Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

ANALYSIS OF THE ELECTRO-OPTICAL FRONT END FOR THE NEW 40 GHz BUNCH ARRIVAL TIME MONITOR*

IBIC2012, Tsukuba, Japan, Oct 1-4, 2012

*The work is supported by Federal Ministry of Education and Research of Germany (BMBF) within FSP 301 under the contract numbers 05K10GU2 and 05K10RDA.

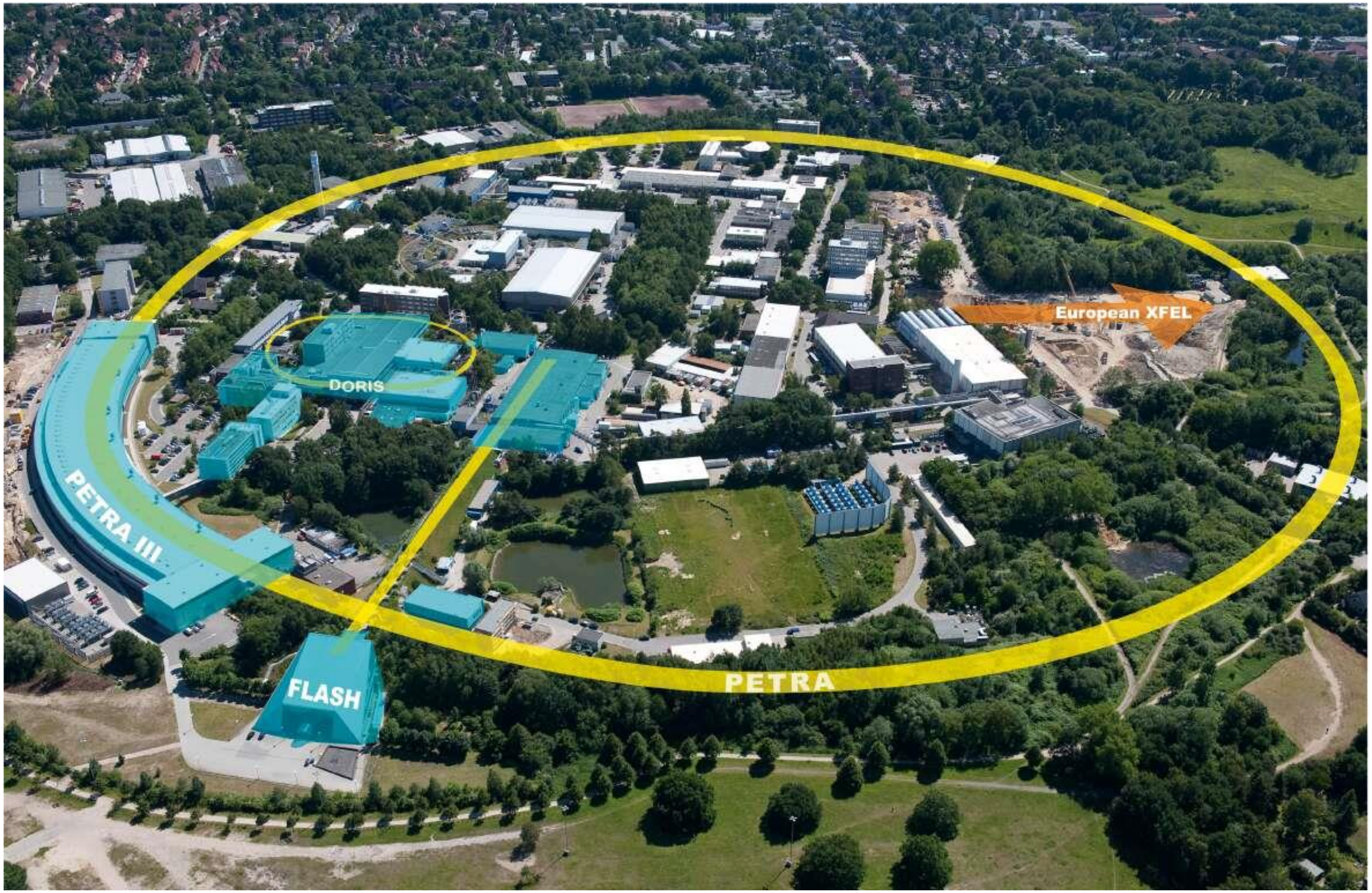
Alexander Kuhl
alexander.kuhl@desy.de

Outline

- Introduction
- Synchronization of FLASH
- BAM system
- Old and new Pickup
- RF calculation
- Monte Carlo Simulation
- Results
- Outlook

Alexander Kuhl
Alexander.kuhl@desy.de

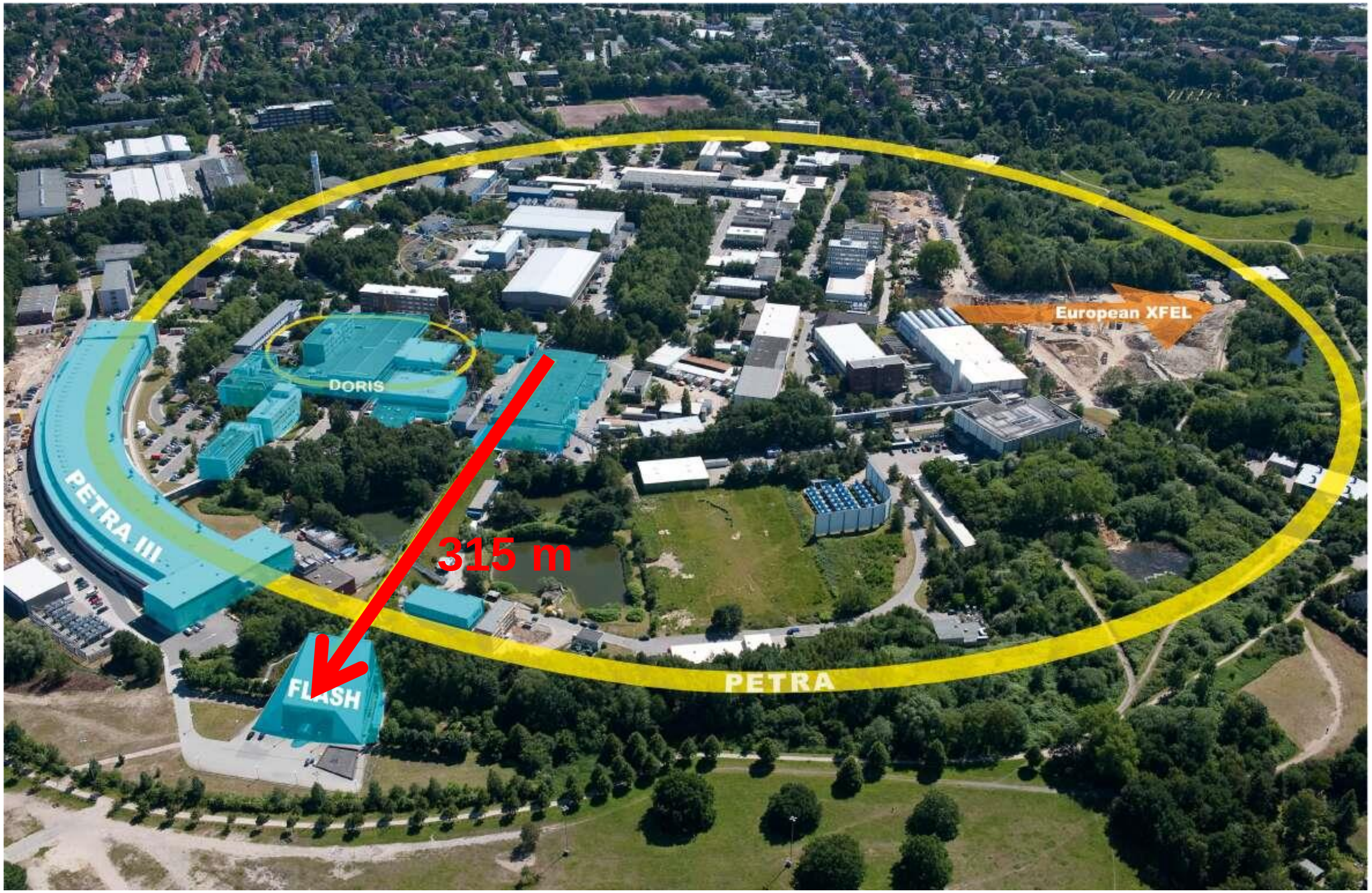
Introduction



Picture: www.desy.de

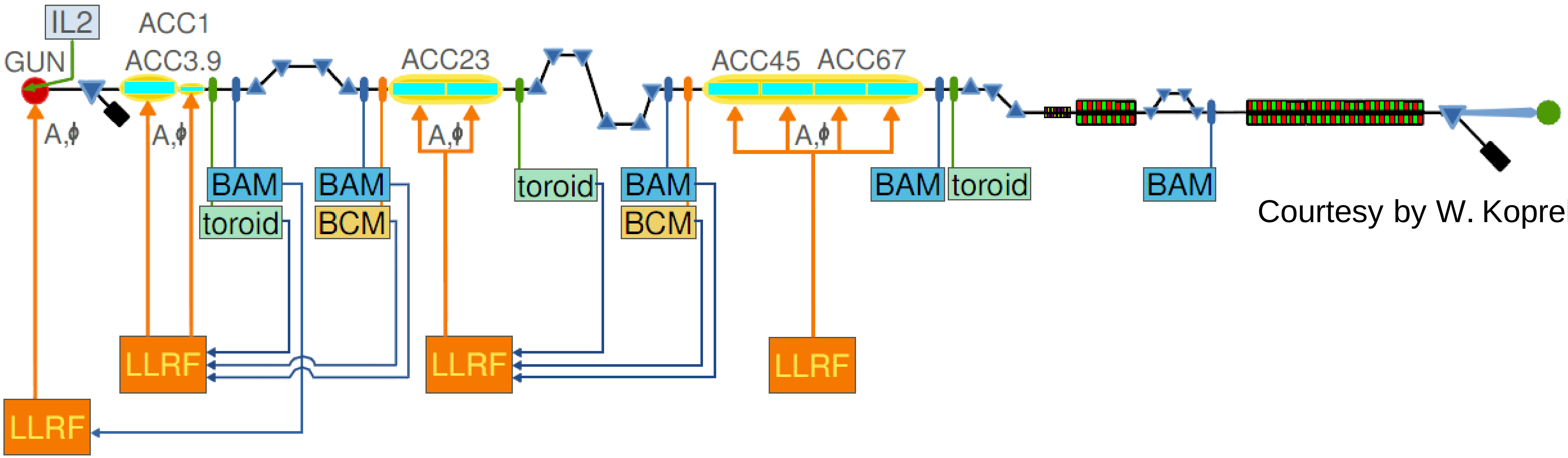
Alexander Kuhl
Alexander.kuhl@desy.de

Introduction



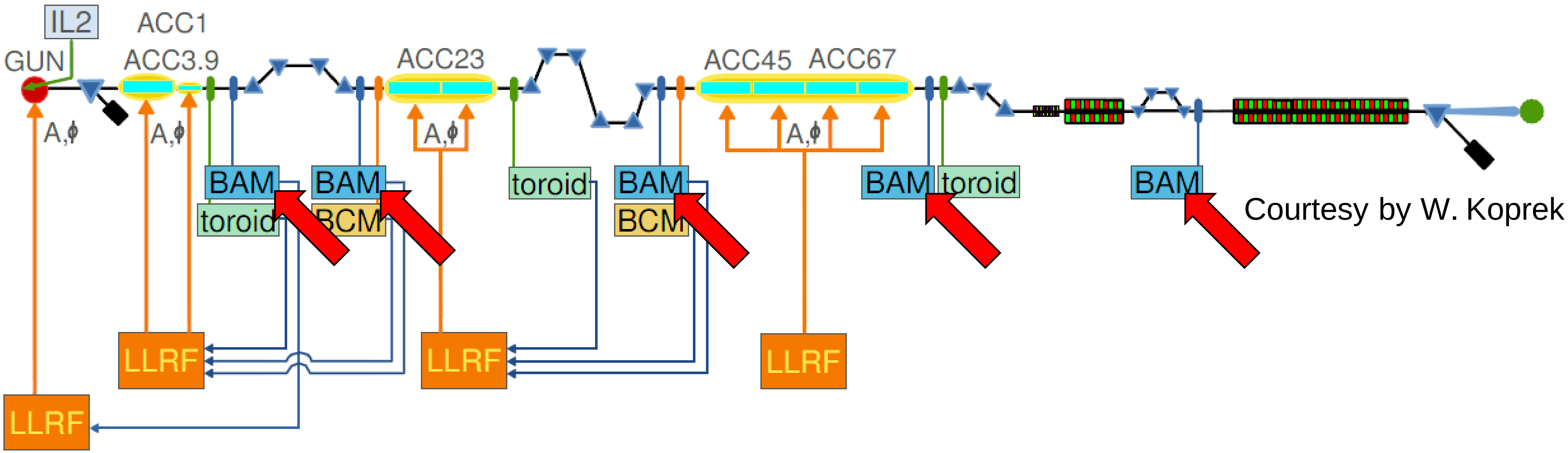
Picture: www.desy.de

The FLASH Accelerator



Courtesy by W. Koprek

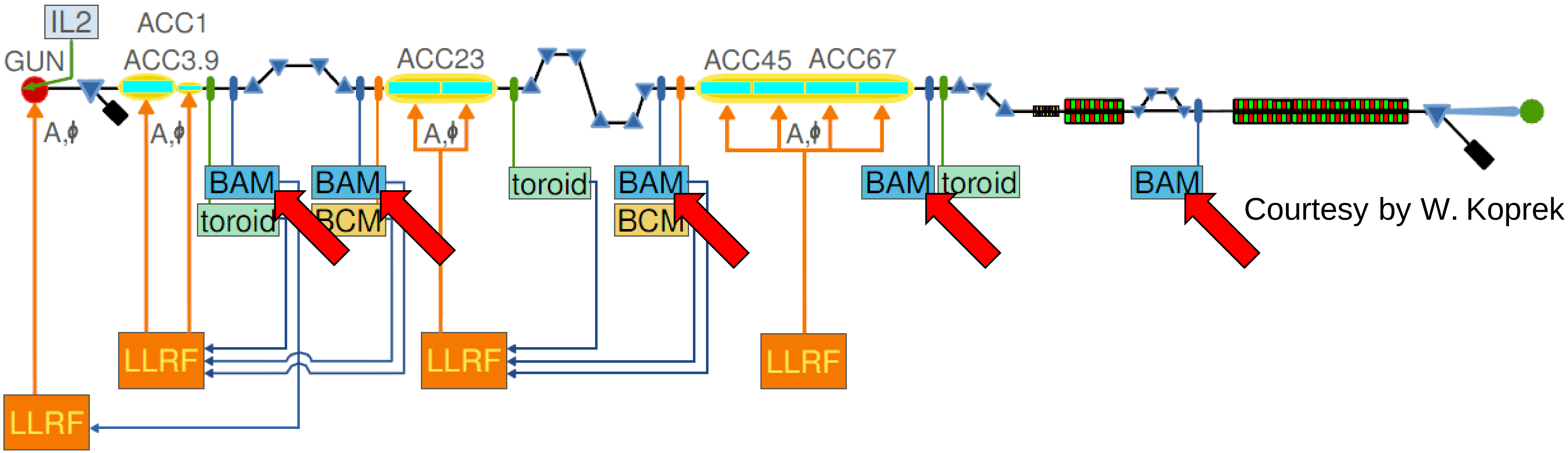
The FLASH Accelerator



Courtesy by W. Koprek

Synchronization of FLASH

The FLASH Accelerator



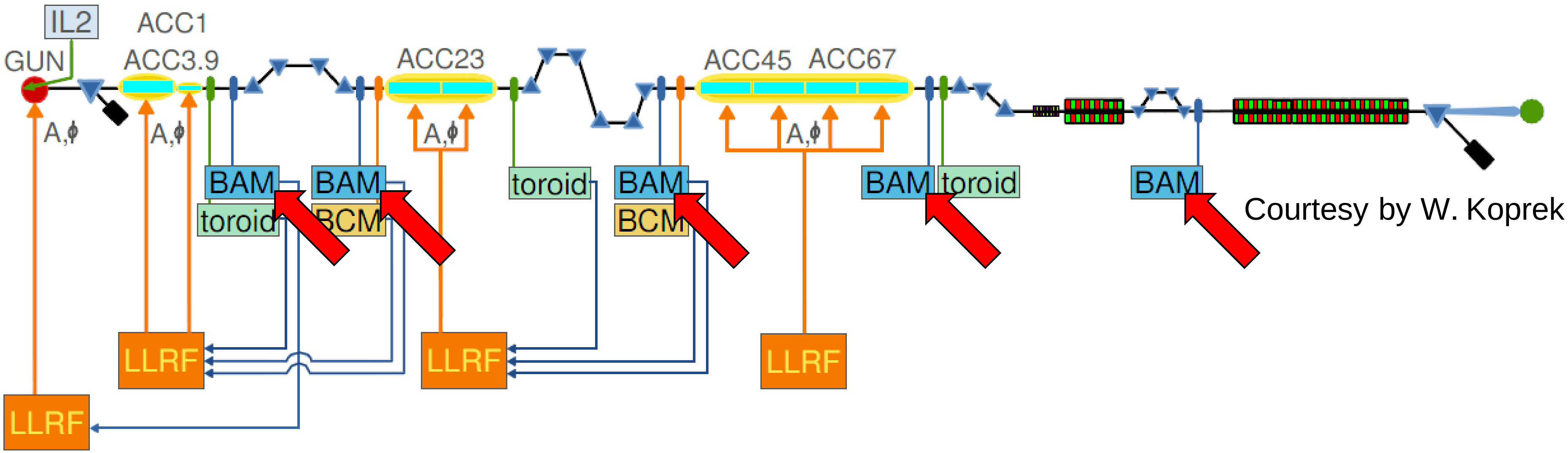
Courtesy by W. Koprek

Accuracy of arrival time measurement: < 10 fs
Reachable beam stability with feedback: < 25 fs

Bunch charge > 500 pC

Synchronization of FLASH

The FLASH Accelerator



Courtesy by W. Koprek

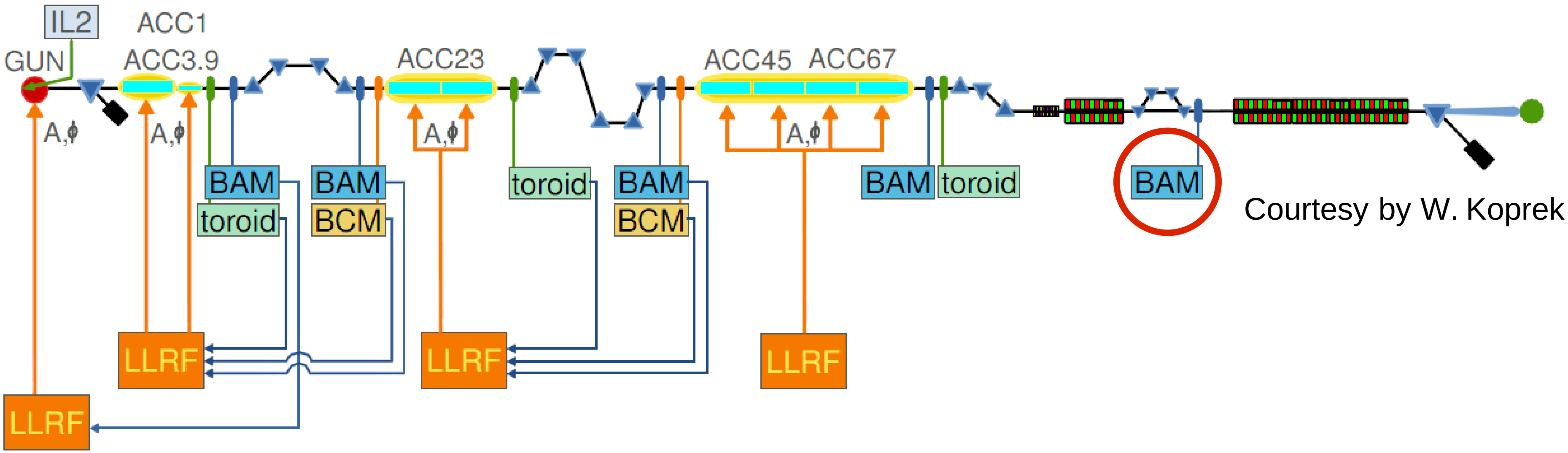
Accuracy of arrival time measurement:	< 10 fs
Reachable beam stability with feedback:	< 25 fs

Bunch charge > 500 pC

New requirement:
Accuracy of arrival time measurement = 10 fs with 20 pC bunch charge

BAM system

The FLASH Accelerator



Courtesy by W. Koprek

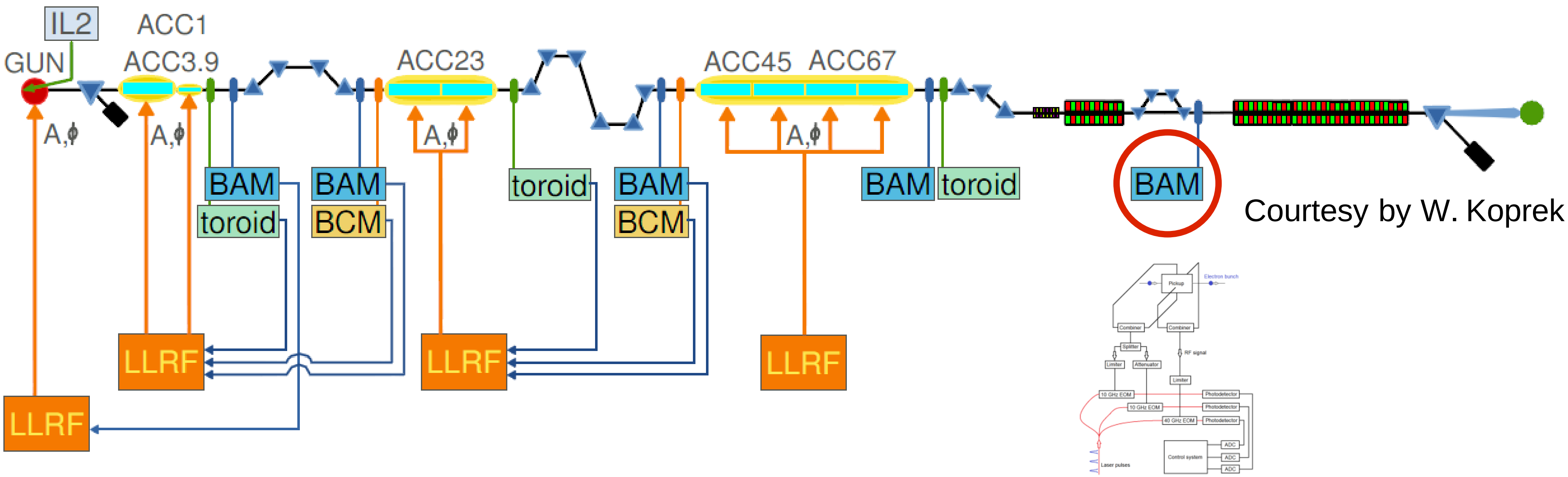
Accuracy of arrival time measurement: < 10 fs
Reacheble Beam stability with feedback: < 25 fs

Bunch charge > 500 pC

New requirement:
Accuracy of arrival time measurement = 10 fs with 20 pC bunch charge

BAM system

The FLASH Accelerator



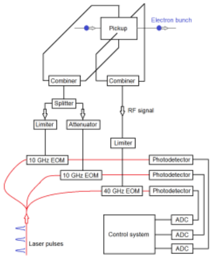
Courtesy by W. Koprek

Accuracy of arrival time measurement:	< 10 fs
Reacheble Beam stability with feedback:	< 25 fs

Bunch charge > 500 pC

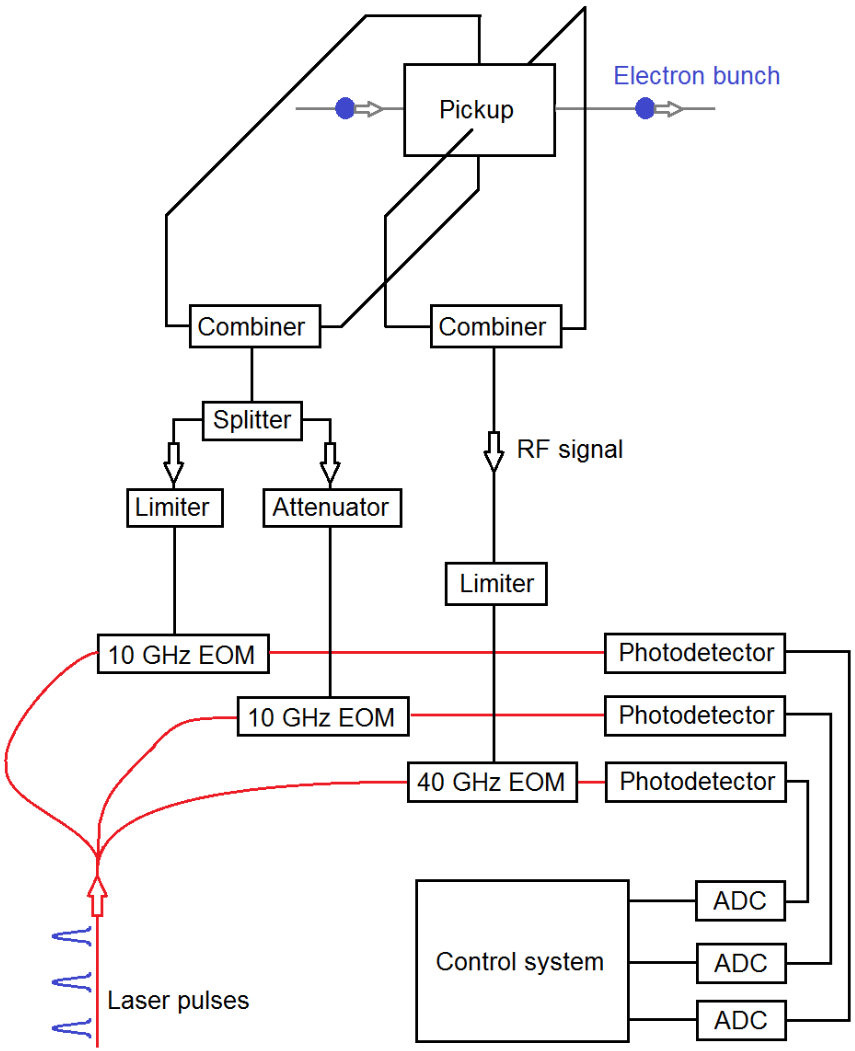
→ New requirement:
Accuracy of arrival time measurement = 10 fs with 20 pC bunch charge

BAM system

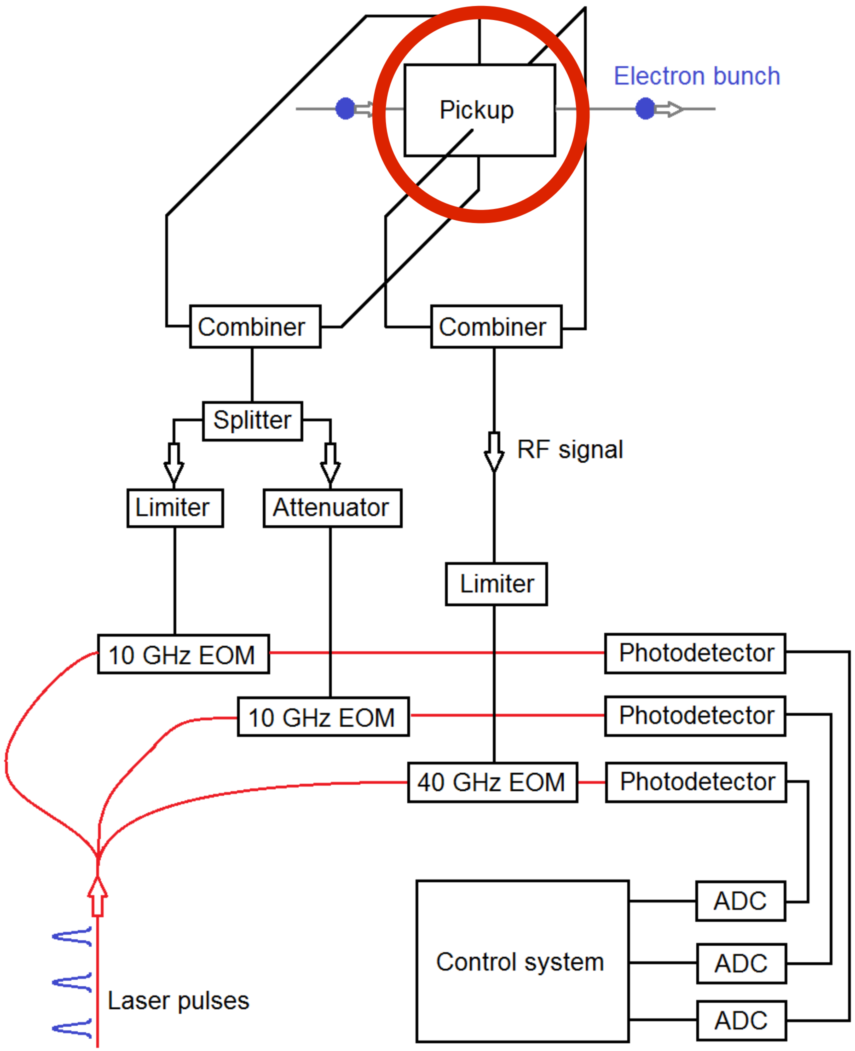


Alexander Kuhl
Alexander.kuhl@desy.de

BAM system

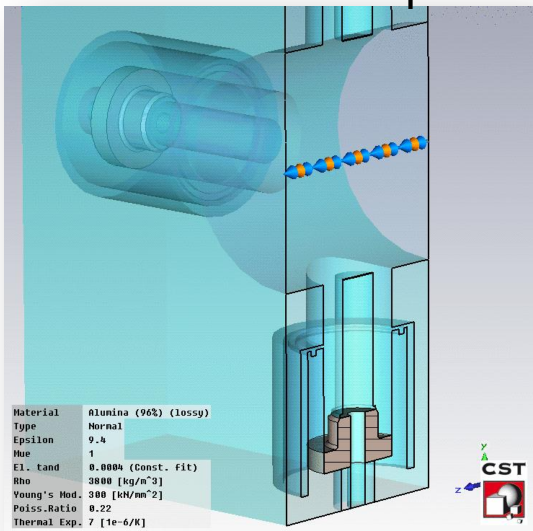

Pickup
Electron bunch
Combiner
Combiner
Splitter
RF signal
Limiter
Attenuator
Limiter
10 GHz EOM
Photodetector
10 GHz EOM
Photodetector
40 GHz EOM
Photodetector
ADC
Control system
ADC
ADC
Laser pulses

BAM system

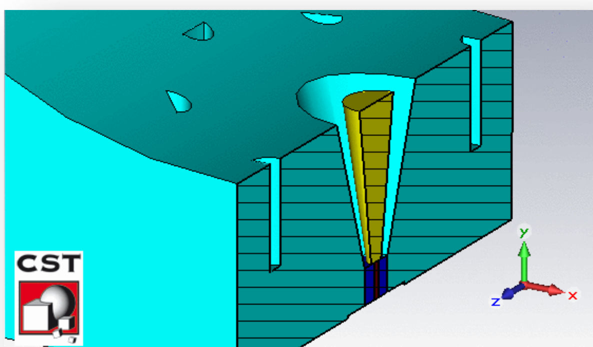

Pickup
Electron bunch
Combiner
Combiner
Splitter
RF signal
Limiter
Attenuator
Limiter
10 GHz EOM
Photodetector
10 GHz EOM
Photodetector
40 GHz EOM
Photodetector
ADC
Control system
ADC
ADC
Laser pulses

Old and new Pickup

Old 10 GHz Pickup

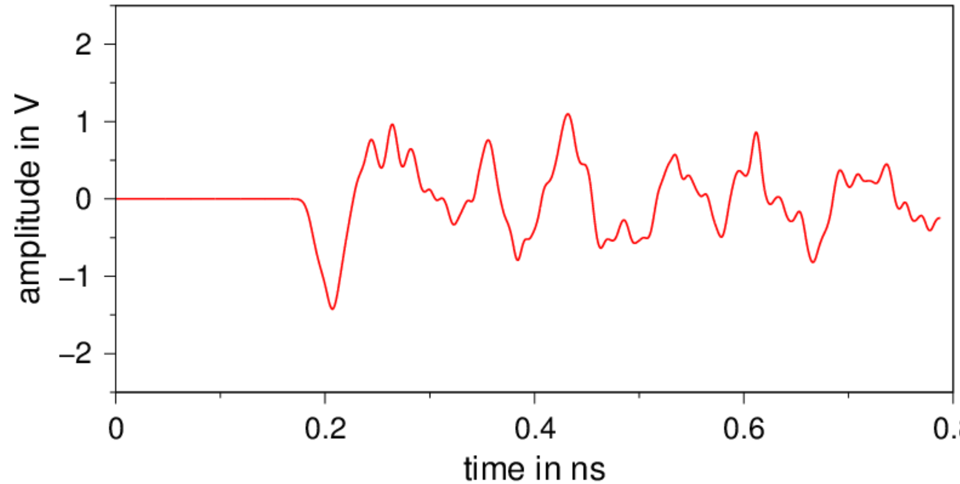


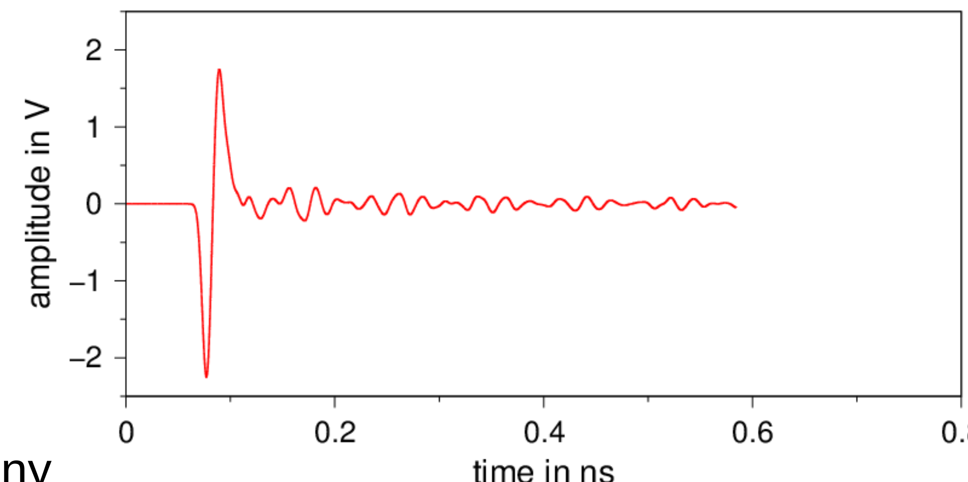
New 40 GHz Pickup



Design at TU Darmstadt, Germany

Simulation with 20 pC bunch charge

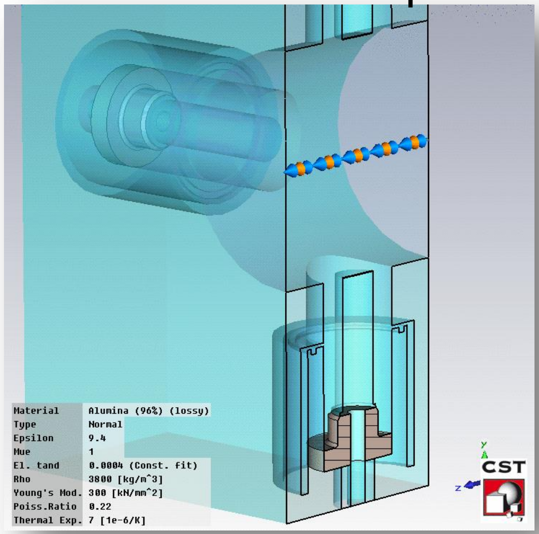




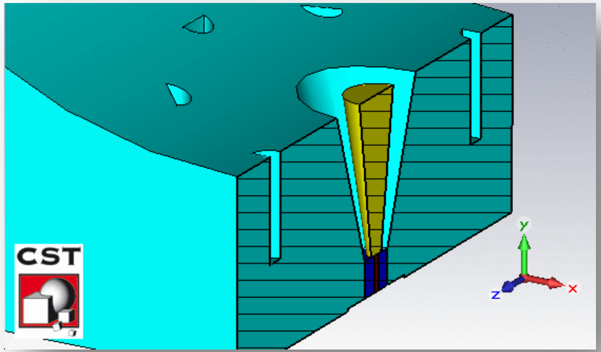
Alexander Kuhl
Alexander.kuhl@desy.de

Old and new Pickup

Old 10 GHz Pickup

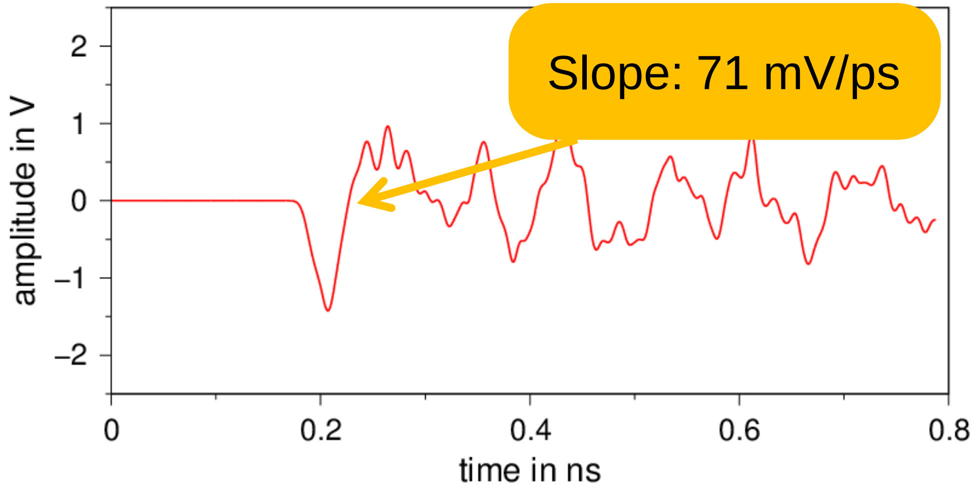


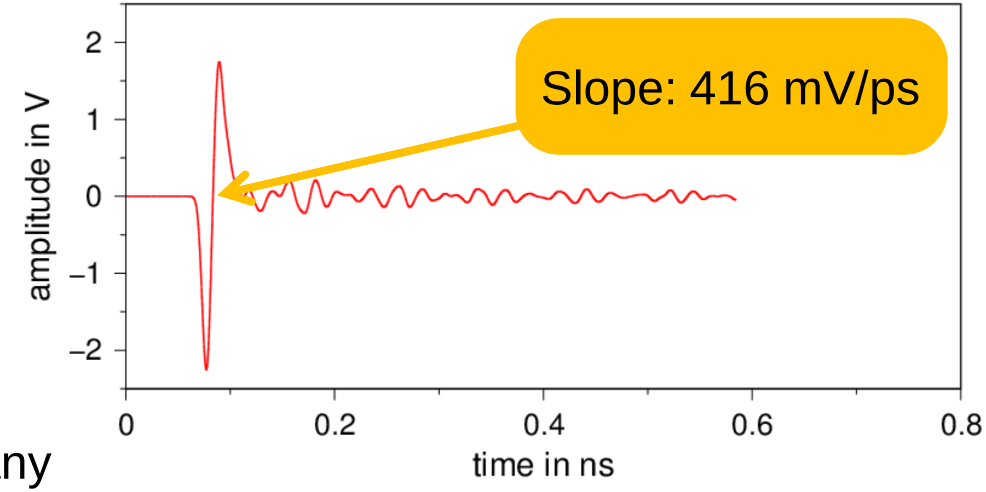
New 40 GHz Pickup



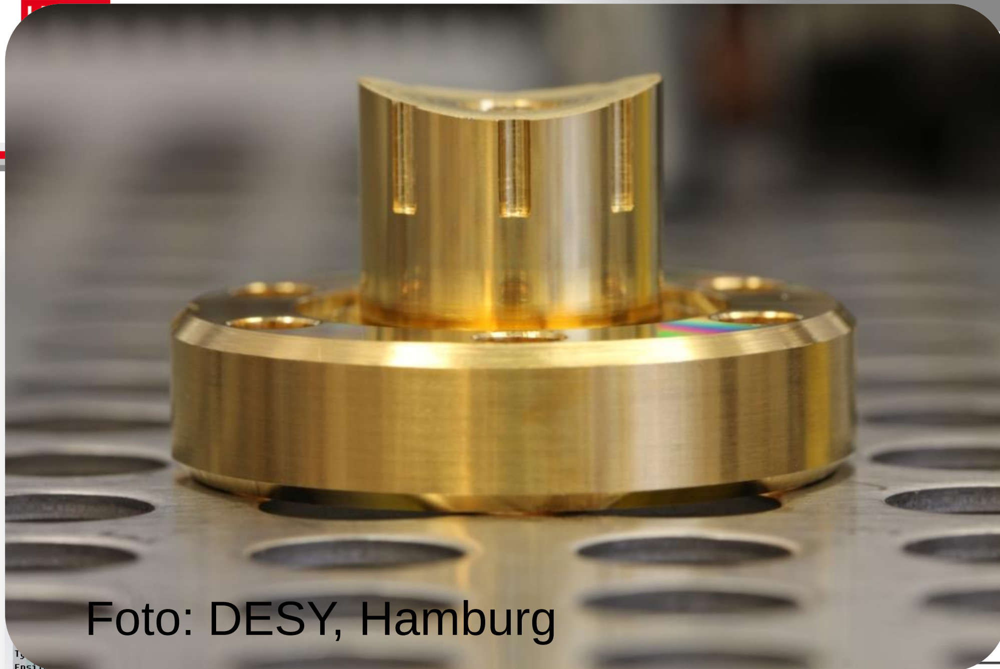
Design at TU Darmstadt, Germany

Simulation with 20 pC bunch charge

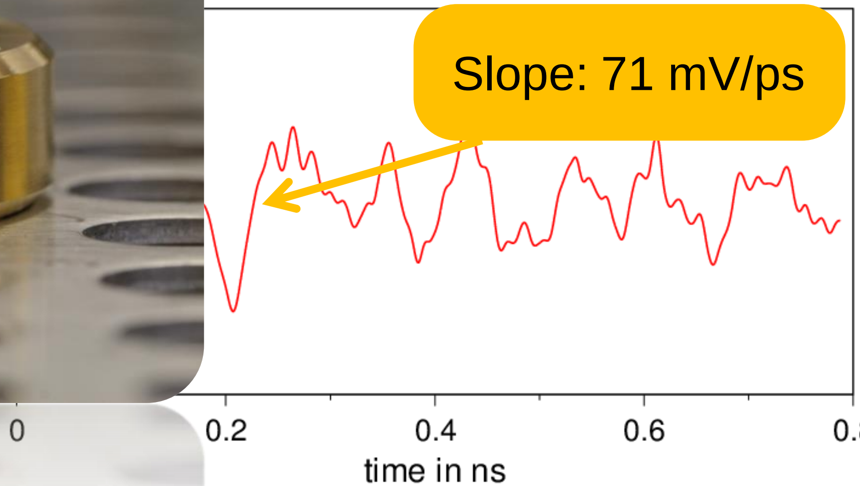




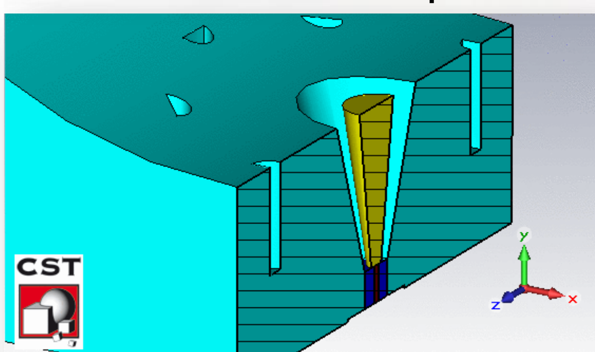
nd new Pickup

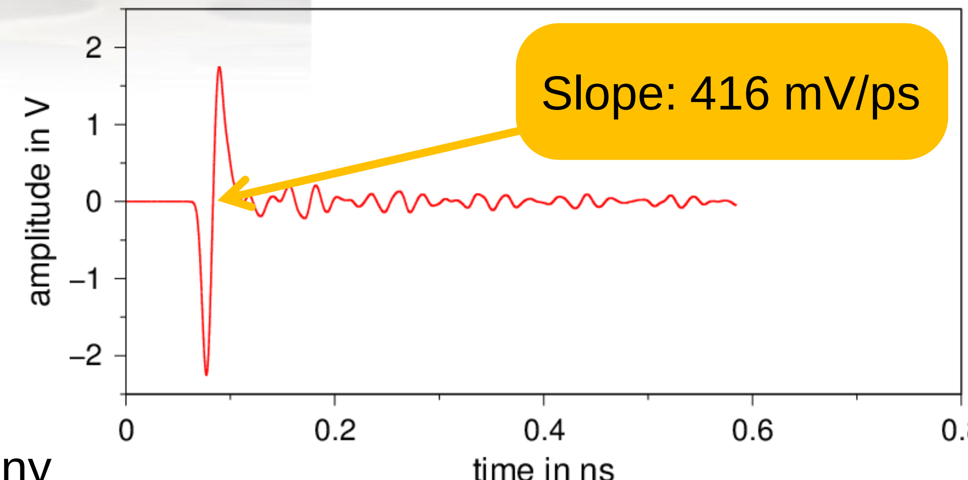


n with 20 pC bunch charge



New 40 GHz Pickup

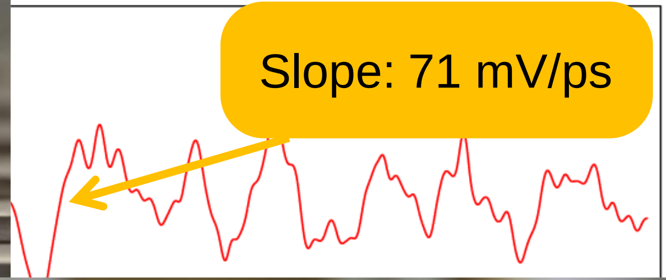




Design at TU Darmstadt, Germany

nd new Pickup

n with 20 pC bunch charge



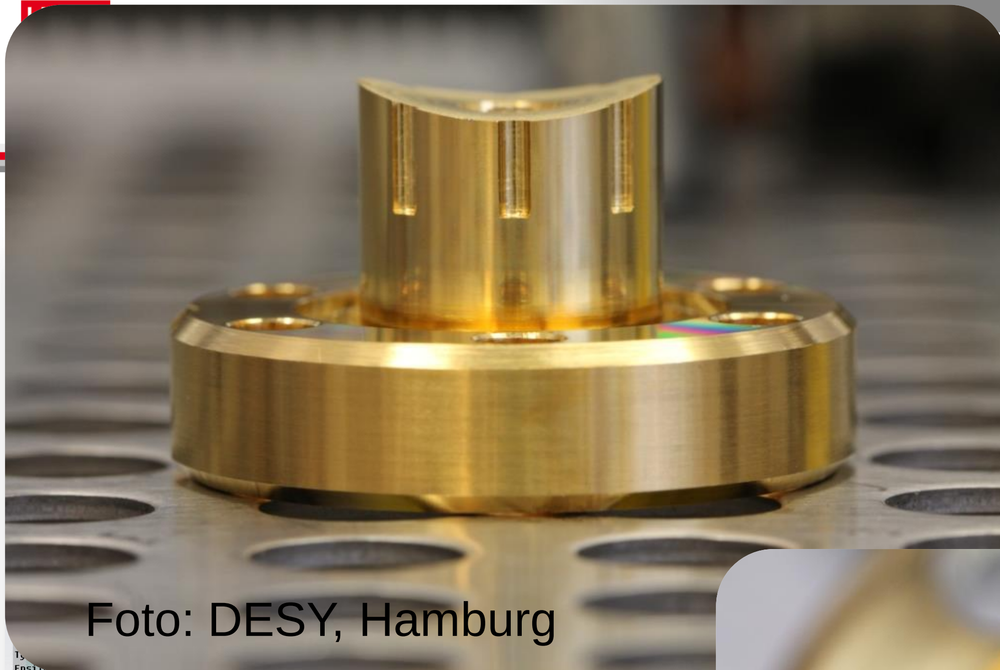
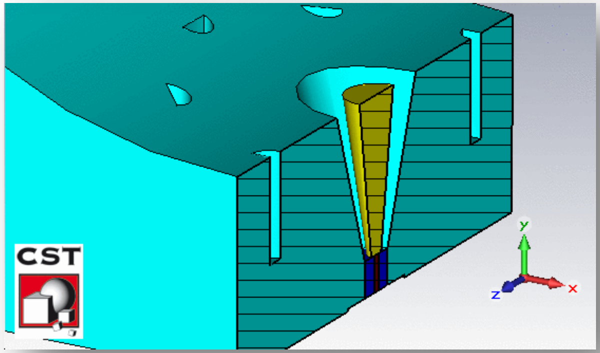


Foto: DESY, Hamburg

New 40 GHz Pickup



Design at TU Darmstadt, Germany

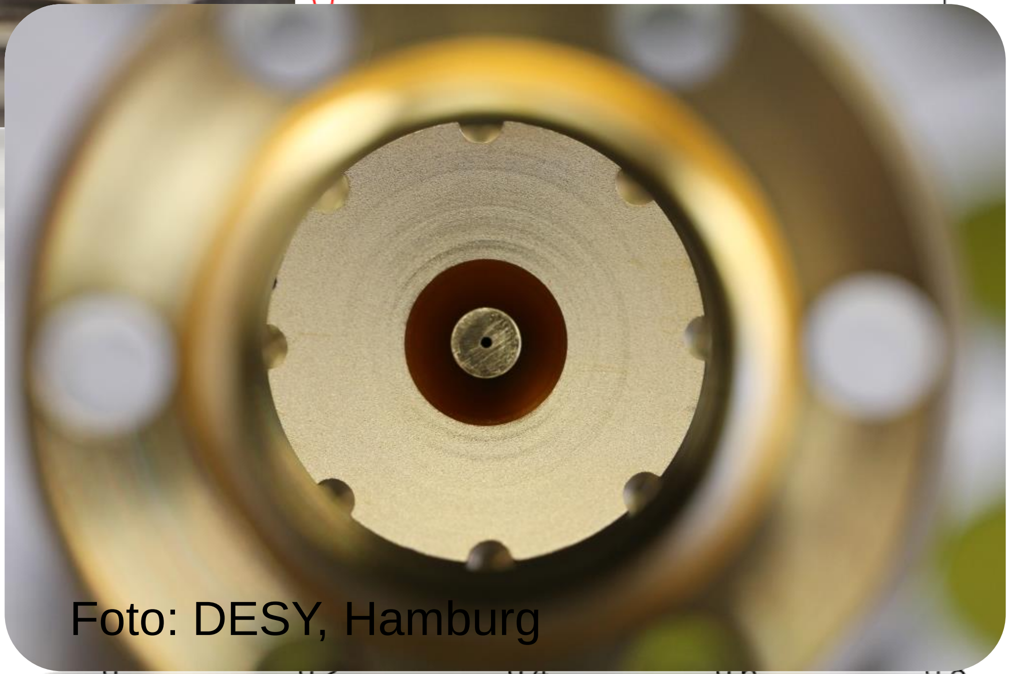
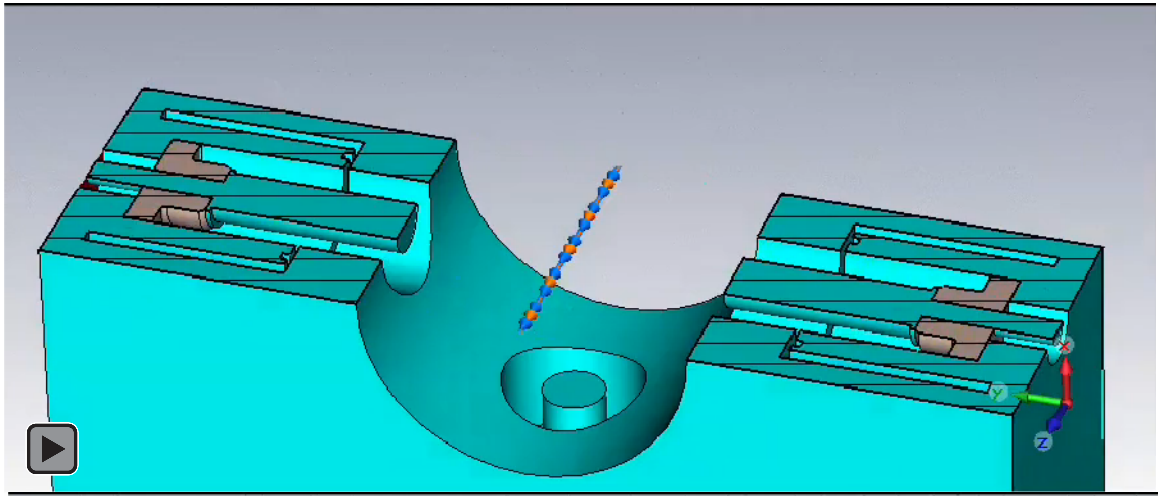
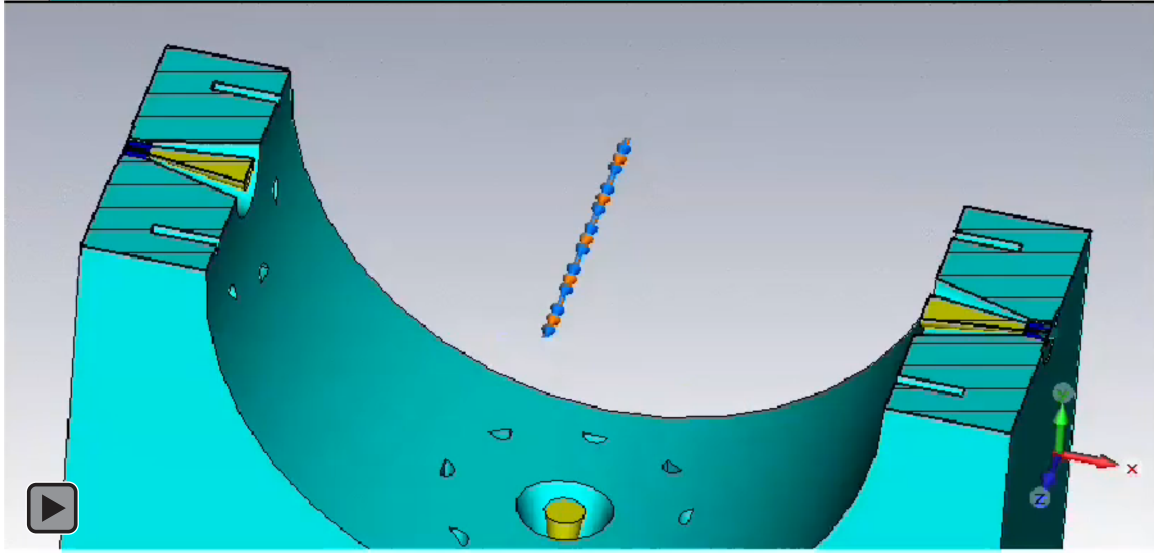


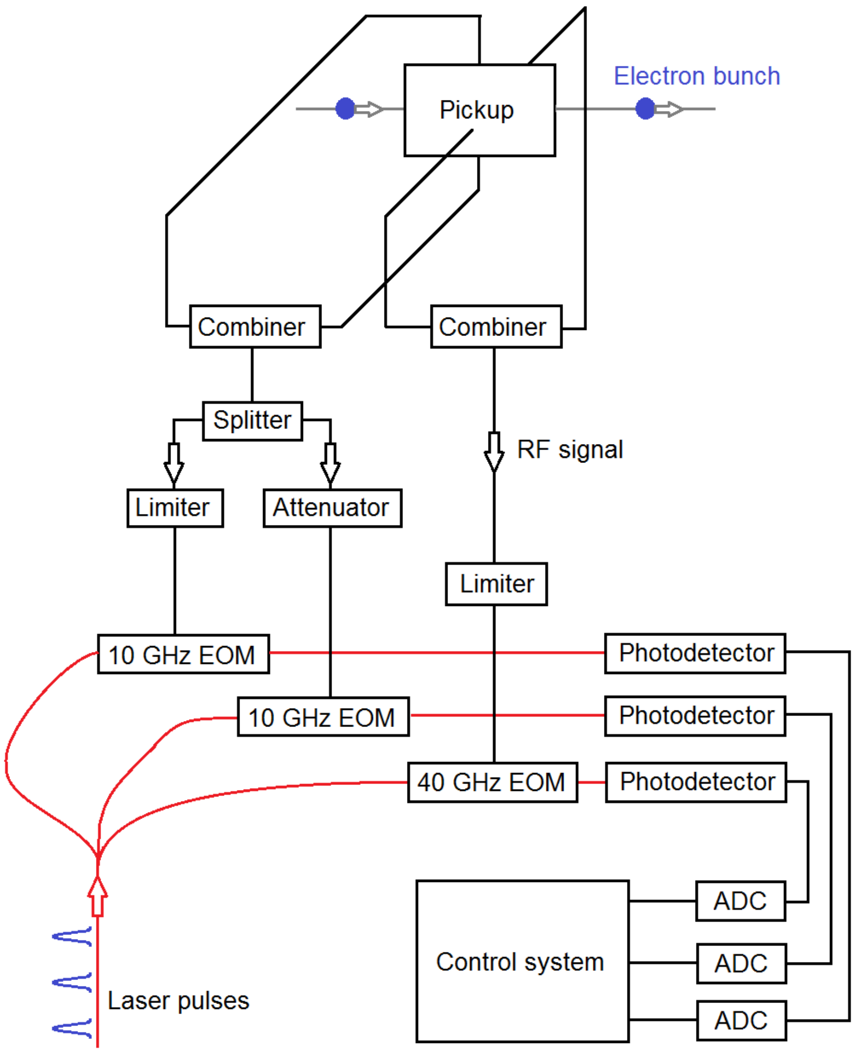
Foto: DESY, Hamburg

Old and new Pickup

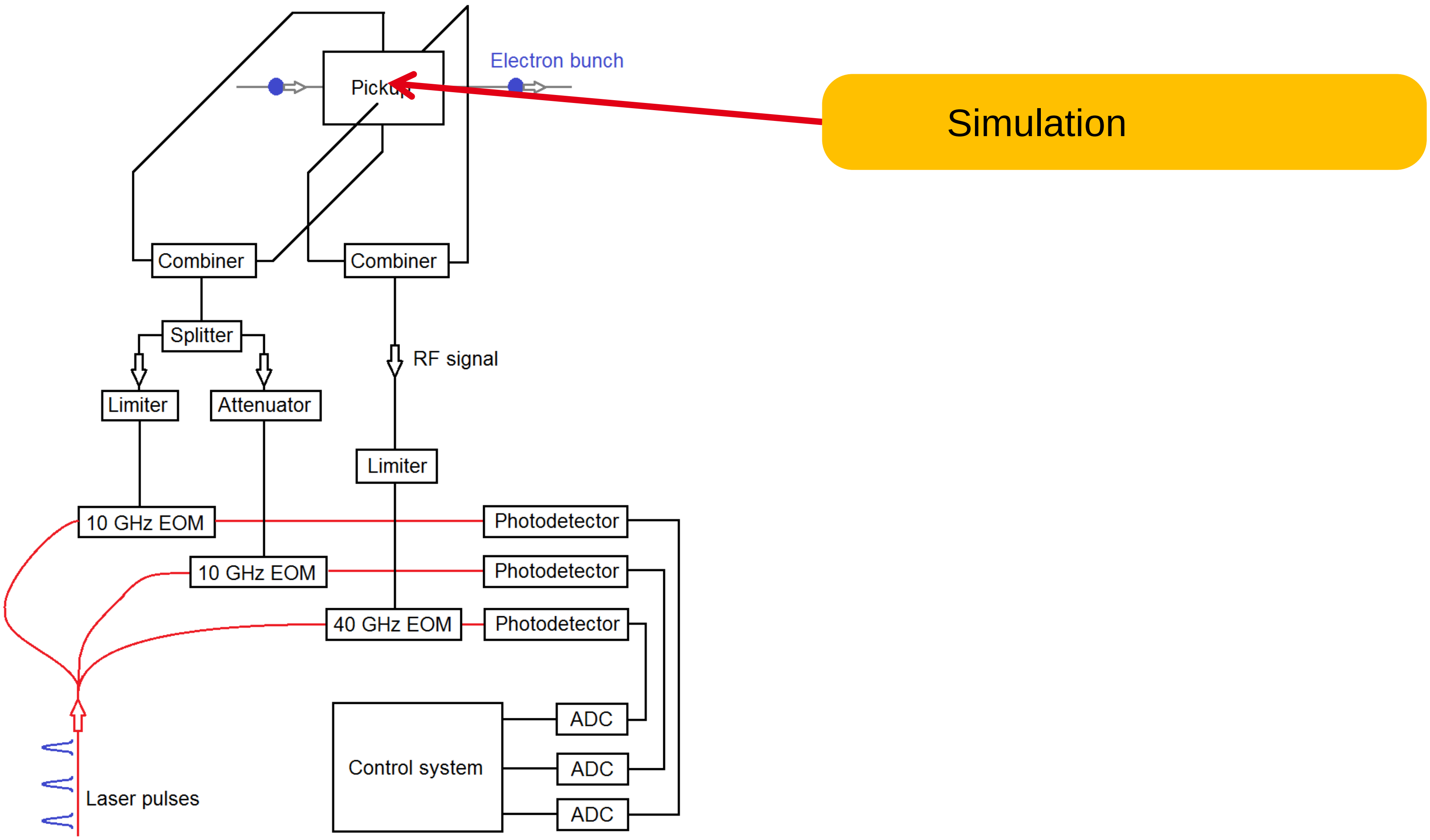




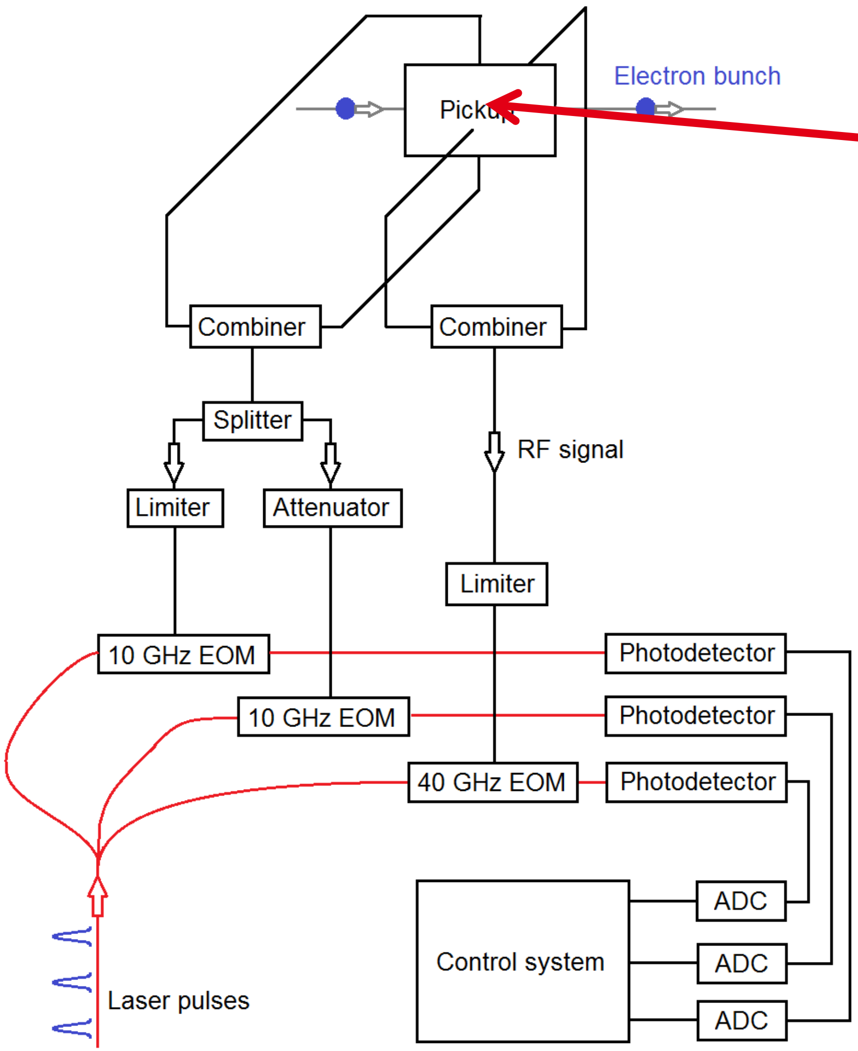
RF calculation



RF calculation



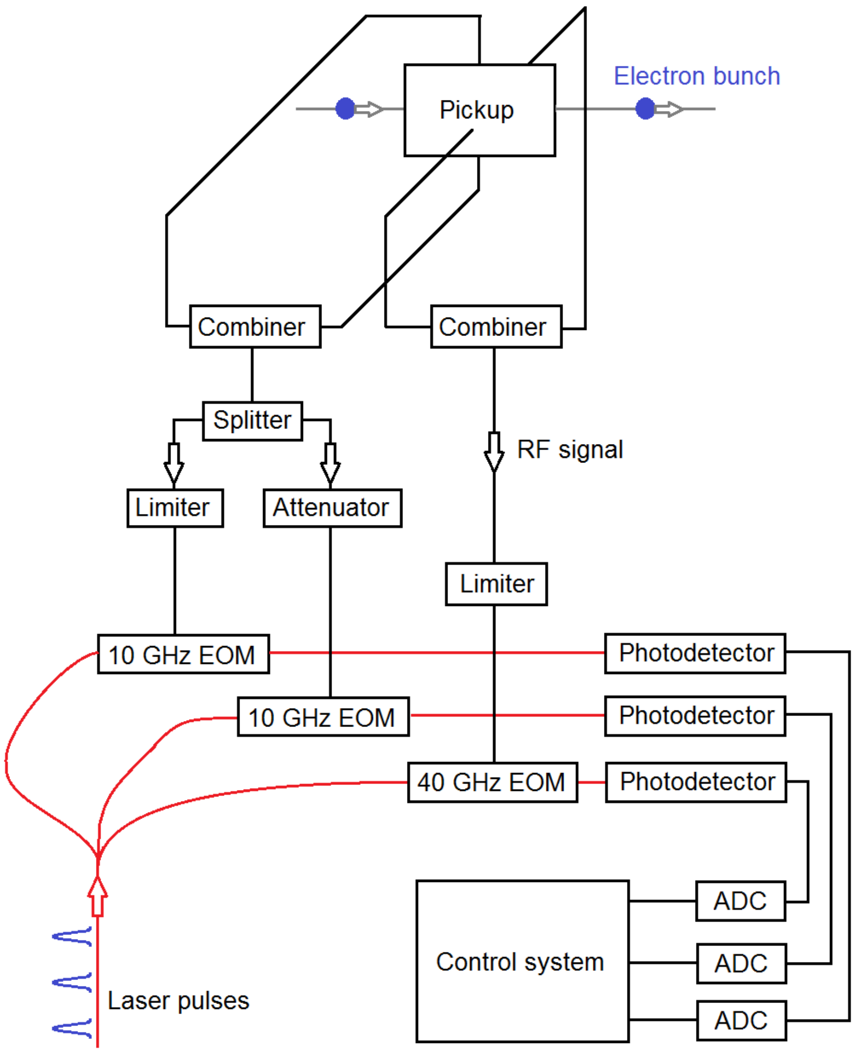
RF calculation



Simulation

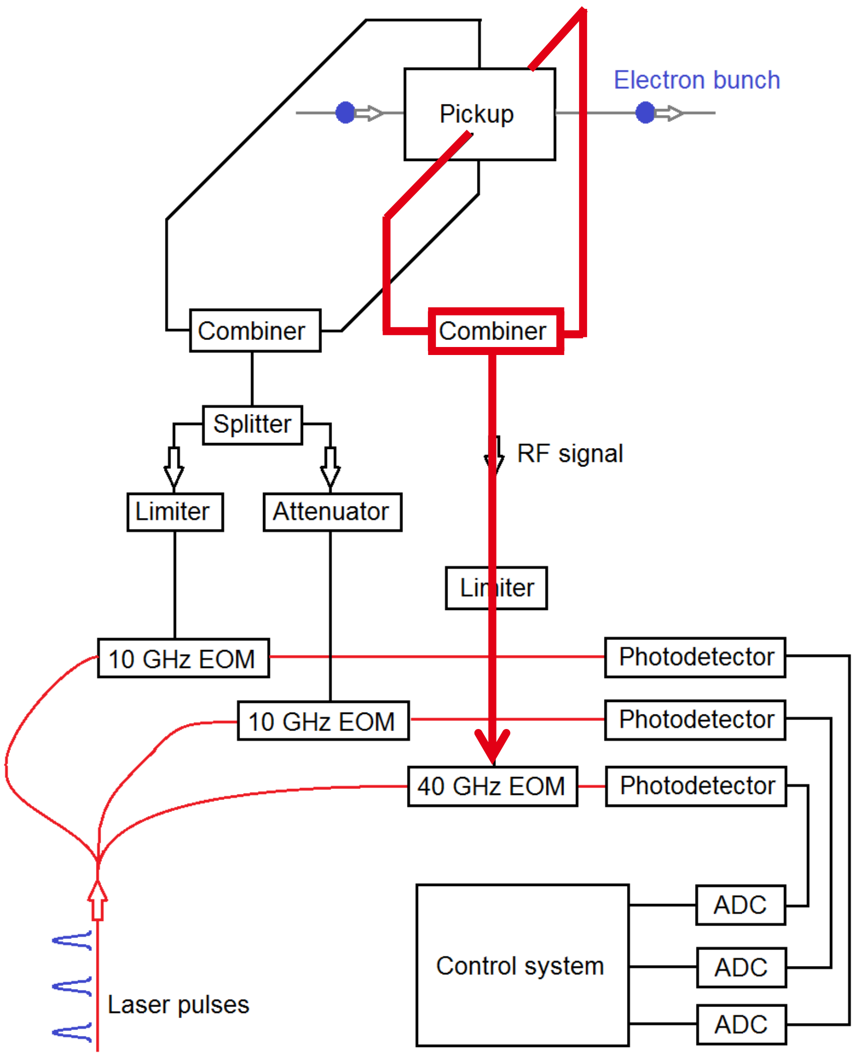
IBIC 2012 - MOPA46
A. Angelovski et. al.

RF calculation



Simulation

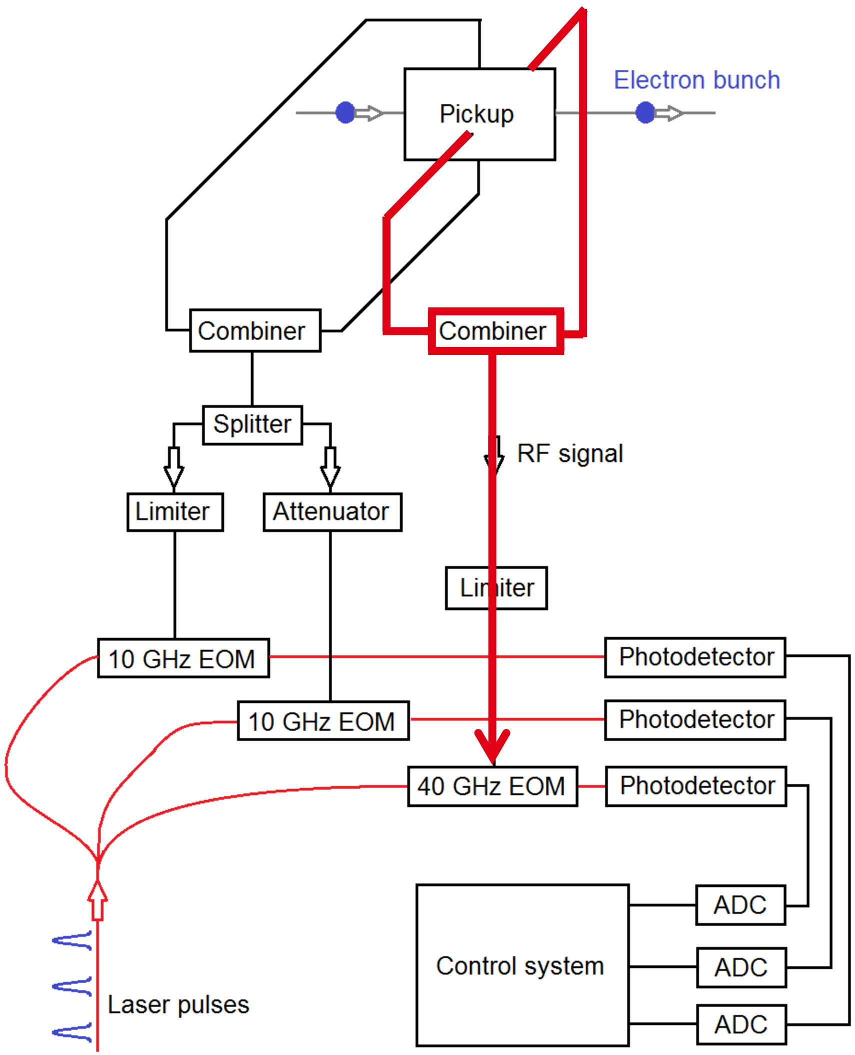
RF calculation



Simulation

Signal extrapolated by using S-parameters
- Cable
- Combiner

RF calculation



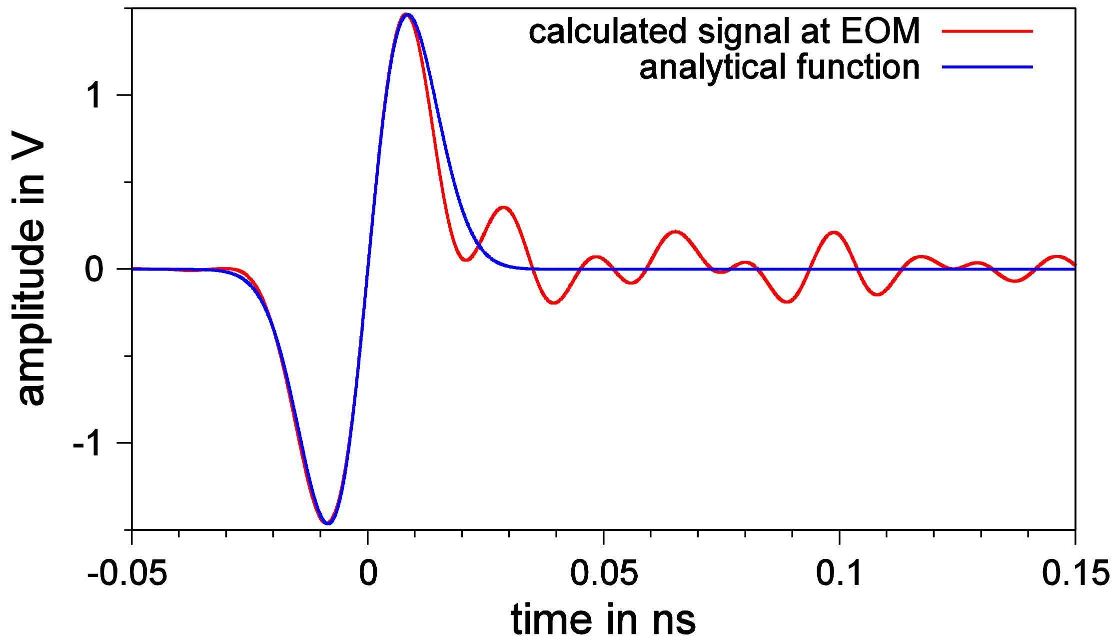
Simulation

Signal extrapolated by using S-parameters
- Cable
- Combiner

IBIC 2012 - MOPA43
A. Penirschke et. al.

RF calculation

Signal at the 40 GHz EOM



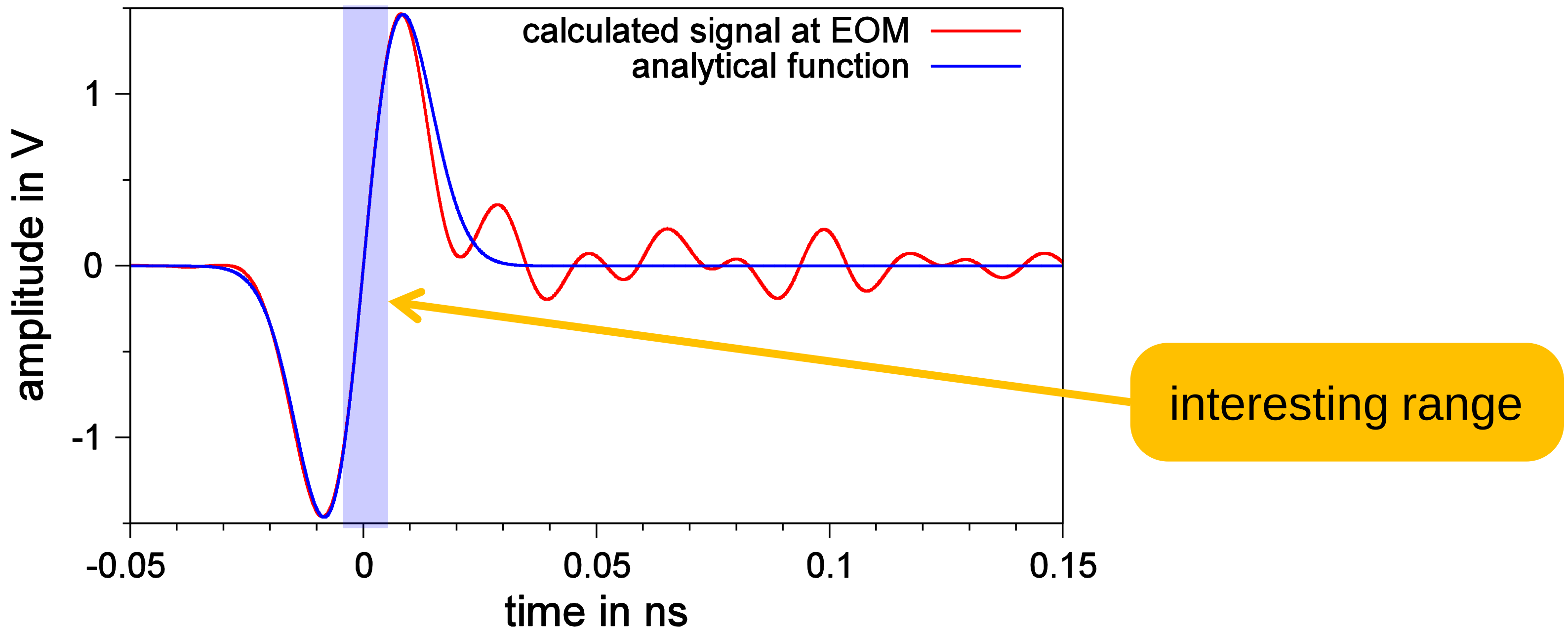
$$U(t) = t\,S\,e^{-\left(\frac{t\,S}{A\ e^{0.5}}\right)^2}$$

S	Slope:	286 mV/ps
A	Amplitude:	1.463 V

Alexander Kuhl
Alexander.kuhl@desy.de

RF calculation

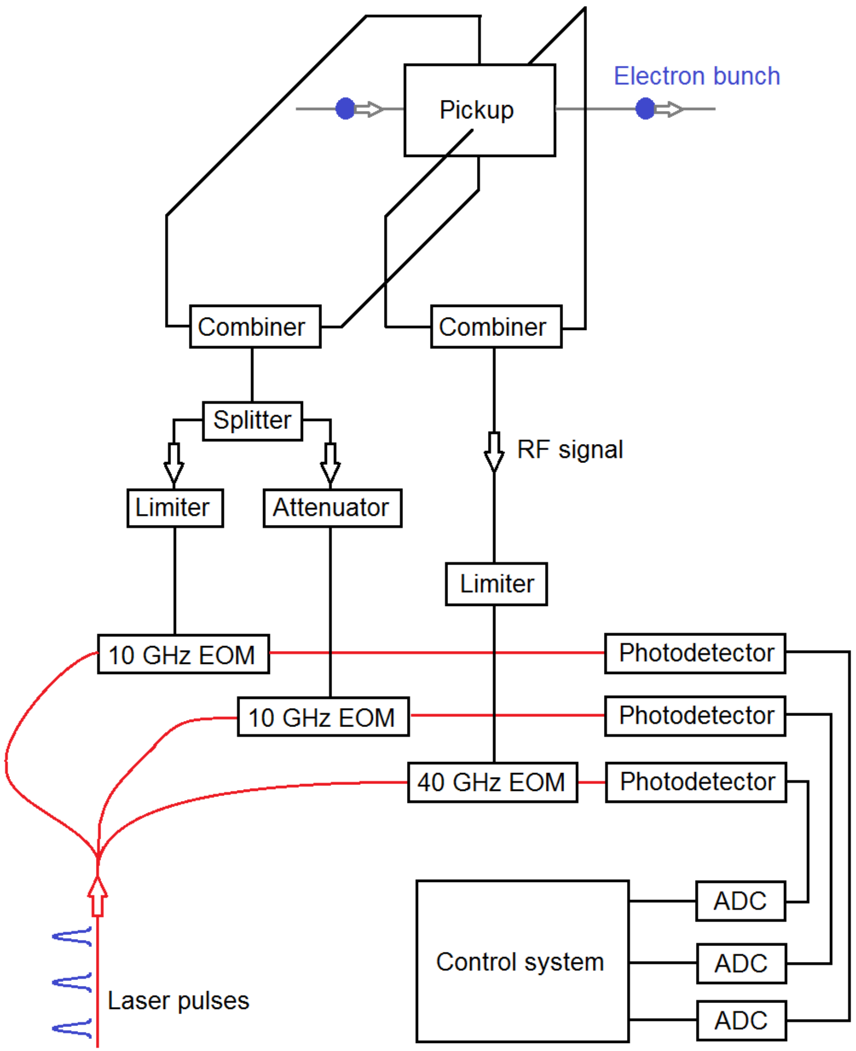
Signal at the 40 GHz EOM



$$U(t) = t\,S\,e^{-\left(\frac{t\,S}{A\ e^{0.5}}\right)^2}$$

S	Slope:	286 mV/ps
A	Amplitude:	1.463 V

Electro Optical Modulator (EOM)

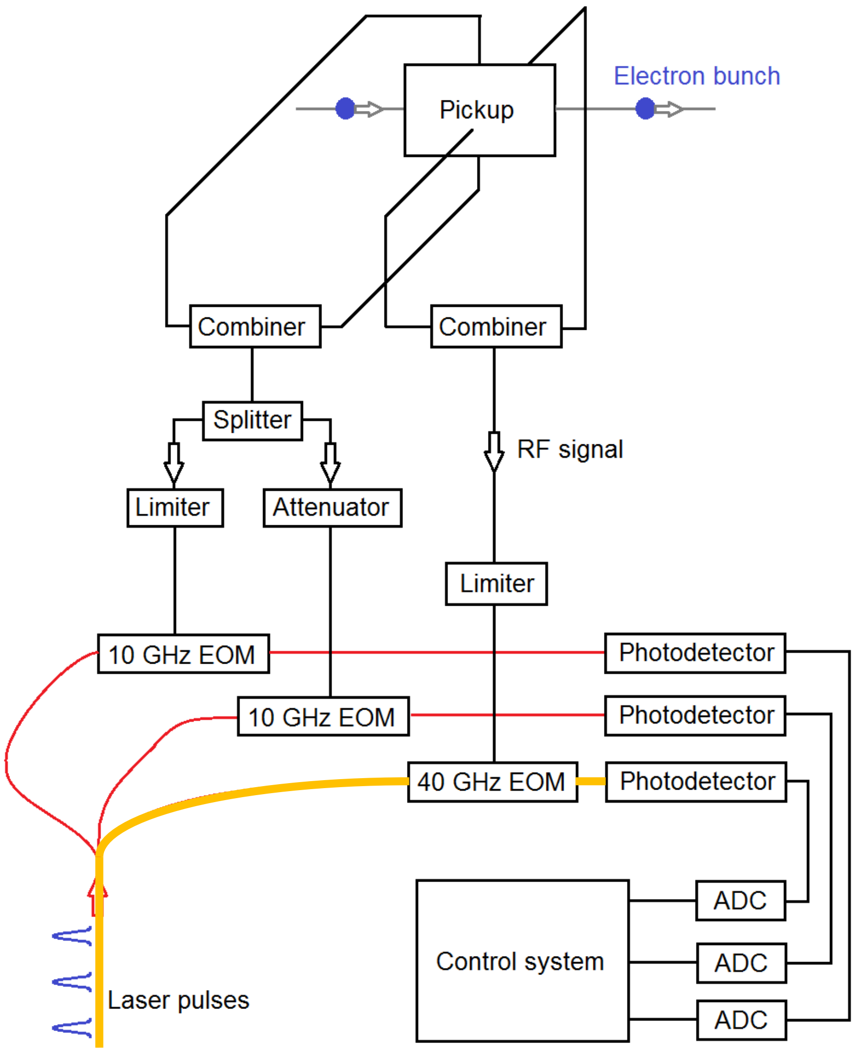


Simulation

Signal extrapolated by using S-parameters

- Cable
- Combiner

Electro Optical Modulator (EOM)



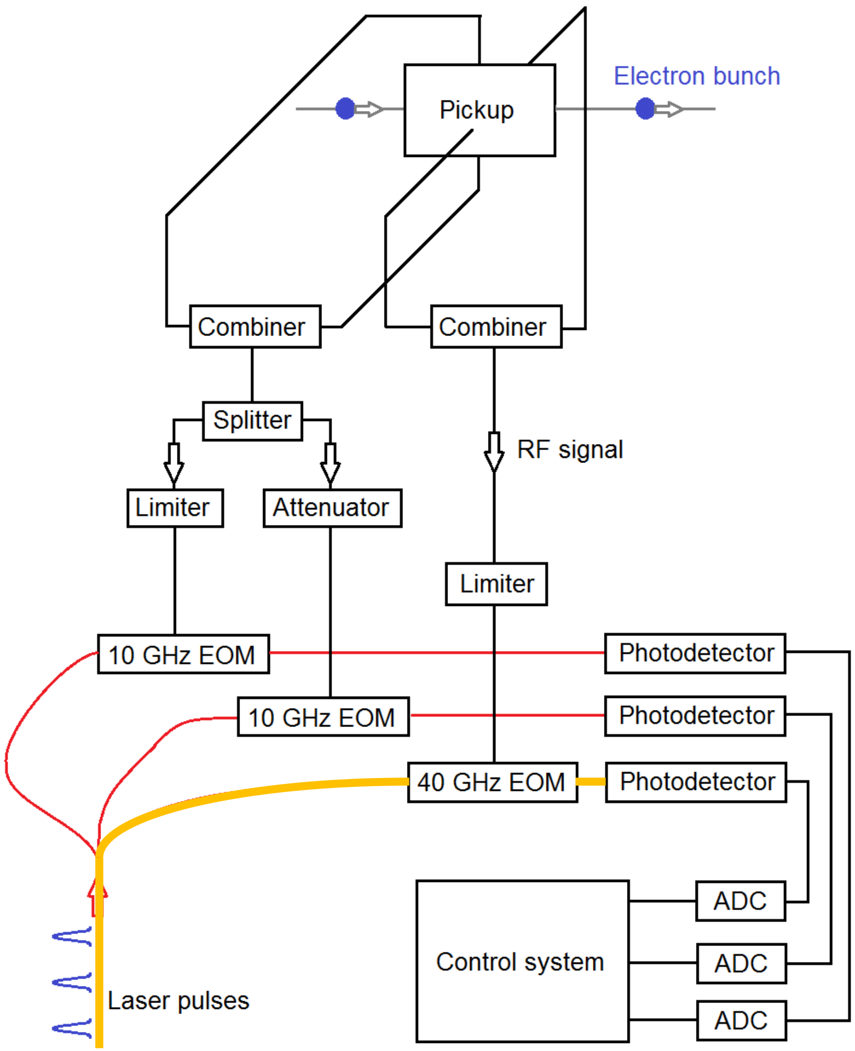
Simulation

Signal extrapolated by using S-parameters

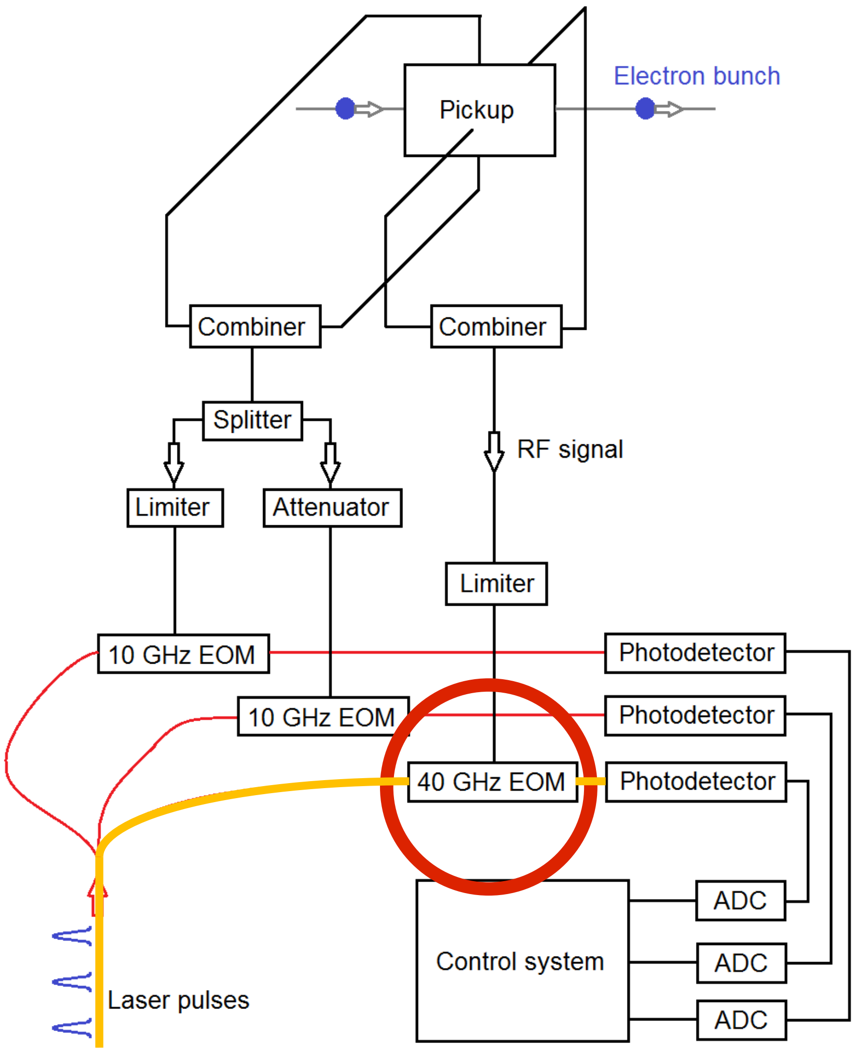
- Cable
- Combiner

Alexander Kuhl
Alexander.kuhl@desy.de

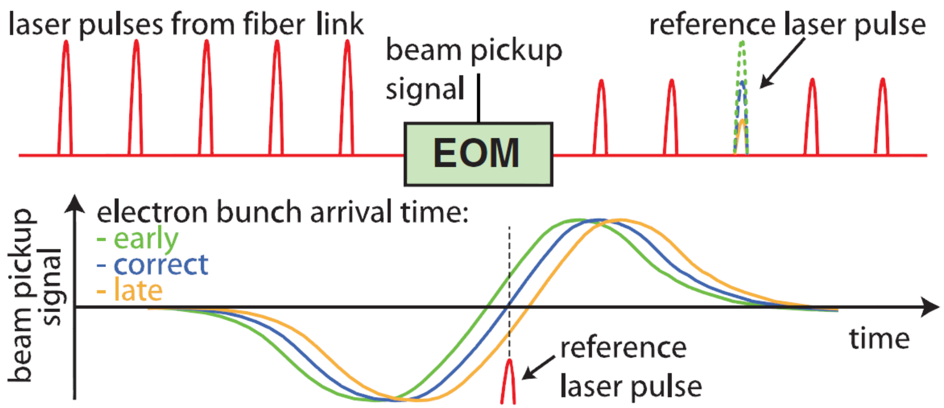
Electro Optical Modulator (EOM)



Electro Optical Modulator (EOM)

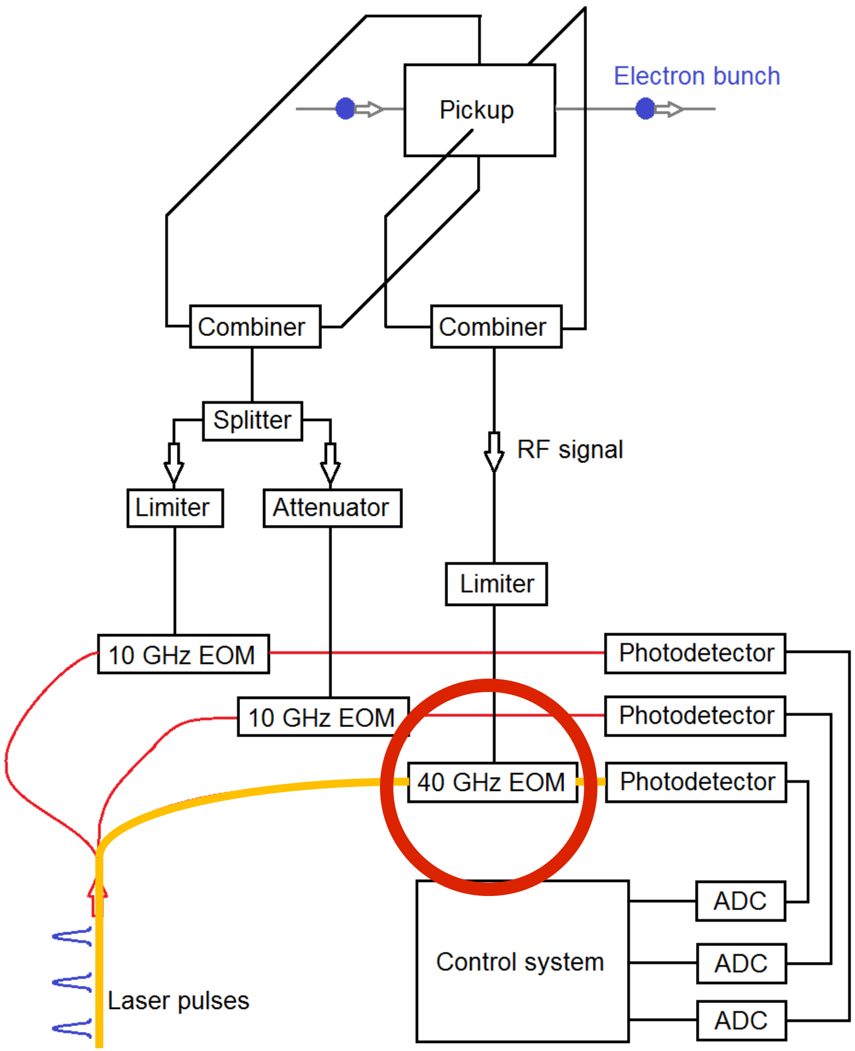


Principle of measurement

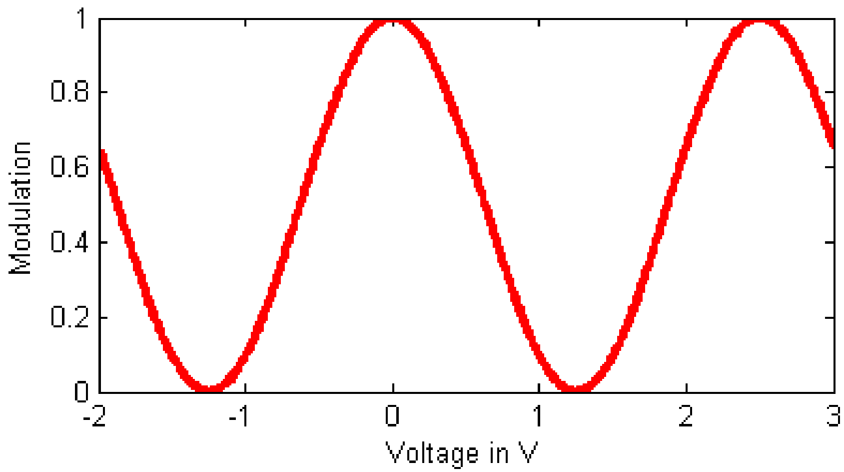


Courtesy by F. Löhl

Electro Optical Modulator (EOM)



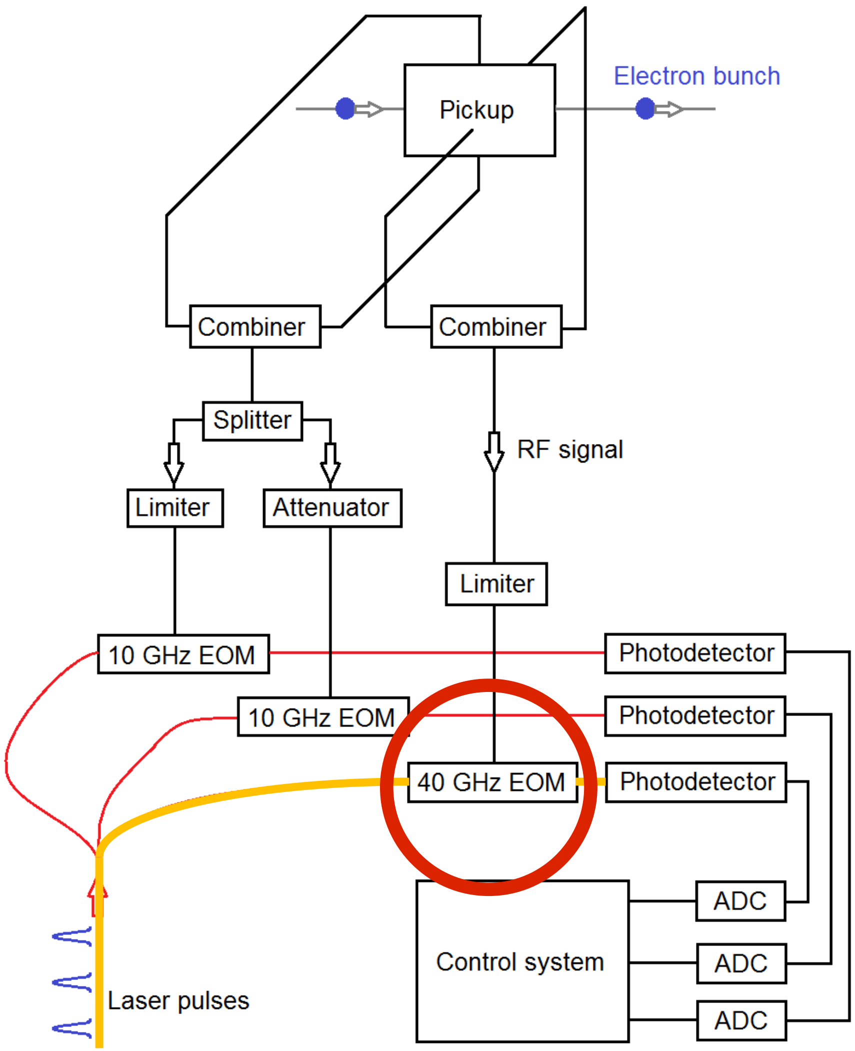
Modulation of the laser pulse



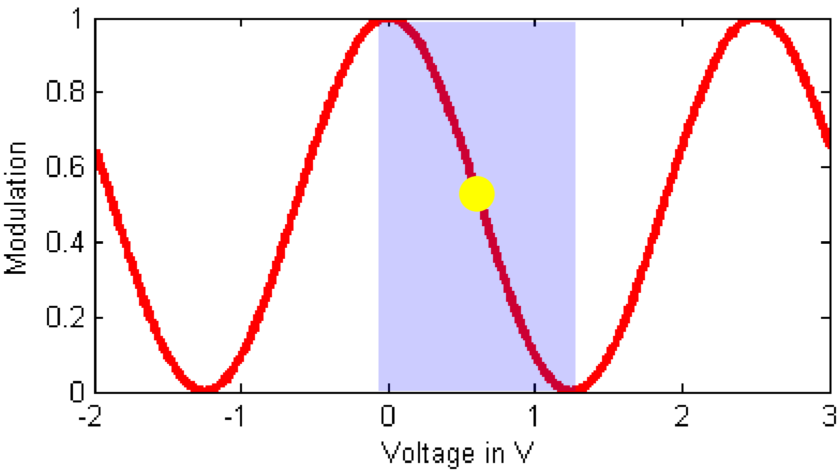
$$M = \frac{I_{out}}{I_{in}} = \frac{1}{2} + \frac{1}{2}\cos\left(\delta_0 + \frac{\pi}{U_\pi}U(t_m)\right)$$

M = Modulation
I = Laser amplitude
δ_0 = intrinsic operation point
U_π = Voltage to change M from 0 to 1

Electro Optical Modulator (EOM)



Modulation of the laser pulse

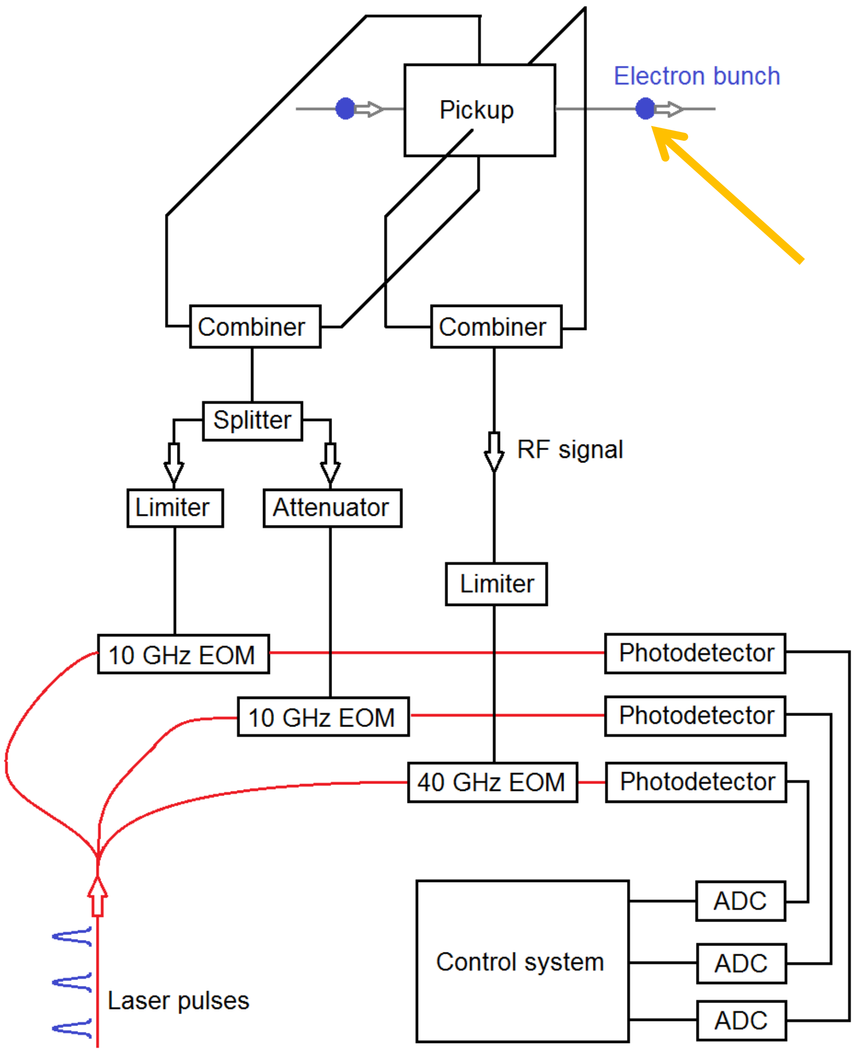


$$M = \frac{I_{out}}{I_{in}} = \frac{1}{2} + \frac{1}{2}\cos\left(\delta_0 + \frac{\pi}{U_\pi} U(t_m)\right)$$

M = Modulation
I = Laser amplitude
δ_0 = intrinsic operation point
U_π = Voltage to change M from 0 to 1

Alexander Kuhl
Alexander.kuhl@desy.de

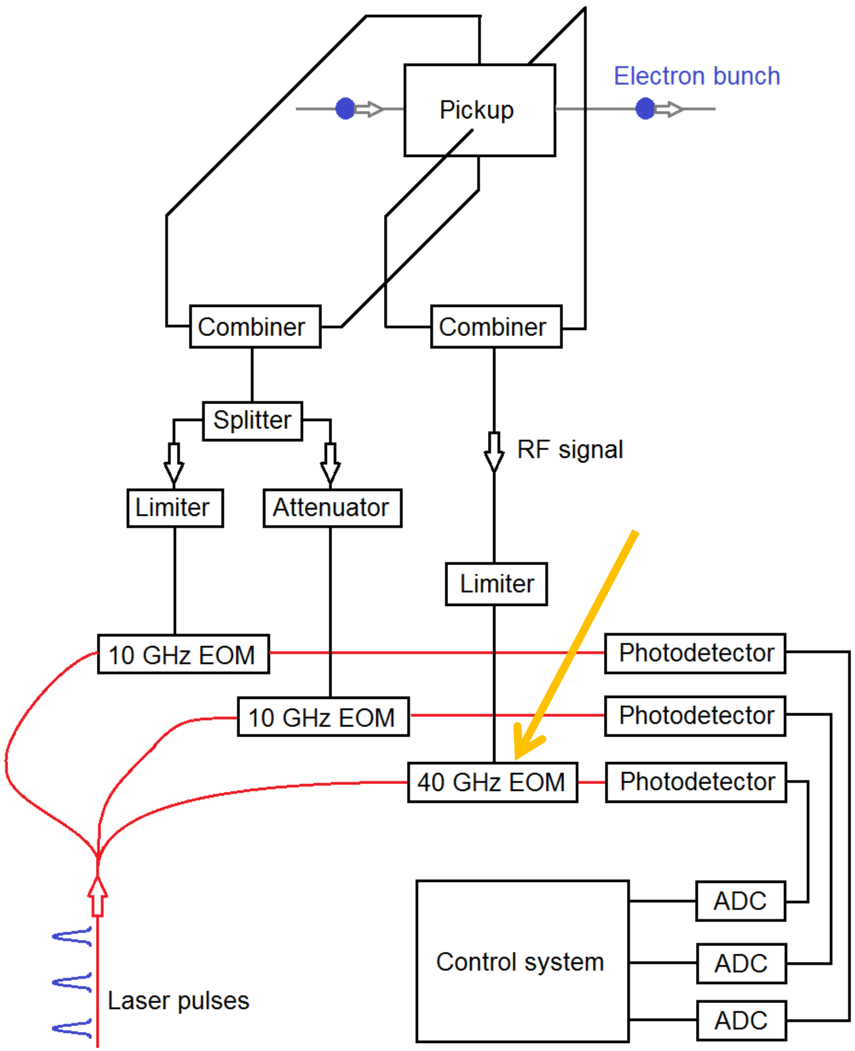
Monte Carlo Simulation



Influence of different jitter sources on the arrival time measurement

Parameter	Assumed RMS values
Bunch charge	1 %

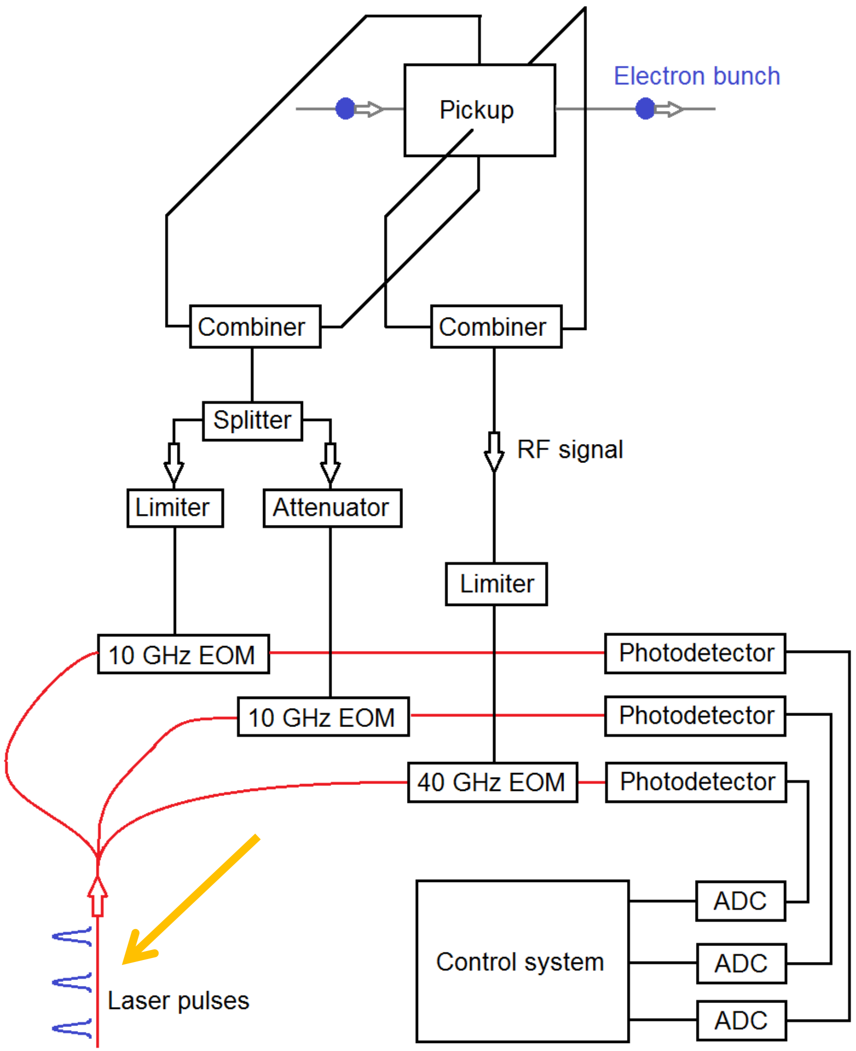
Monte Carlo Simulation



Influence of different jitter sources on the arrival time measurement

Parameter	Assumed RMS values
Bunch charge	1 %
Bias voltage	0.5 mV
RF voltage	0.5 mV

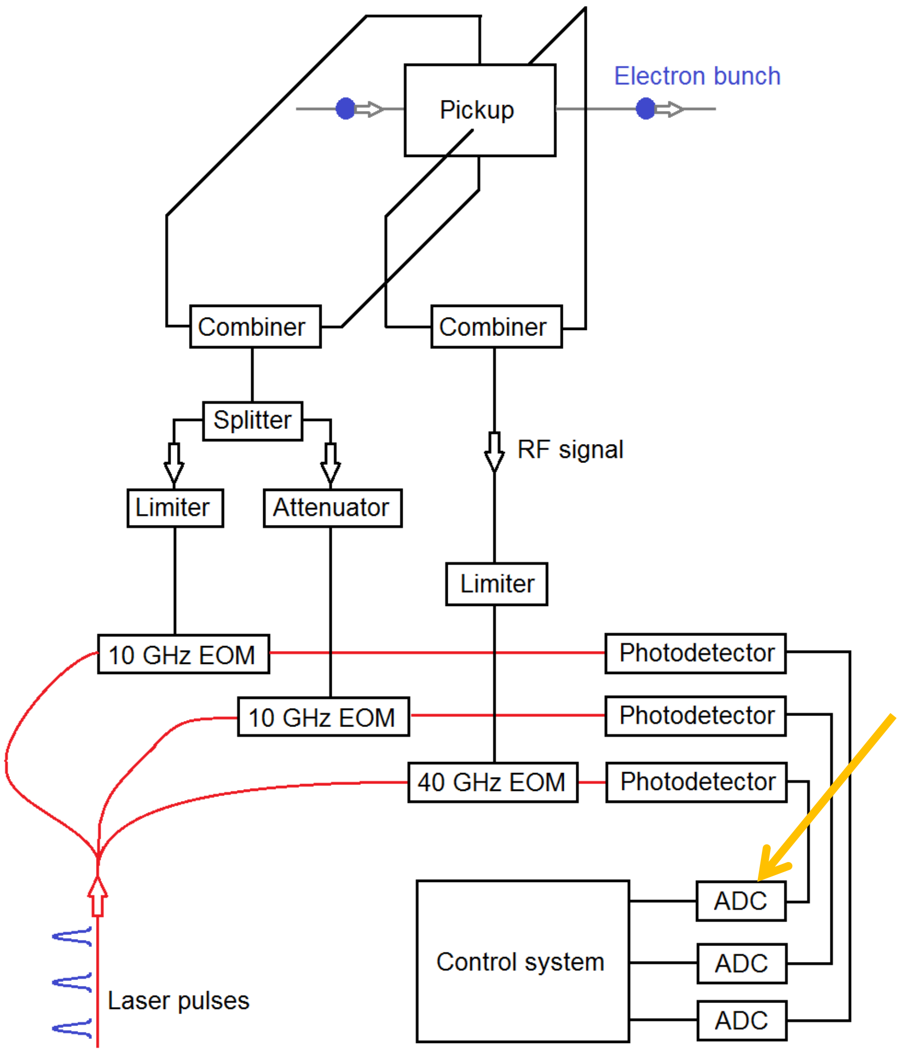
Monte Carlo Simulation



Influence of different jitter sources on the arrival time measurement

Parameter	Assumed RMS values
Bunch charge	1 %
Bias voltage	0.5 mV
RF voltage	0.5 mV
Laser amplitude	0.35 %
Laser timing	2.5 fs

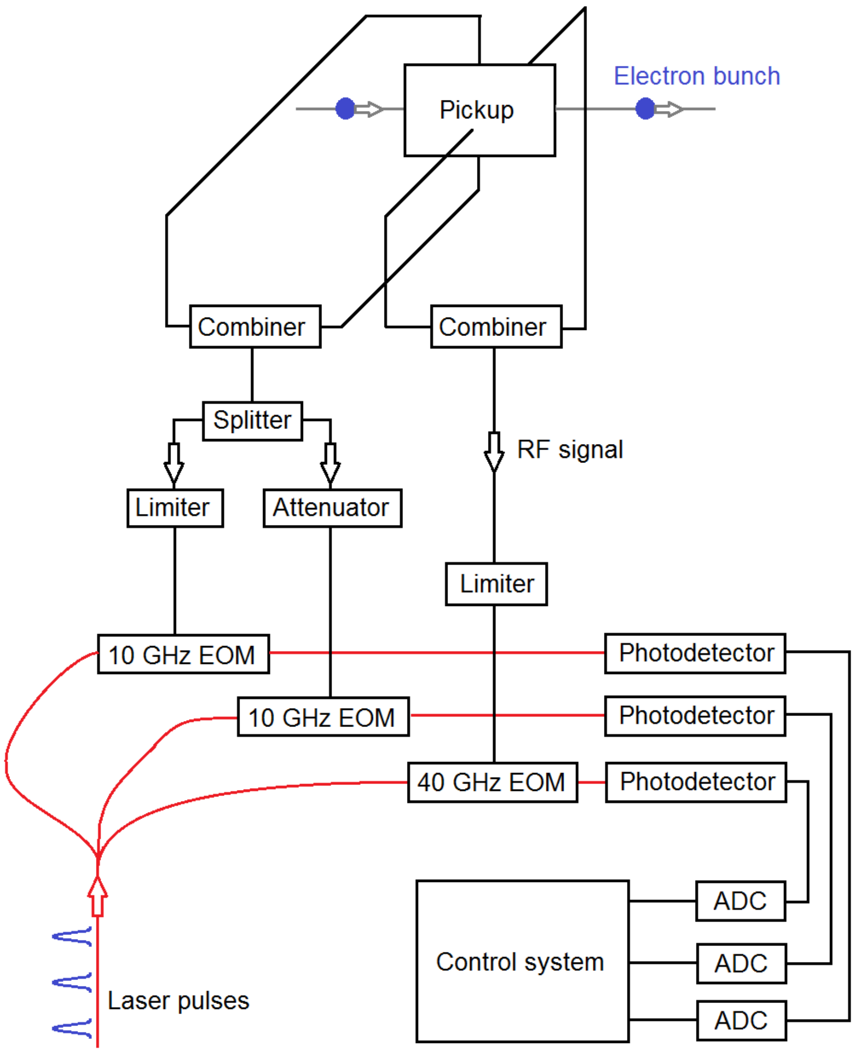
Monte Carlo Simulation



Influence of different jitter sources on the arrival time measurement

Parameter	Assumed RMS values
Bunch charge	1 %
Bias voltage	0.5 mV
RF voltage	0.5 mV
Laser amplitude	0.35 %
Laser timing	2.5 fs
ADC channel (16bit)	20

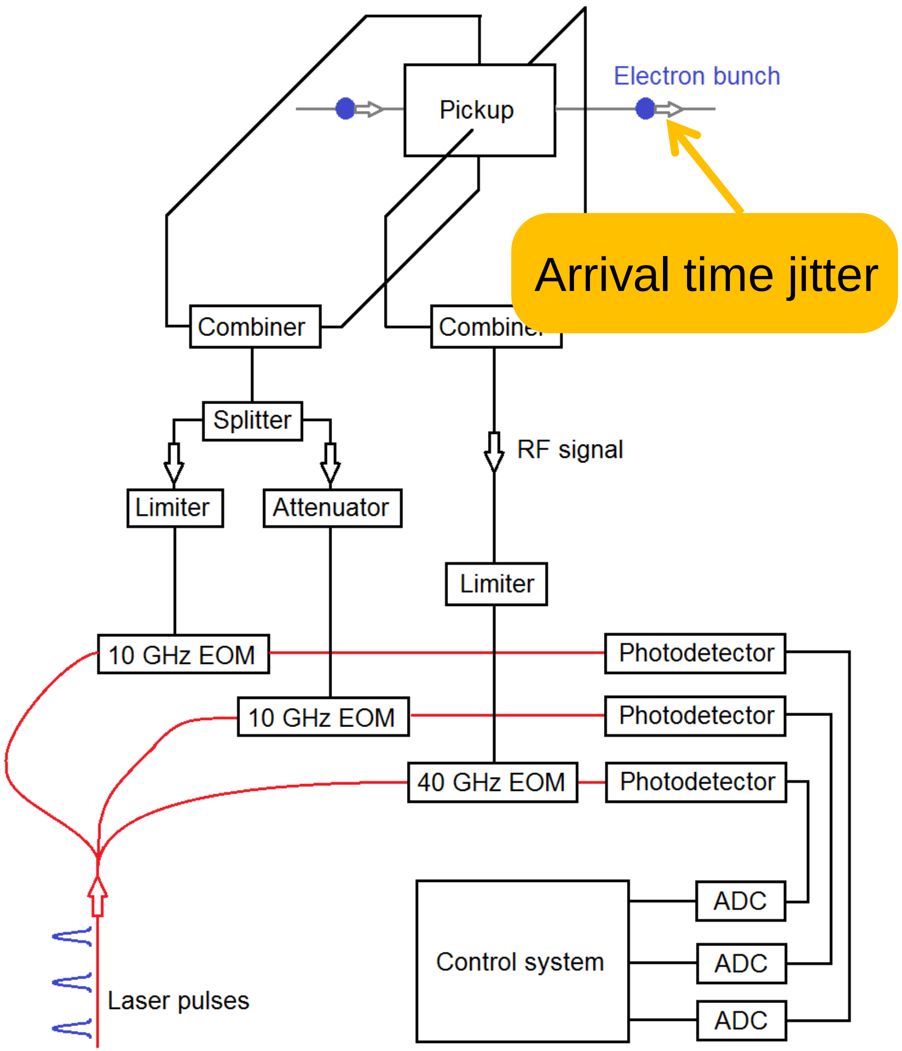
Monte Carlo Simulation



Influence of different jitter sources on the arrival time measurement

Parameter	Assumed RMS values
Bunch charge	1 %
Bias voltage	0.5 mV
RF voltage	0.5 mV
Laser amplitude	0.35 %
Laser timing	2.5 fs
ADC channel (16bit)	20

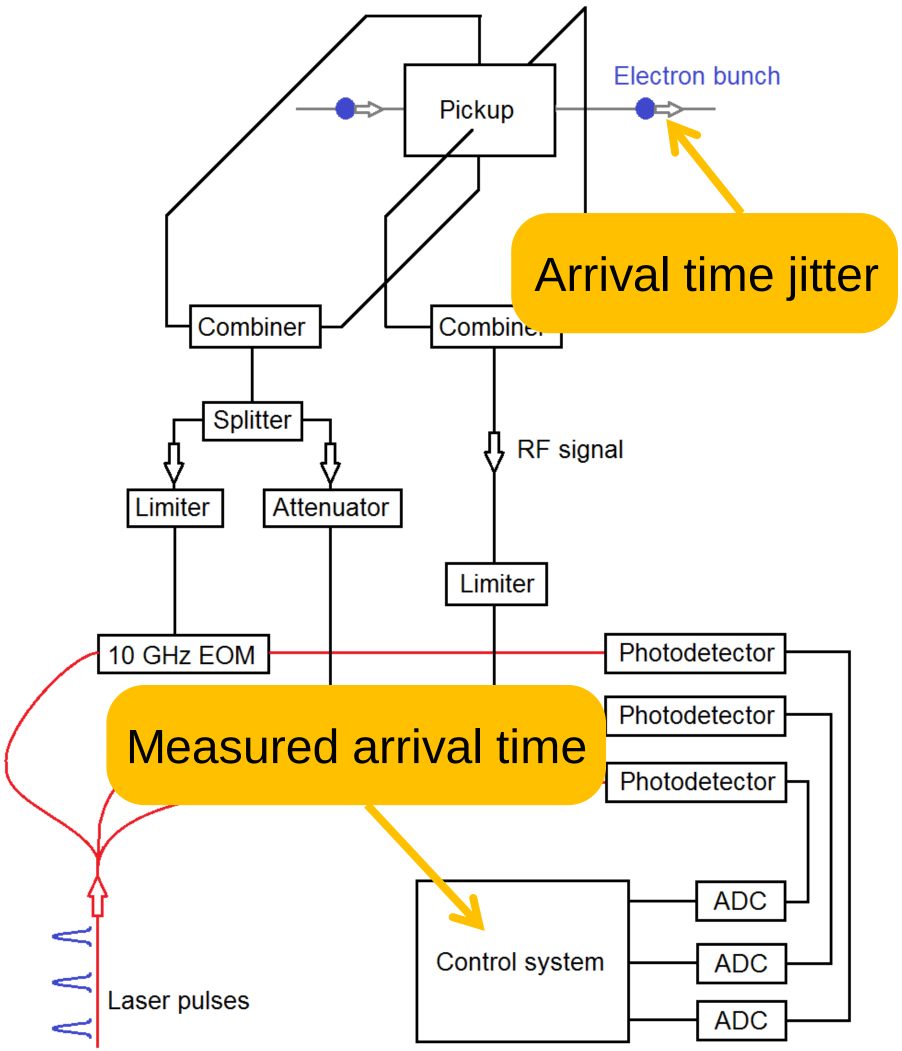
Monte Carlo Simulation



Influence of different jitter sources on the arrival time measurement

Parameter	Assumed RMS values
Bunch charge	1 %
Bias voltage	0.5 mV
RF voltage	0.5 mV
Laser amplitude	0.35 %
Laser timing	2.5 fs
ADC channel (16bit)	20

Monte Carlo Simulation



Influence of different jitter sources on the arrival time measurement

Parameter	Assumed RMS values
Bunch charge	1 %
Bias voltage	0.5 mV
RF voltage	0.5 mV
Laser amplitude	0.35 %
Laser timing	2.5 fs
ADC channel (16bit)	20

Monte Carlo Simulation

Monte Carlo Simulation

*Normaly distributed

Monte Carlo Simulation

Monte Carlo Simulation

1. Random set of the Parameter*

*Normaly distributed

Monte Carlo Simulation

Monte Carlo Simulation

1. Random set of the Parameter*
2. Also a random value for the arrival time of the bunch*

*Normaly distributed

Alexander Kuhl
Alexander.kuhl@desy.de

Monte Carlo Simulation

Monte Carlo Simulation

1. Random set of the Parameter*
2. Also a random value for the arrival time of the bunch*
3. Calculation of the measured arrival time

*Normaly distributed

Alexander Kuhl
Alexander.kuhl@desy.de

Monte Carlo Simulation

Monte Carlo Simulation

1. Random set of the Parameter*
2. Also a random value for the arrival time of the bunch*
3. Calculation of the measured arrival time
4. Compare

*Normaly distributed

Monte Carlo Simulation

Monte Carlo Simulation

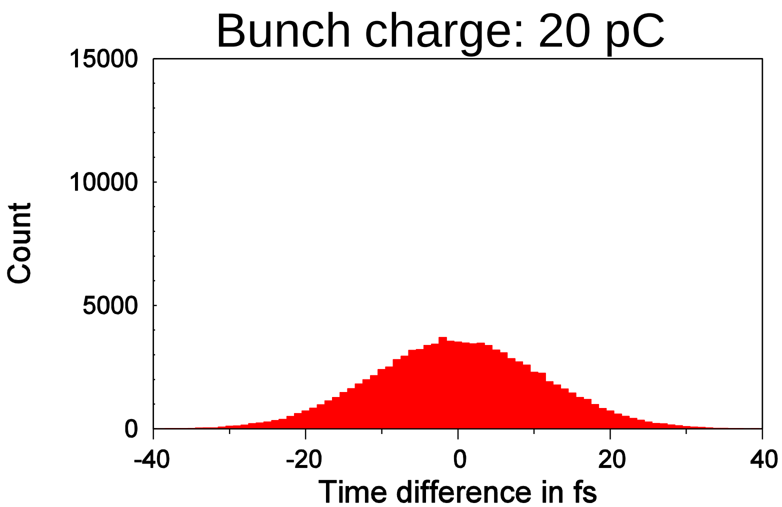
1. Random set of the Parameter*
2. Also a random value for the arrival time of the bunch*
3. Calculation of the measured arrival time
4. Compare
5. Repeat this 100.000 times

*Normaly distributed

Monte Carlo Simulation

Monte Carlo Simulation

1. Random set of the Parameter*
2. Also a random value for the arrival time of the bunch*
3. Calculation of the measured arrival time
4. Compare
5. Repeat this 100.000 times



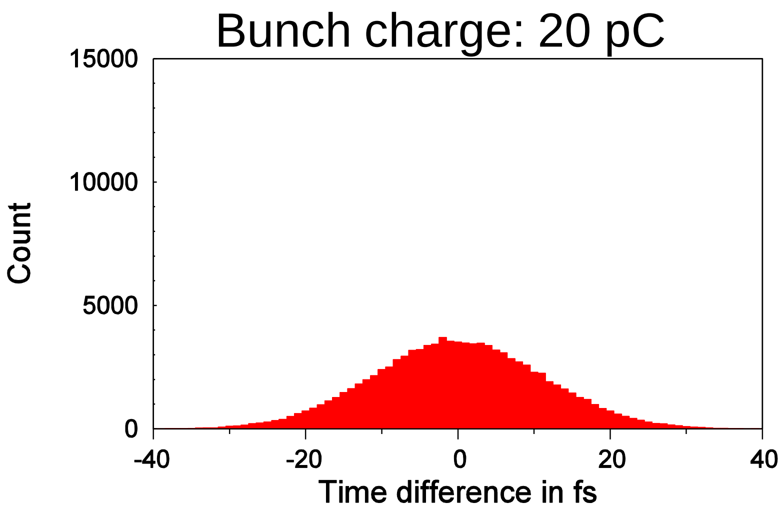
Simulated measurement accuracy = 11fs RMS

*Normaly distributed

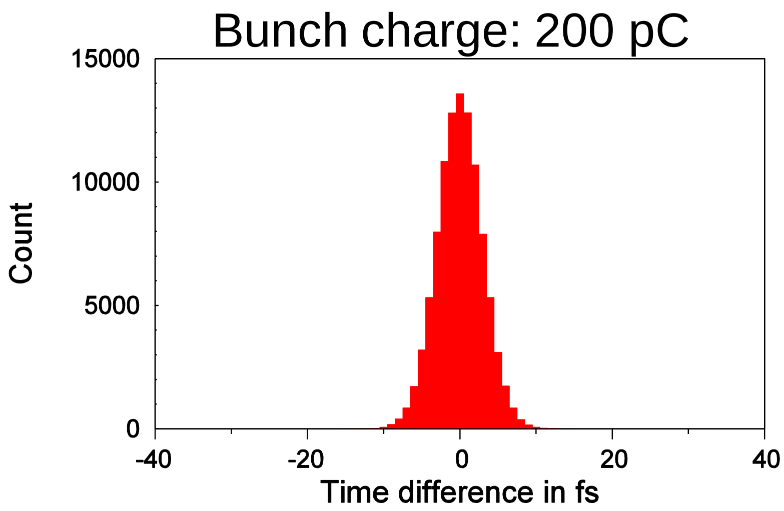
Monte Carlo Simulation

Monte Carlo Simulation

1. Random set of the Parameter*
2. Also a random value for the arrival time of the bunch*
3. Calculation of the measured arrival time
4. Compare
5. Repeat this 100.000 times



Simulated measurement accuracy = 11fs RMS



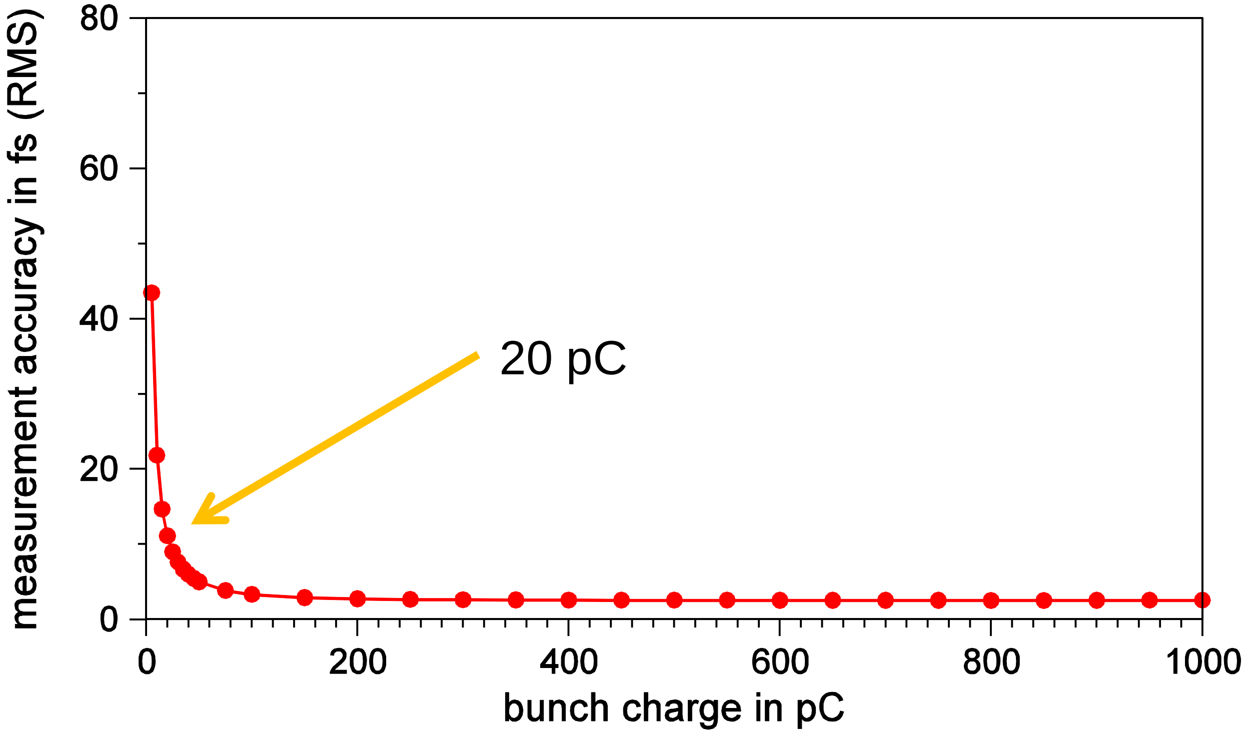
Simulated measurement accuracy = 3 fs RMS

*Normaly distributed

Results

Simulated timing resolution with different bunch charges

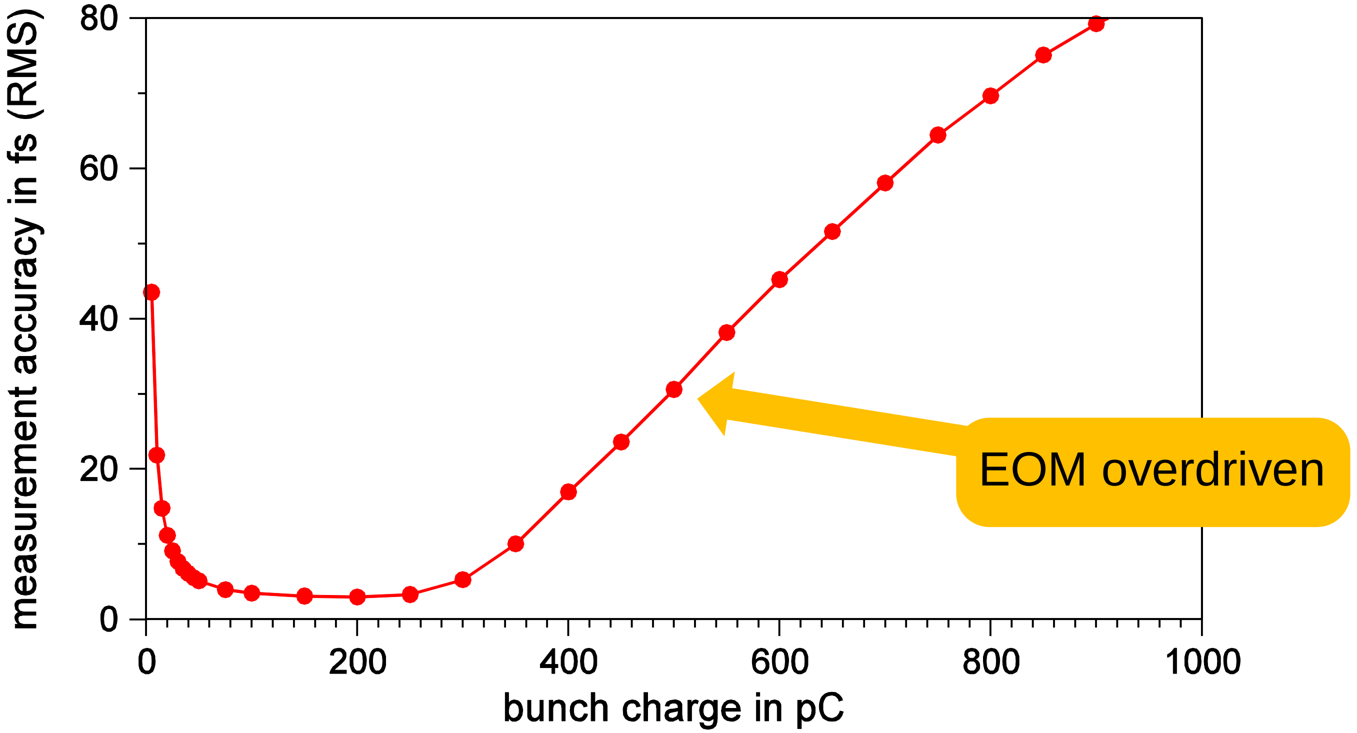
Random value for the arrival time of the bunch: 25 fs RMS



Results

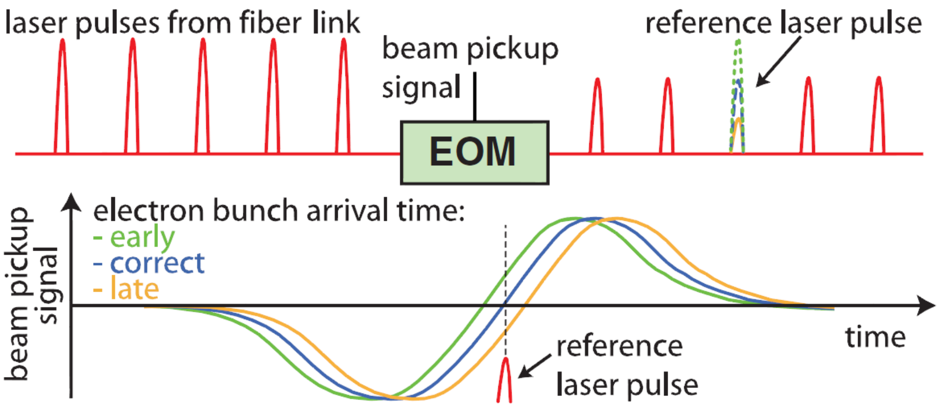
Simulated timing resolution with different bunch charges

Random value for the arrival time of the bunch: 100 fs RMS



Results

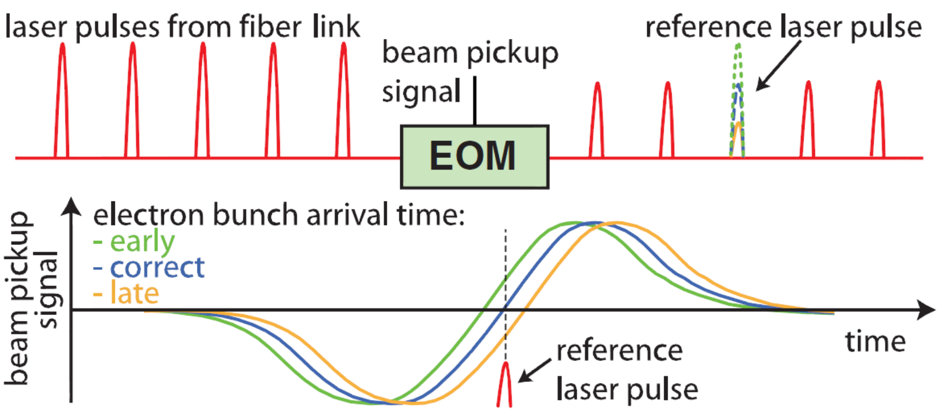
Back to principle of measurement



Courtesy by F. Löhl

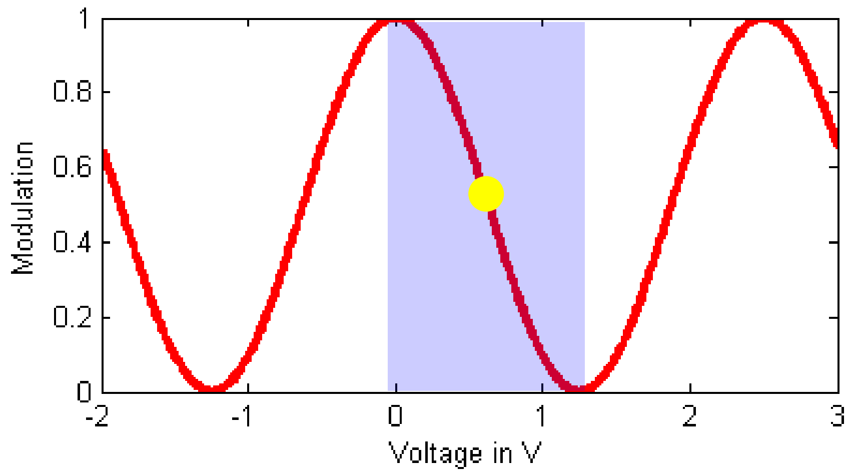
Results

Back to principle of measurement



Courtesy by F. Löhl

Modulation of the laser pulse

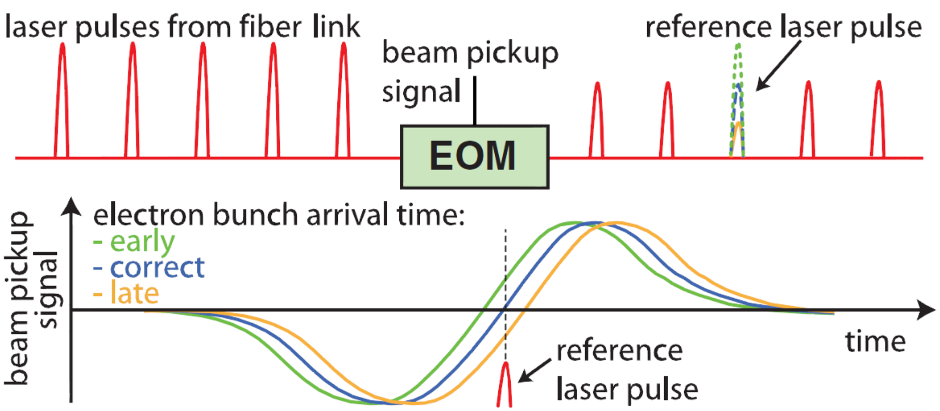


$$M = \frac{I_{out}}{I_{in}} = \frac{1}{2} + \frac{1}{2}\cos\left(\delta_0 + \frac{\pi}{U_\pi} U(t_m)\right)$$

M = Modulation
I = Laser amplitude
δ_0 = intrinsic operation point
U_π = Voltage to change M from 0 to 1

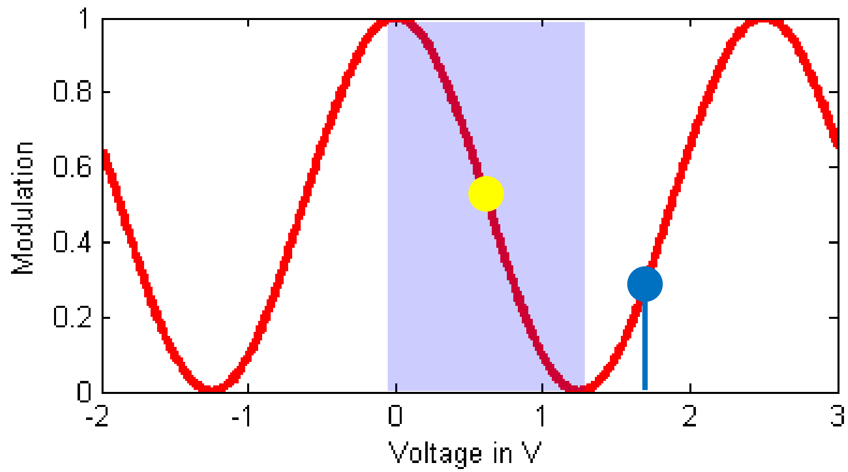
Results

Back to principle of measurement



Courtesy by F. Löhl

Modulation of the laser pulse

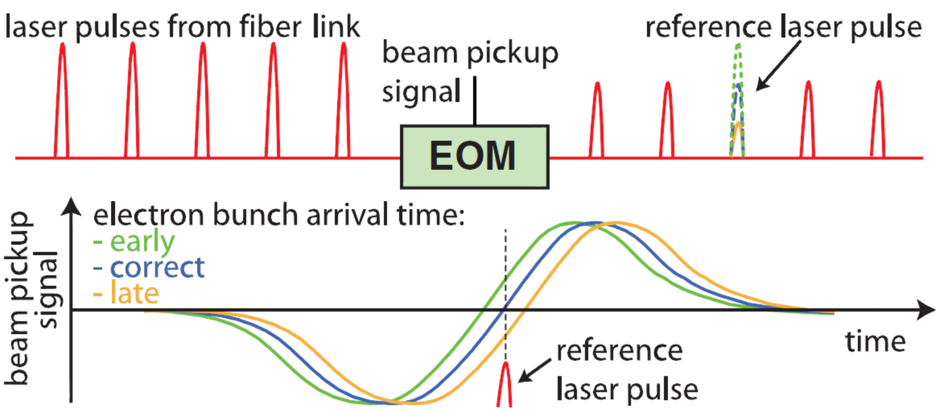


$$M = \frac{I_{out}}{I_{in}} = \frac{1}{2} + \frac{1}{2}\cos\left(\delta_0 + \frac{\pi}{U_\pi} U(t_m)\right)$$

M = Modulation
I = Laser amplitude
δ_0 = intrinsic operation point
U_π= Voltage to change M from 0 to 1

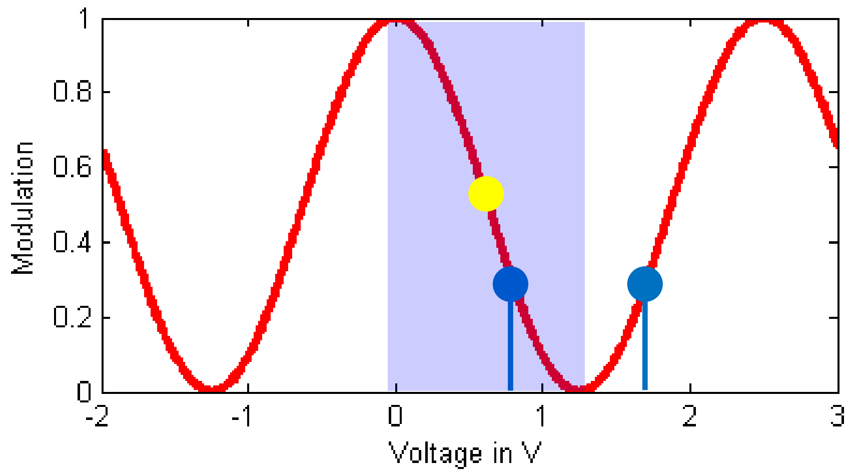
Results

Back to principle of measurement



Courtesy by F. Löhl

Modulation of the laser pulse

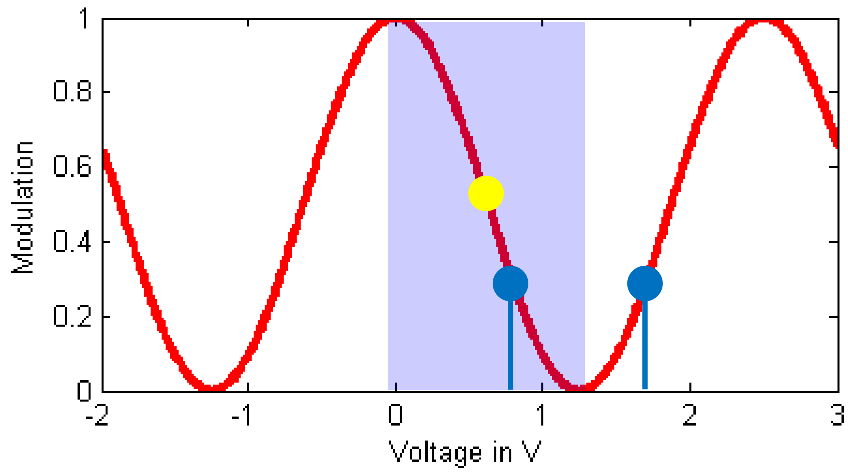


$$M = \frac{I_{out}}{I_{in}} = \frac{1}{2} + \frac{1}{2}\cos\left(\delta_0 + \frac{\pi}{U_\pi}U(t_m)\right)$$

M = Modulation
I = Laser amplitude
δ_0 = intrinsic operation point
U_π= Voltage to change M from 0 to 1

Results

Modulation of the laser pulse

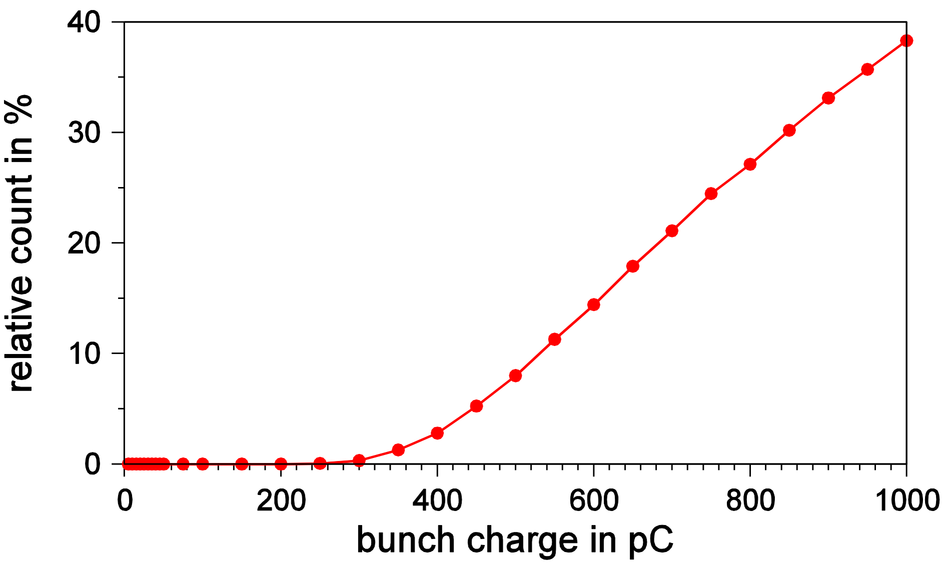


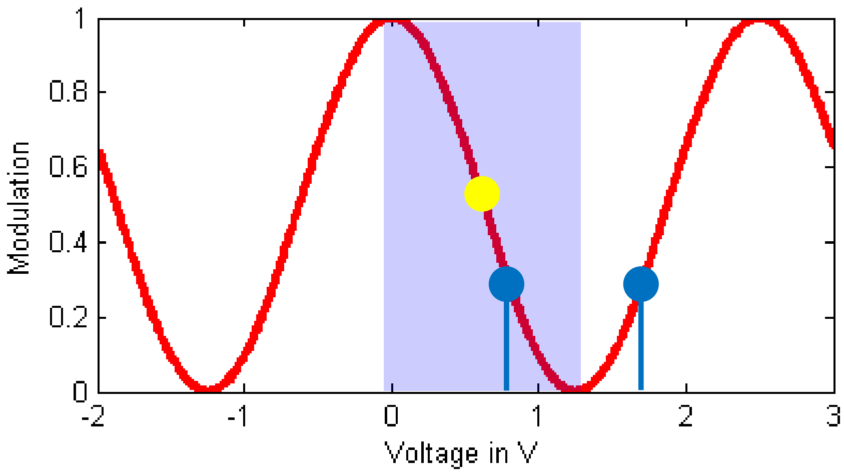
$$M = \frac{I_{out}}{I_{in}} = \frac{1}{2} + \frac{1}{2}\cos\left(\delta_0 + \frac{\pi}{U_\pi}U(t_m)\right)$$

M = Modulation
I = Laser amplitude
δ_0 = intrinsic operation point
U_π= Voltage to change M from 0 to 1

Results

Modulation of the laser pulse

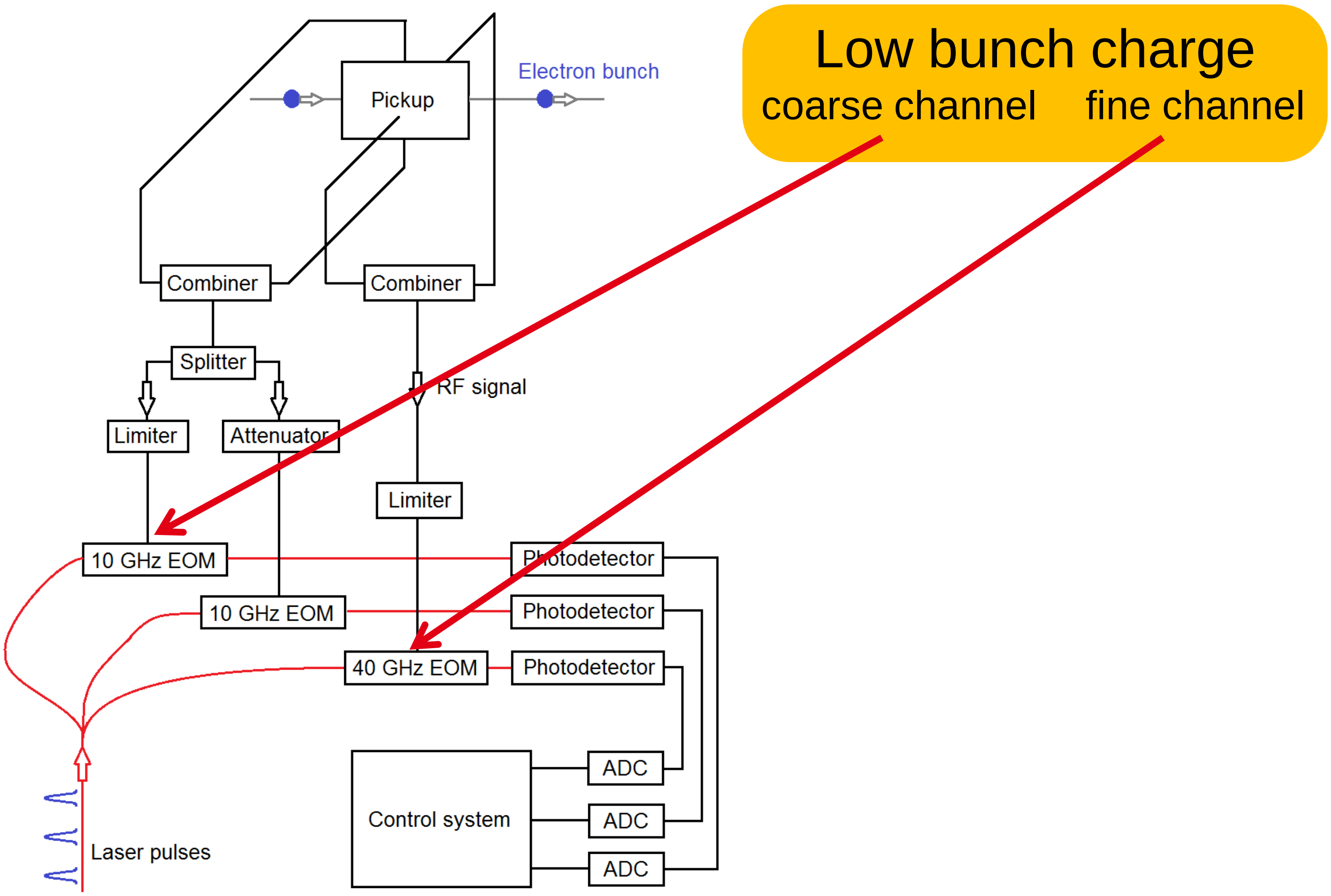




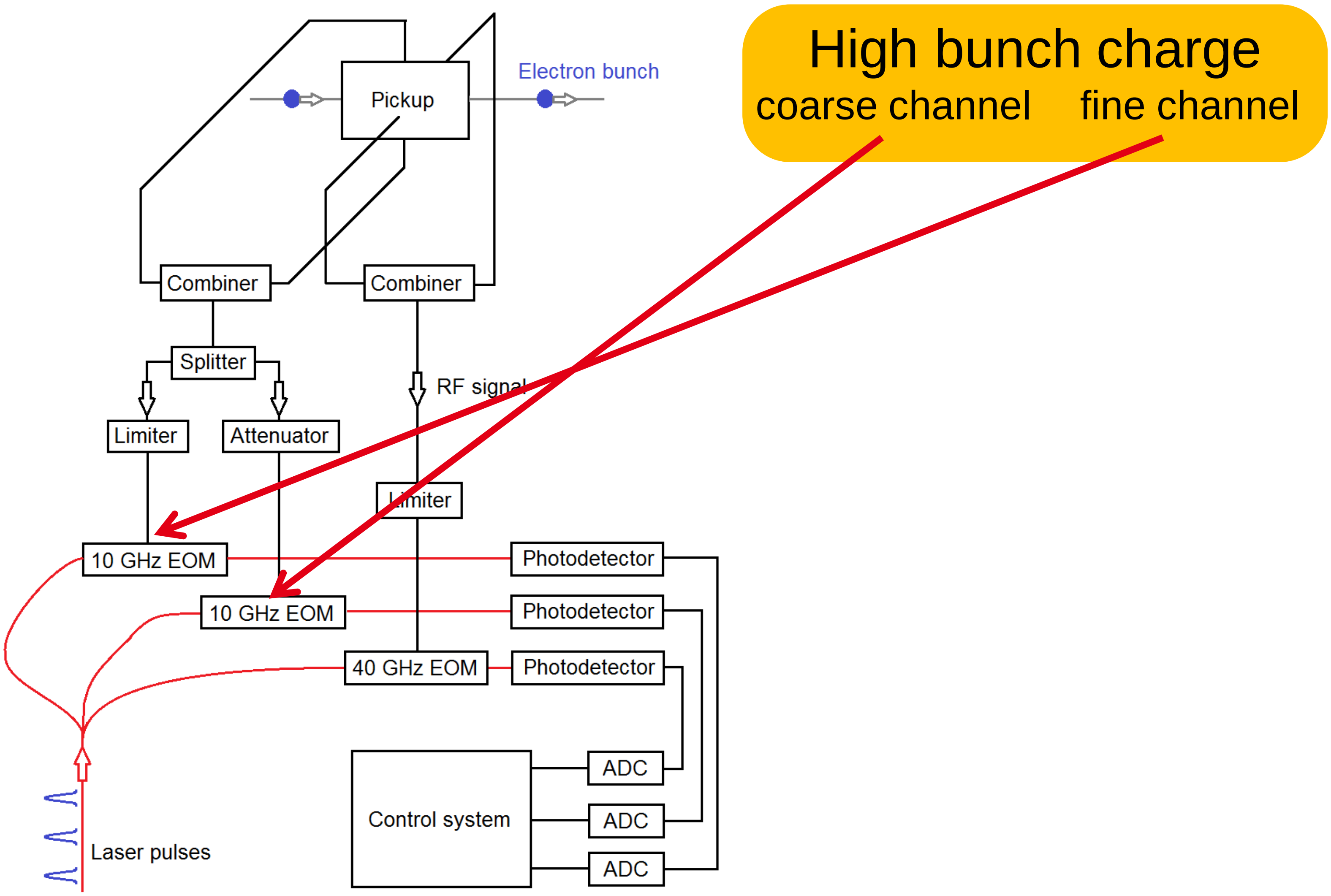
$$M = \frac{I_{out}}{I_{in}} = \frac{1}{2} + \frac{1}{2}\cos\left(\delta_0 + \frac{\pi}{U_\pi}U(t_m)\right)$$

M = Modulation
I = Laser amplitude
δ_0 = intrinsic operation point
U_π= Voltage to change M from 0 to 1

Results


Pickup
Electron bunch
Combiner
Combiner
Splitter
RF signal
Limiter
Attenuator
Limiter
10 GHz EOM
10 GHz EOM
40 GHz EOM
Photodetector
Photodetector
Photodetector
Control system
ADC
ADC
ADC
Laser pulses
Low bunch charge
coarse channel
fine channel

Results


High bunch charge
coarse channel
fine channel
Electron bunch
Pickup
Combiner
Combiner
Splitter
Limiter
Attenuator
RF signal
Limiter
10 GHz EOM
10 GHz EOM
40 GHz EOM
Photodetector
Photodetector
Photodetector
ADC
ADC
ADC
Control system
Laser pulses

Outlook

Work done

- Design a new pickup
- Manufacturing this new pickup
- Design new front end system
- Installation of the pickup in FLASH

Future work

- Manufacturing the new front end system
- Measurements with beam
- Integration in the control system

- Upgrade the other 4 BAM-systems

Alexander Kuhl
Alexander.kuhl@desy.de

END

Aleksandar Angelovski
Marie Kristin Bock
Michael Bousonville
Patrick Gessler
Rolf Jakoby
Wolfgang F.O. Müller
Andreas Penirschke
Juliane Rönsch-Schulenburg
Jörg Roßbach
Holger Schlarb
Sascha M. Schnepp
Silke Vilcins-Czvitkovits
Thomas Weiland

END

TECHNISCHE UNIVERSITÄT DARMSTADT

Microwaves & Optics
Hans Busch Institut

Institut für Theorie Elektromagnetischer Felder
Computational Electromagnetics Laboratory

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

DESY

Aleksandar Angelovski
Marie Kristin Czwalinna
Michael Bousonville
Patrick Gessler
Rolf Jakoby
Wolfgang F.O. Müller
Andreas Penirschke
Juliane Rönsch-Schulenburg
Jörg Roßbach
Holger Schlarb
Sascha M. Schnepp
Silke Vilcins-Czvitkovits
Thomas Weiland