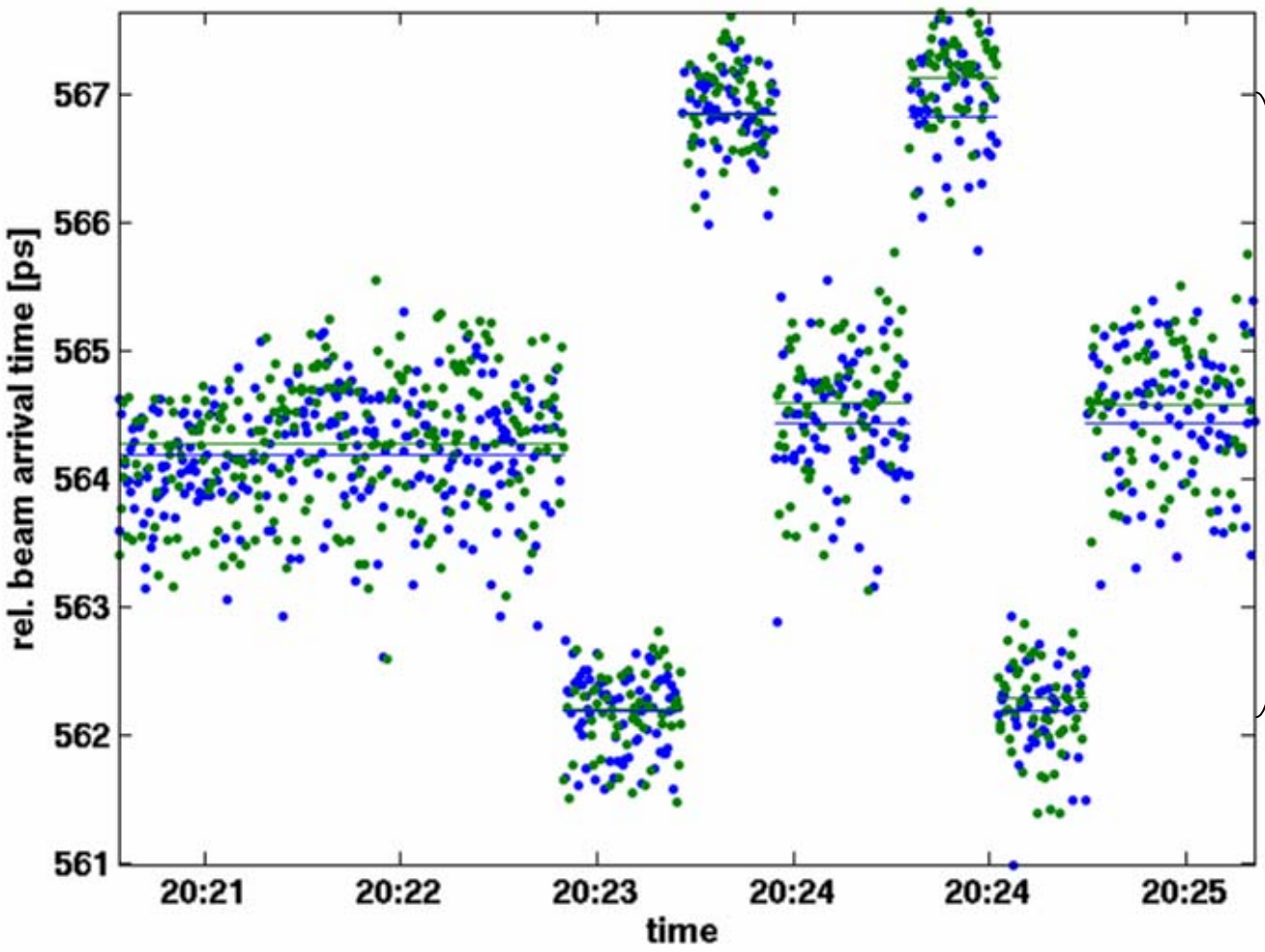
ACC1 gradient

15.70 MV / m

15.65 MV / m

15.60 MV / m

First Results:
Rel. Beam Arrival Time for Different ACC1 Gradients



ACC1 gradient

15.70 MV / m

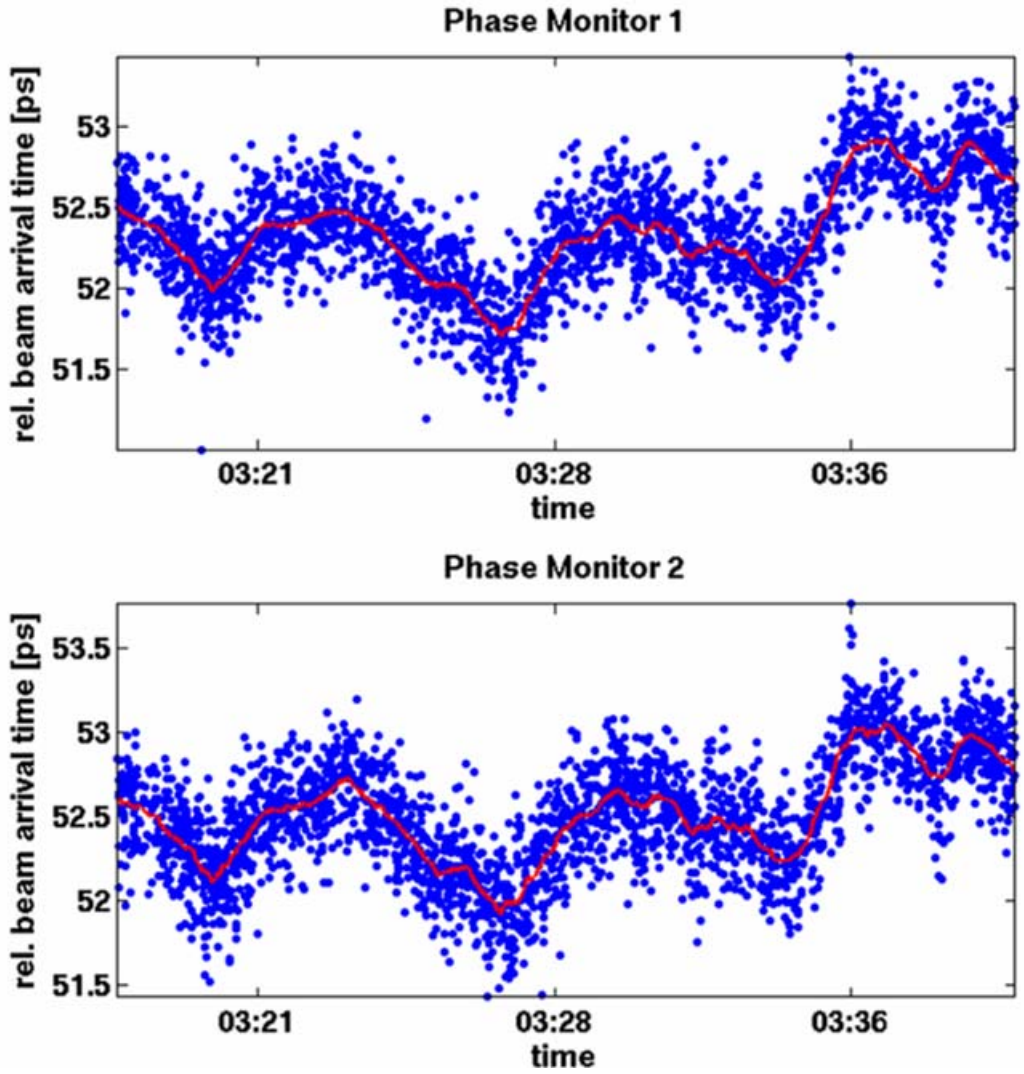
$\Delta t \approx 4.6$ ps

rms jitter ≈ 0.5 ps

Comparison measure-
ment withTCAV yielded
an arrival time change
of about 5 ps

15.63 MV / m

First Results:
Comparison Measurement between two Monitors



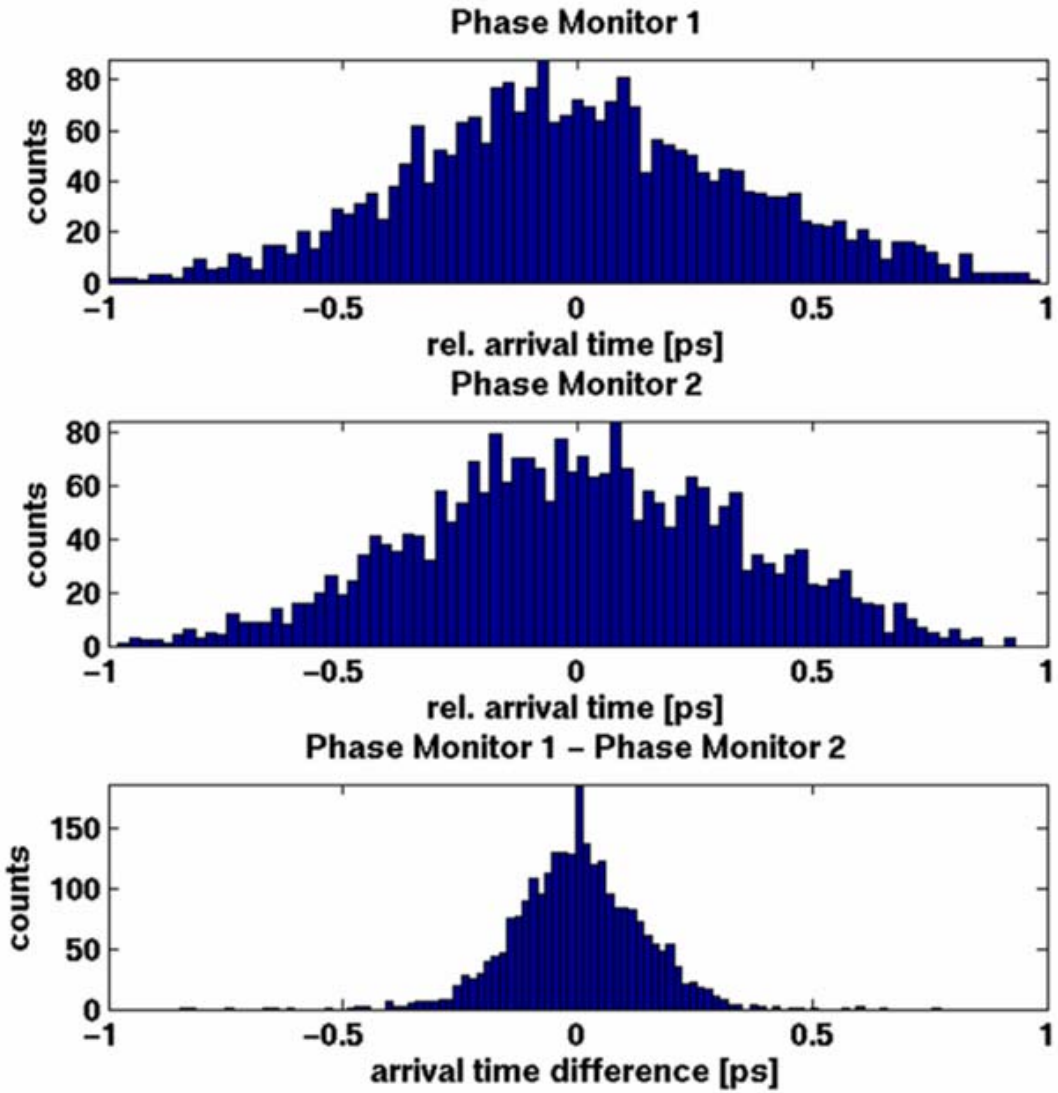
The signal of the beam pick-up was splitted which yields a lower resolution.

The rms-resolution of the phase monitors was estimated from the laser amplitude noise and the slope from the calibration:

Phase Monitor 1: **99 fs**

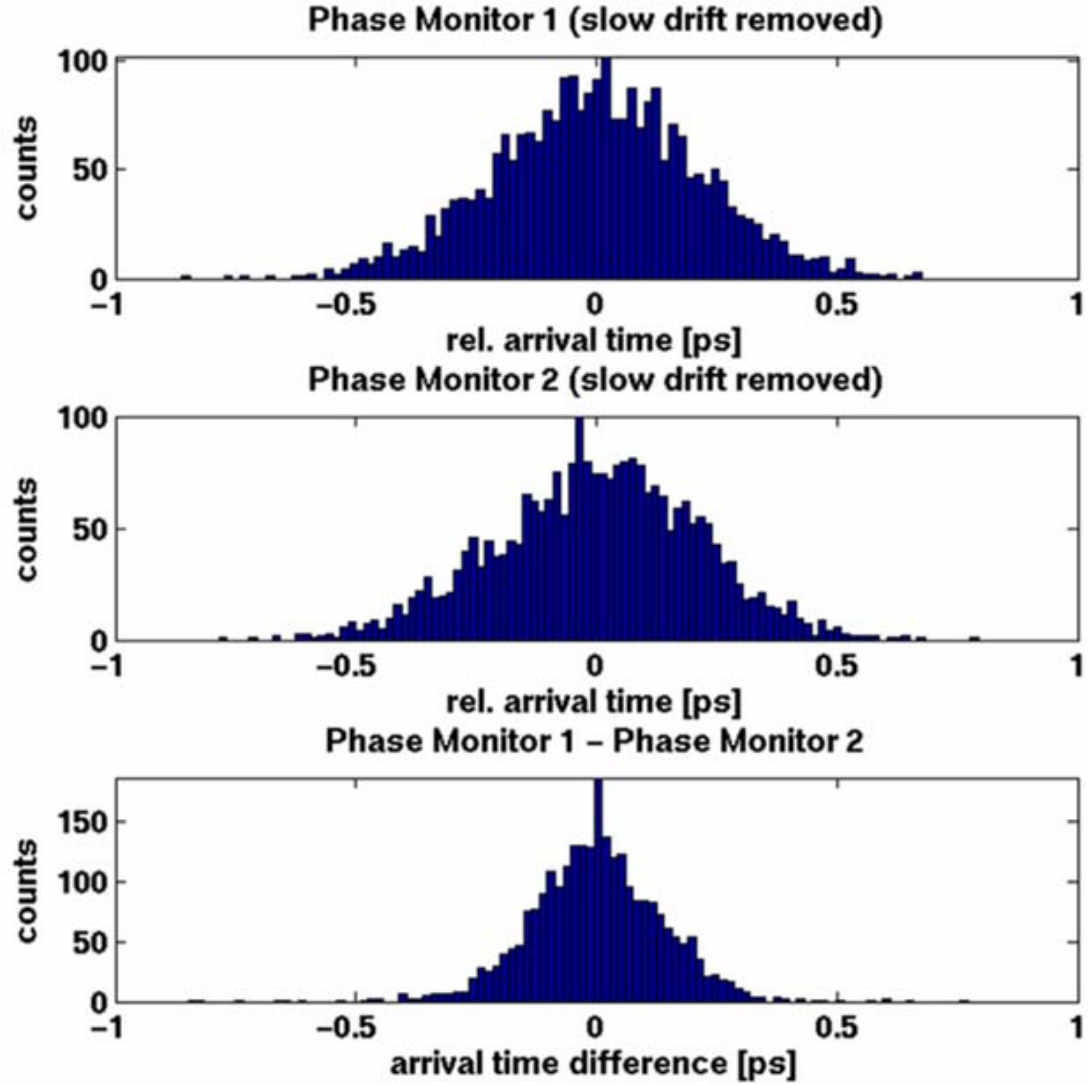
Phase Monitor 2: **114 fs**

First Results:
Comparison Measurement between two Monitors



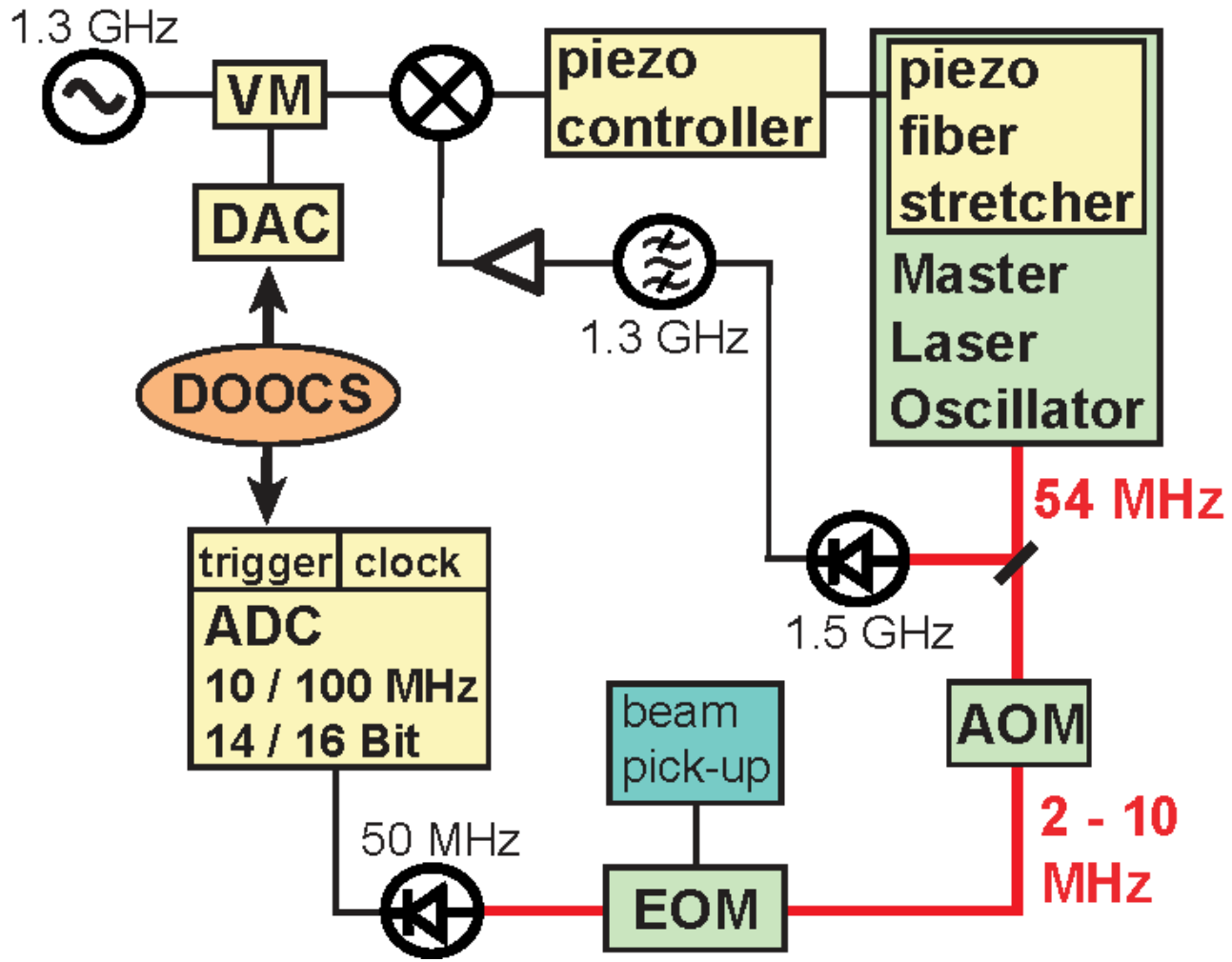
	rms jitter
e^--beam (BPhM1)	**357 fs**
e^--beam (BPhM2)	**342 fs**
BPhM1 – BPhM2	**138.8 fs**

First Results:
Comparison Measurement between two Monitors



	rms jitter
e⁻-beam (BPhM1)	**212.9 fs**
e⁻-beam (BPhM2)	**211.6 fs**
BPhM1 – BPhM2	**138.8 fs**

Possible Upgrade of the Phase-Monitor System



Reduction of the laser repetition rate

- slower photo detector possible
- signal from photo detector can possibly be samples directly
- The requirements on the ADC clock are reduced due to the broader signal after the photo detector
- With a 108 MHz ADC three sample points per laser pulse are available

Summary

- Compact, low cost design
- High resolution: ~30 fs reached, sub-10 fs feasible
- A new beam pick-up design, EOM installation next to pick-up, and faster EOM promise even higher resolution
- Only few drift sources which are not removed by normalization of the laser intensity: beam pick-up, RF cable to EOM, and limiter (the cable can be made very short and the components can be temperature stabilized)
- Same concept usable for many purposes like for BPMs, RF cavity signals, and photo-diode signals

- Only sensitive to center of beam distribution
- In addition techniques like TCAV and EOS are needed for longitudinal pulse shape measurements