Bunch Arrival Time Monitor

—with electro-optical detection scheme

Jinguo Wang

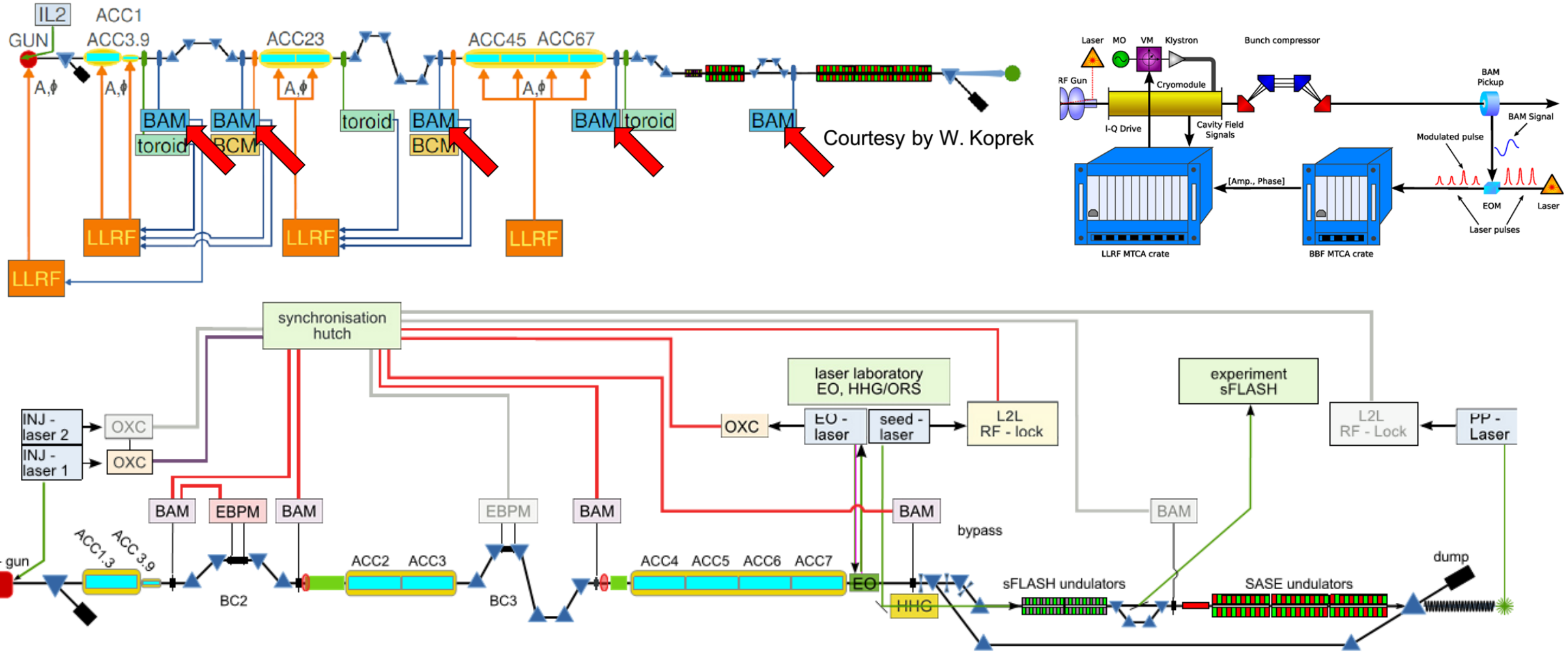
Shanghai Institute of Applied Physics, CAS

SINAP 中国科学院上海应用物理研究所 Shanghai Institute of Applied Physics, Chinese Academy of Sciences

Overview

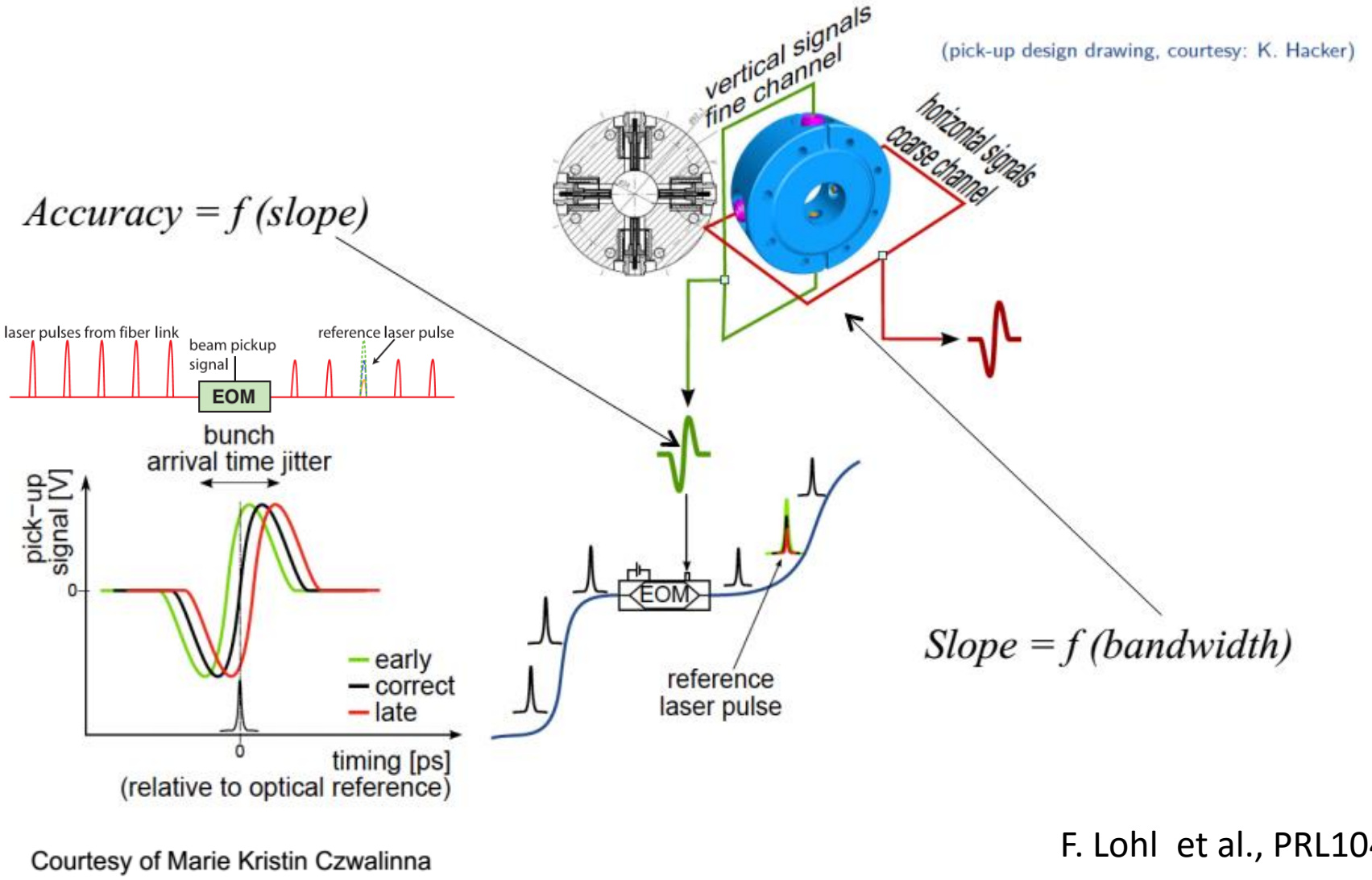
- **Introduction**
- **Arrival-time measurement techniques**
- **Old and new Pickup**
- **Opto-Mechanical Front End**
- **BAM Back End**
- **Prototype MTCA BAM Readout Devices**

Introduction



Schematic of the laser-based synchronisation system at the upgraded FLASH accelerator facility.（2011）

Measurement Principle



Courtesy of Marie Kristin Czwalinna

F. Lohl et al., PRL104,144801 (2010)

Slope and equivalent frequency

$$U(t) = A \cdot \sin(2\pi f_e \cdot t)$$

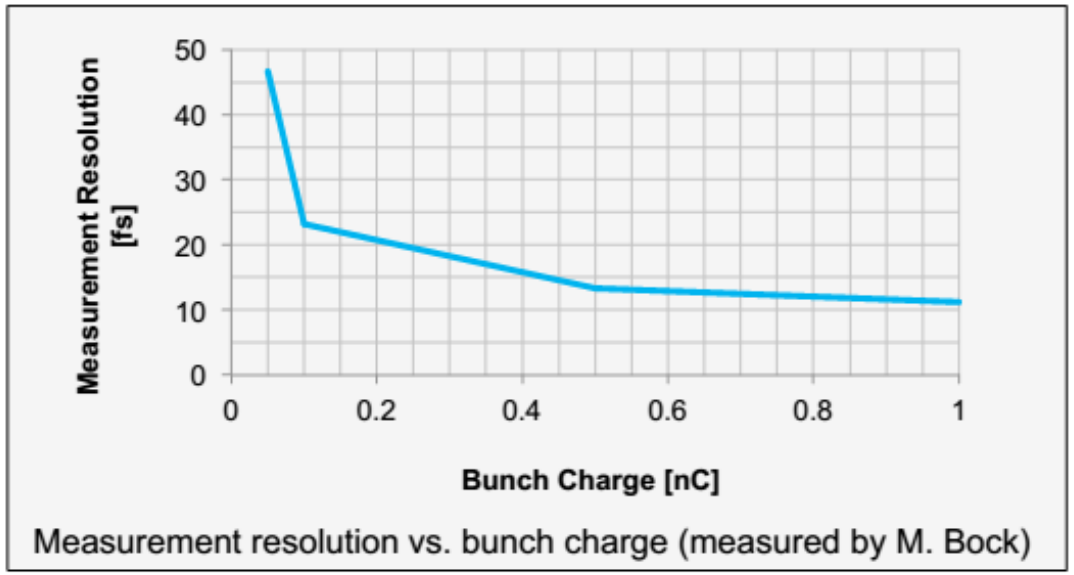
$$S = \pm A \cdot 2\pi f_e \quad \text{with S as Slope}$$

$$\Rightarrow f_e = \frac{|S|}{\pi \cdot U_{\text{peak to peak}}} \quad \text{with} \quad U_{\text{peak to peak}} = 2 \cdot A$$

Measurement Resolution

measurement resolution = f (slope of pickup signal)

slope = f (bunch charge)



Measurement resolution vs. bunch charge (measured by M. Bock)

slope = f (bandwidth of pickup)

bandwidth ↑
bunch charge ↑
=> *measurement resolution* ↑

SXFEL Bunch Charge = 500pC

Higher bandwidth improves measurement resolution specially for low charged bunches

Parameters to improve

Slope ↑

Ringing ↓

There are several factors which influence the ringing.

- Resonances of the pickup itself
- cross talk between the pickups
- interactions between the beam with the surrounding environment

Boundary Condition: Keep peak voltage at 1.5 V

Bandwidth ↑ => Slope ↑ => Measurement Resolution ↑

Reflections in pickup ↓ => Ringing ↓

BAM-Pickup – Design

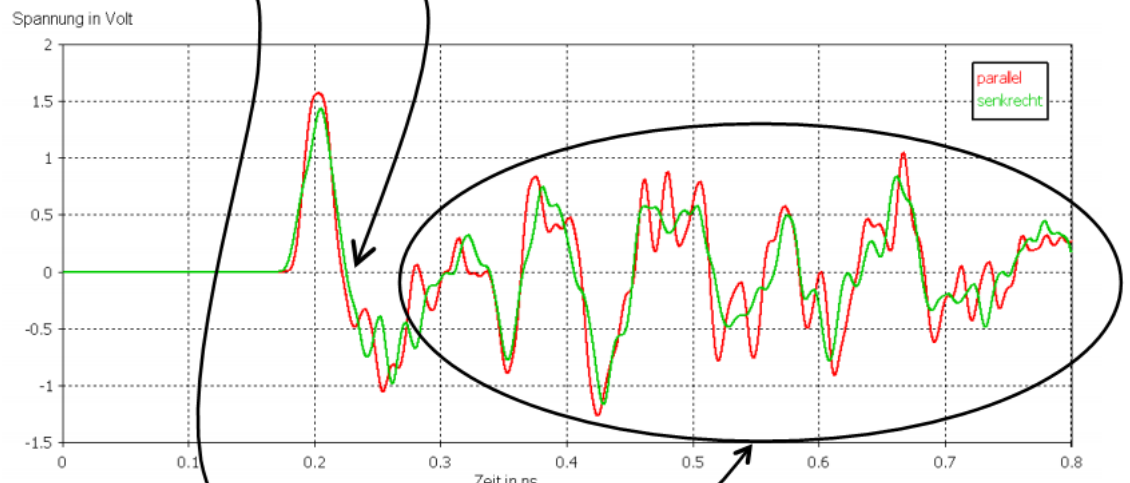
Old Design
Status 2010

Signal of a Single BAM-Feedthrough (simulation)

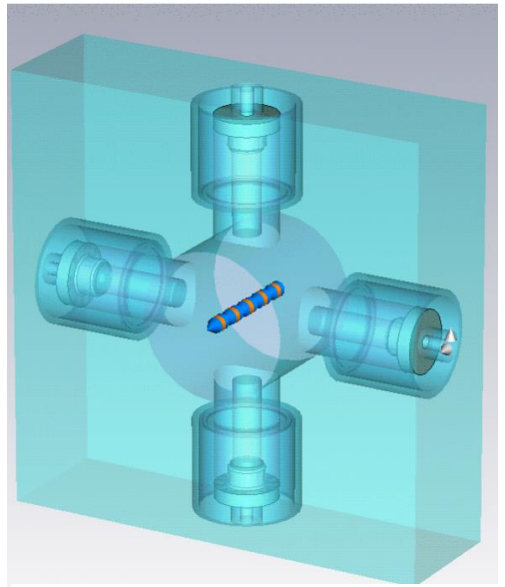
- Standard Bunch:

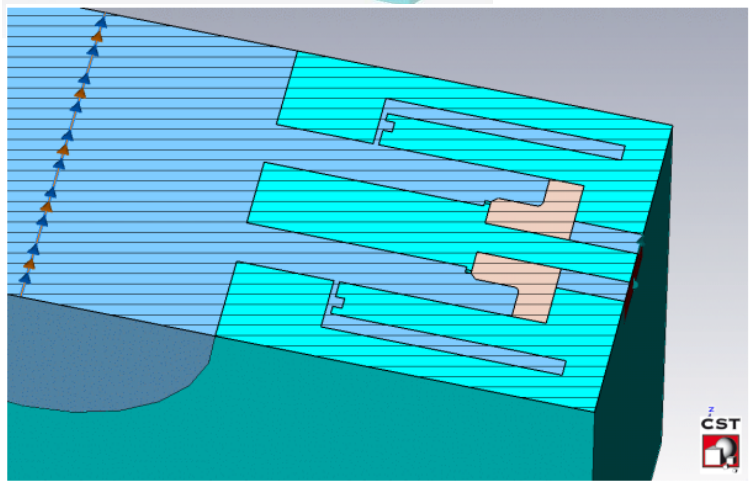
  Charge = 20 pC
  Length = 2.35 mm
  Gaussian shaped

- Slope = 71 mV/ps
- Ringing = 62 %



Alexander Kuhl, TU Darmstadt.



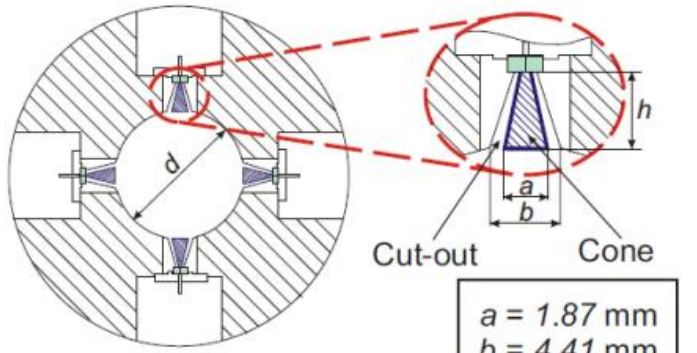


Alexander Kuhl, TU Darmstadt.

BAM-Pickup – Design

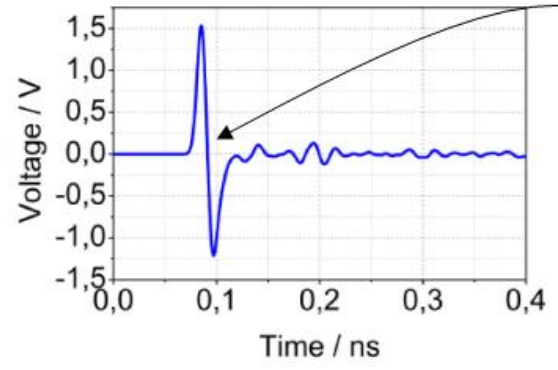
New Design
Status 2011

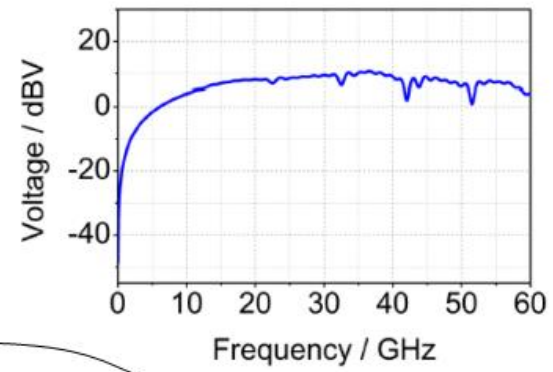
Cone-shaped pickup system
CST optimization of the pickup



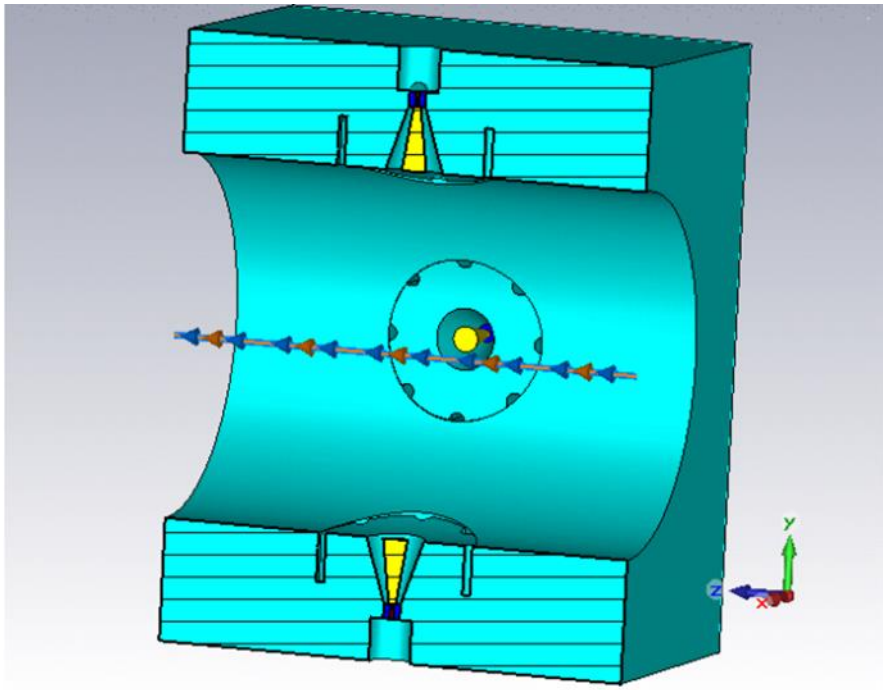
$a = 1.87$ mm
$b = 4.41$ mm
$d = 42.0$ mm
$h = 4.10$ mm

Slope = 382 mV/ps





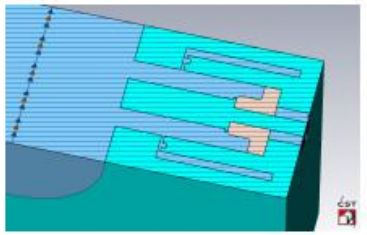
Angelovski et al., TU Darmstadt, IPAC 2011

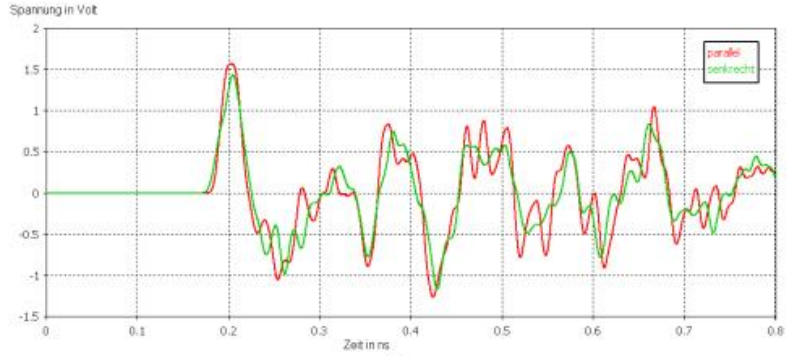


Comparison

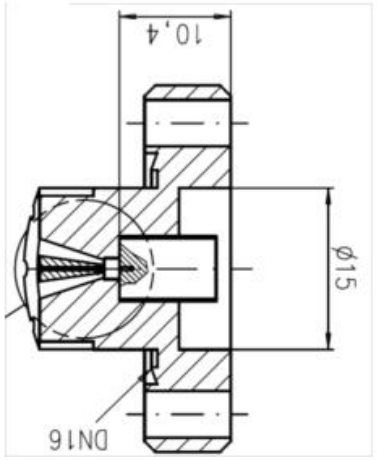
Improvement of performance (simulated)

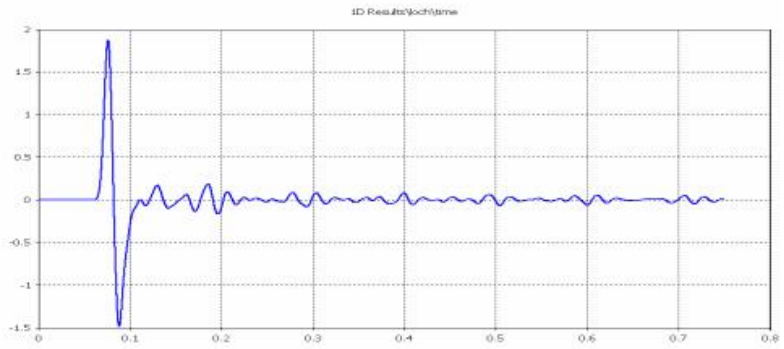
old





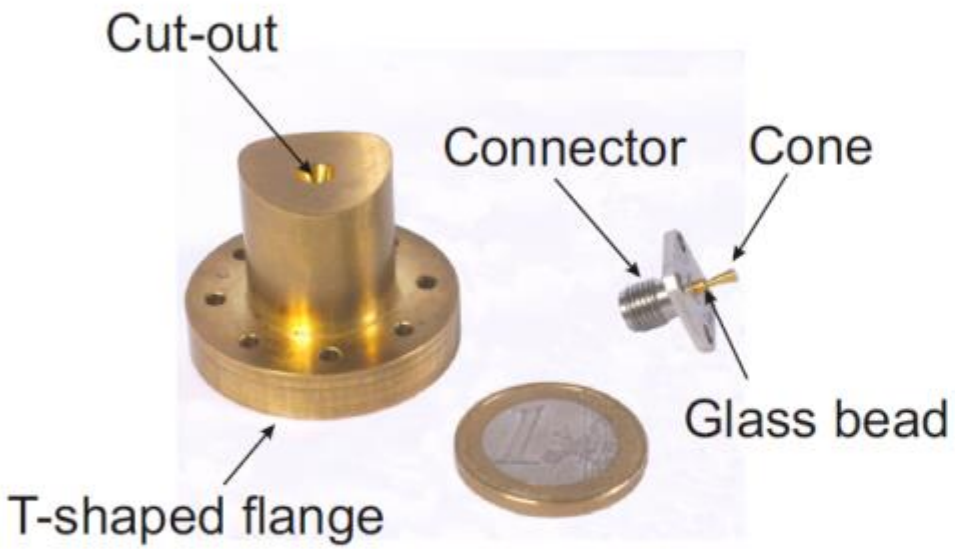
new

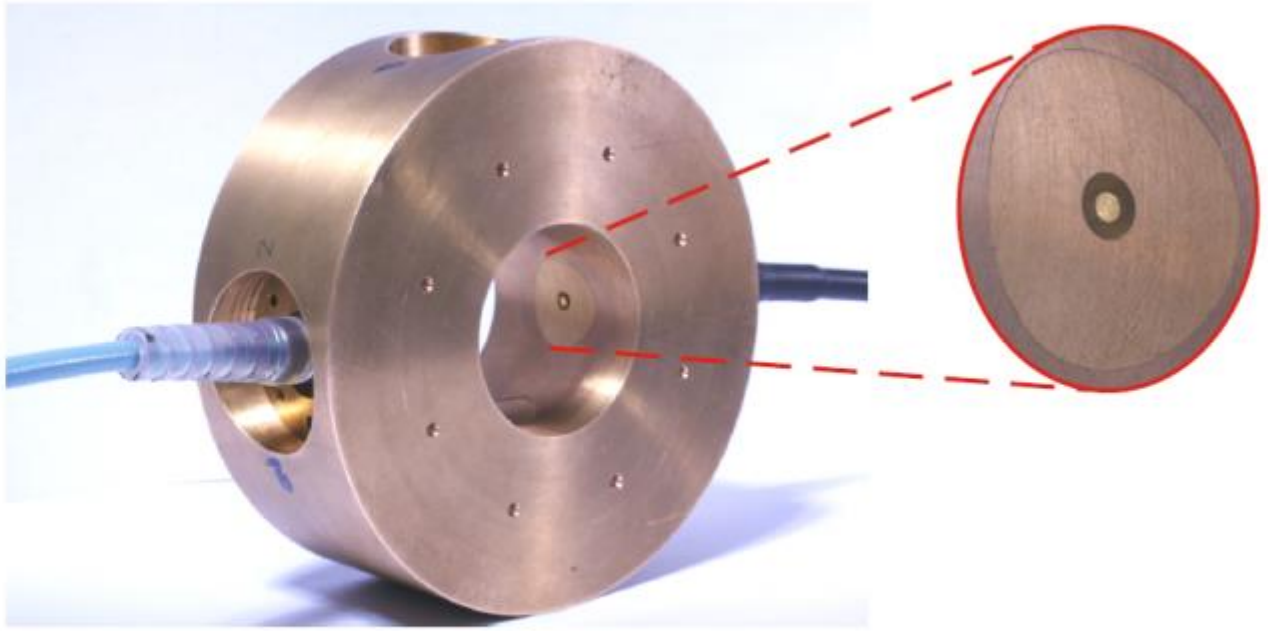




New Design – 40 GHz BAM Pickup

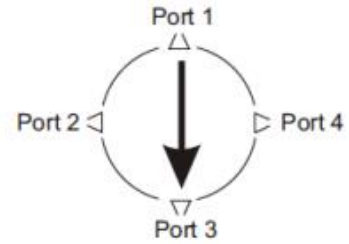
No vacuum suitable Prototype

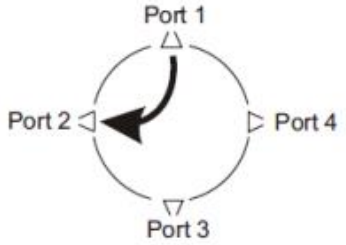


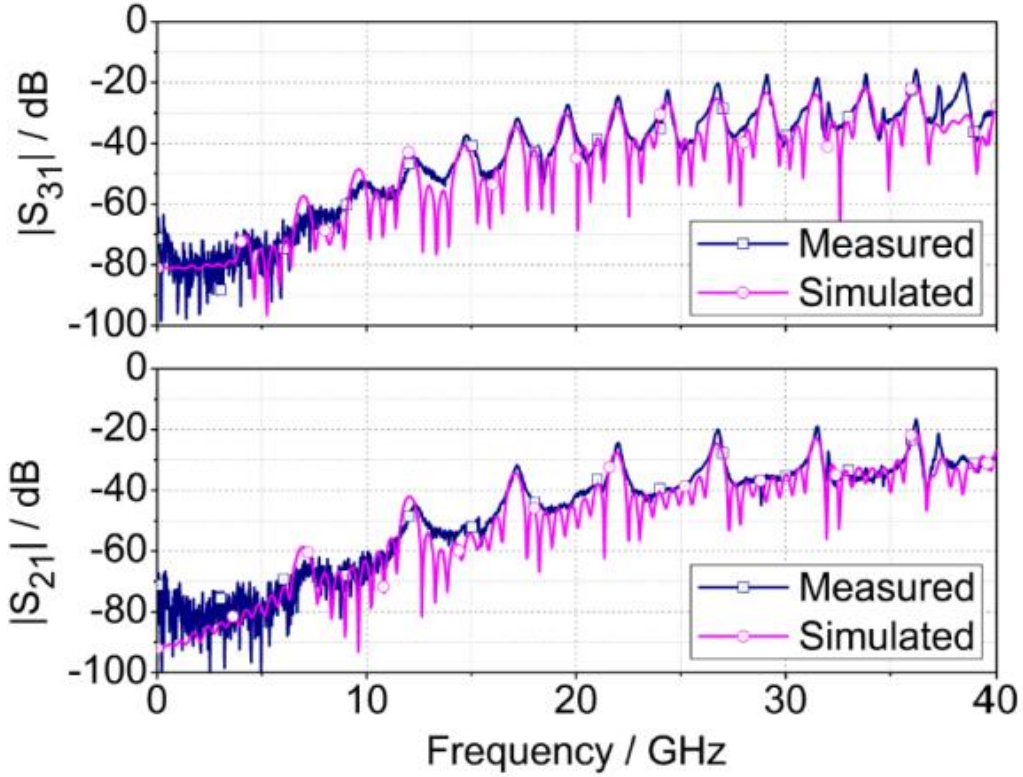


Angelovski et al., TU Darmstadt, IPAC 2011

Verification of simulations with s-parameter measurement



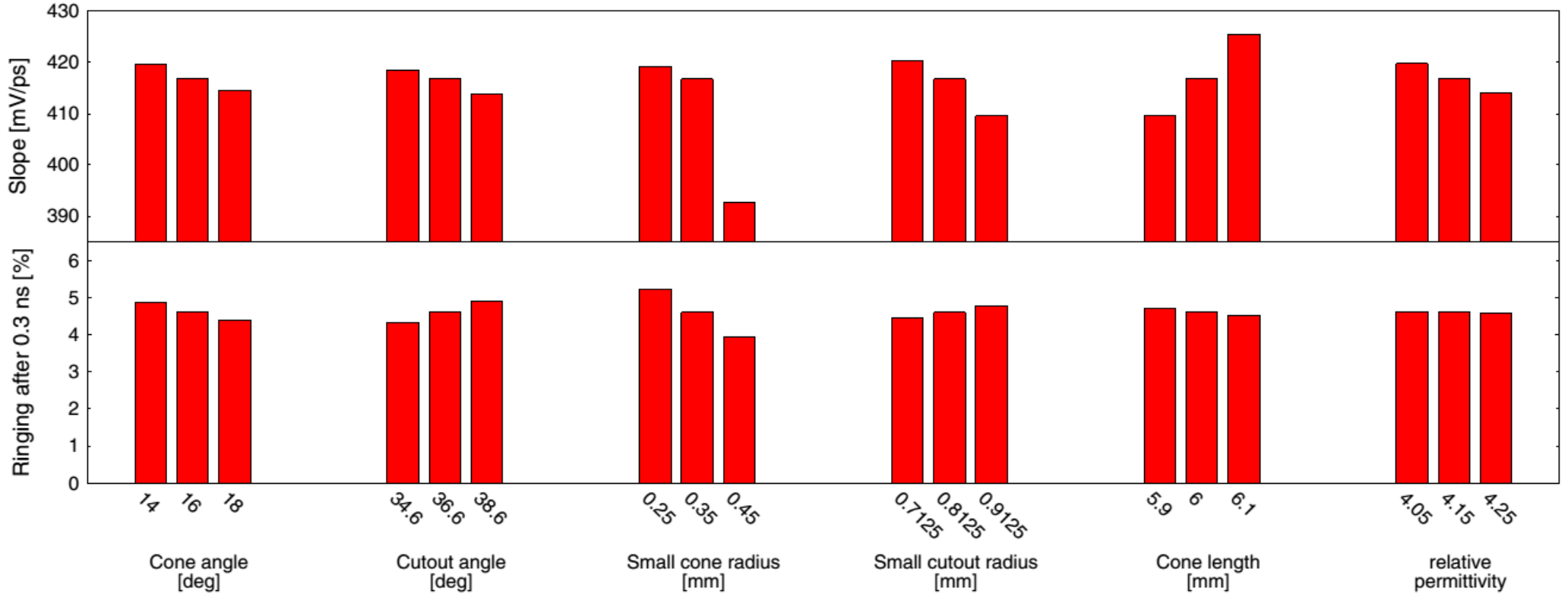




Angelovski et al., TU Darmstadt, IPAC 2011

Measured values of the prototype correspond to the simulated.

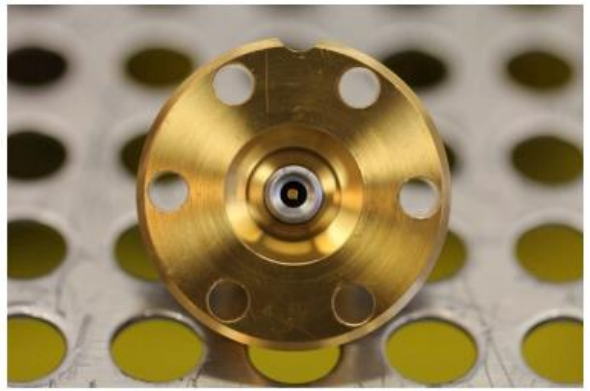
Influence of geometric variations

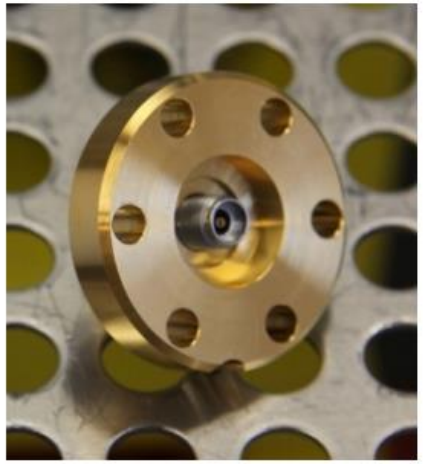


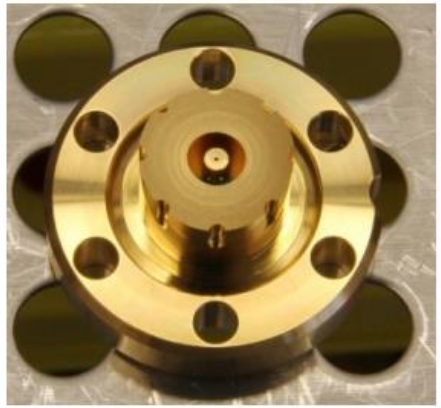
Aleksandar Angelovski et al., 15, 112803 (2012)

Manufacturing of the Pickup

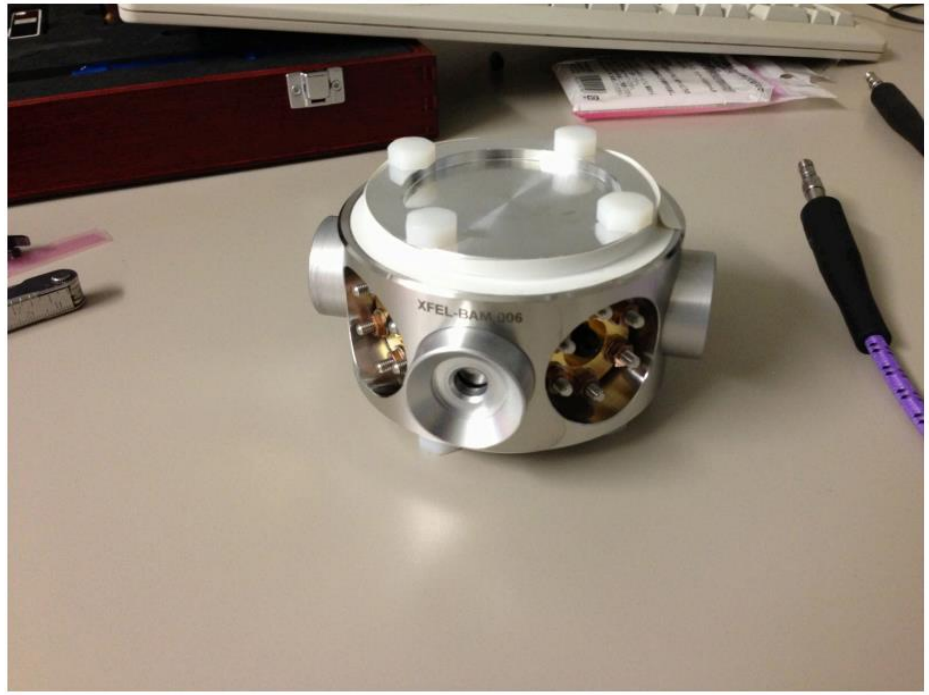
Orient Microwave delivered feedthrough







Courtesy of Jürgen Kruse

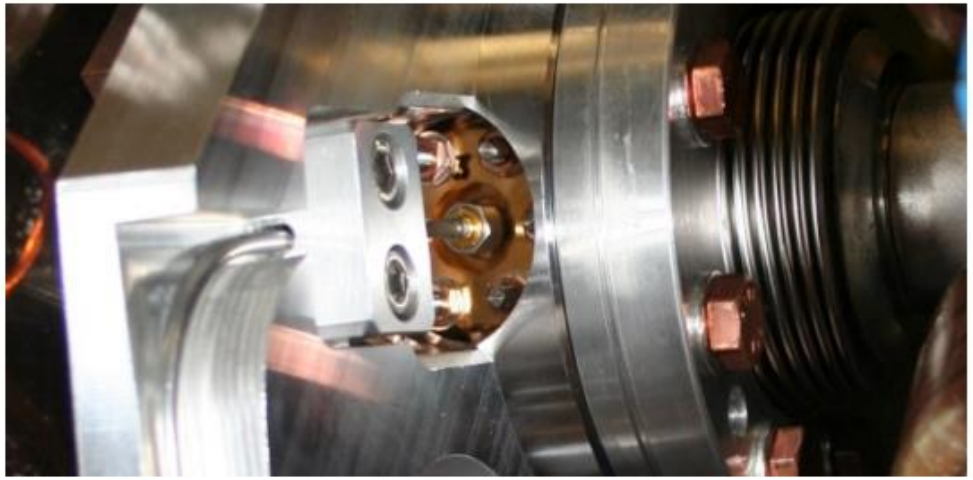


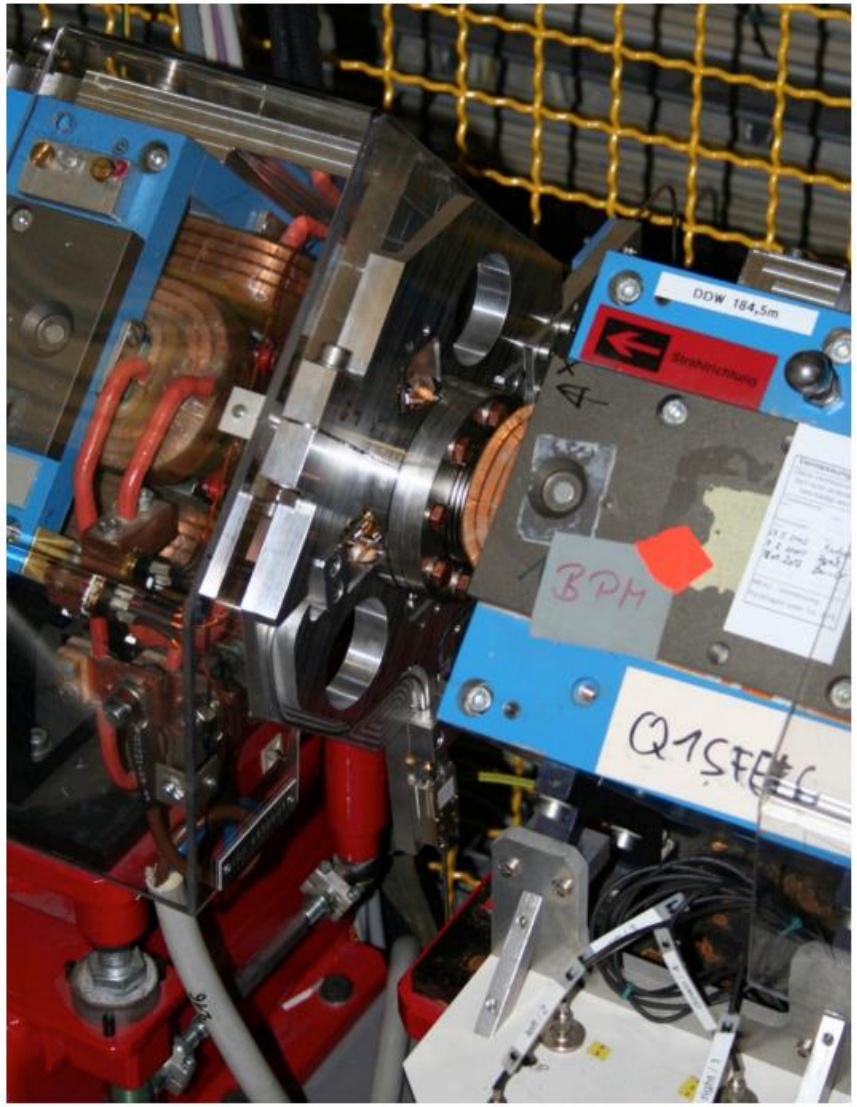
Installation– Details

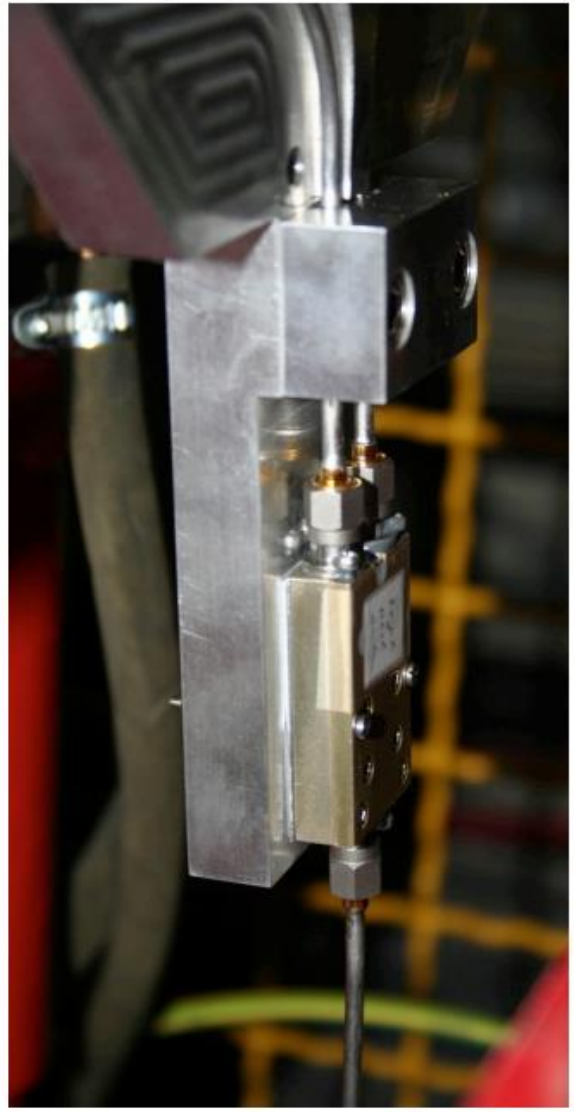
FLASH

SFELC

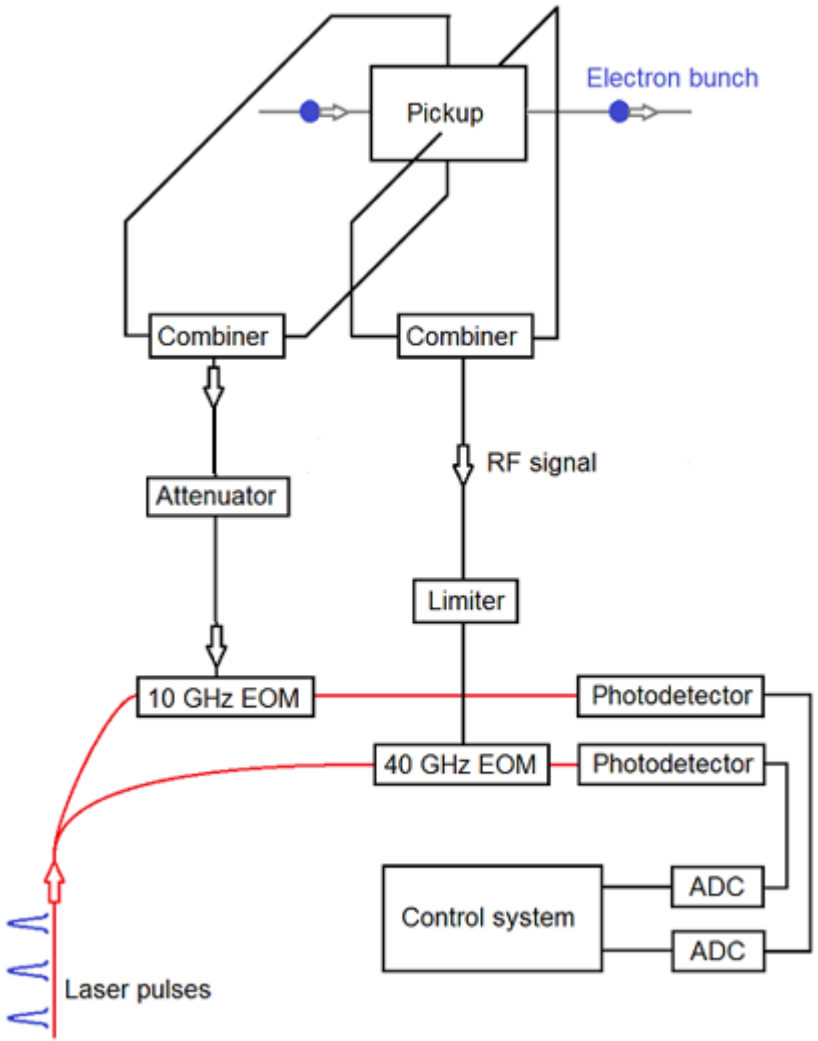
Position 185 m







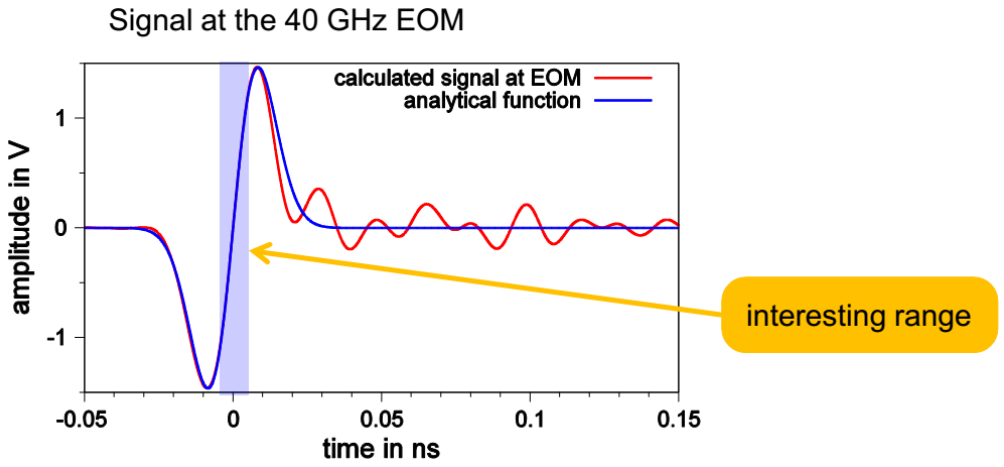
RF calculation



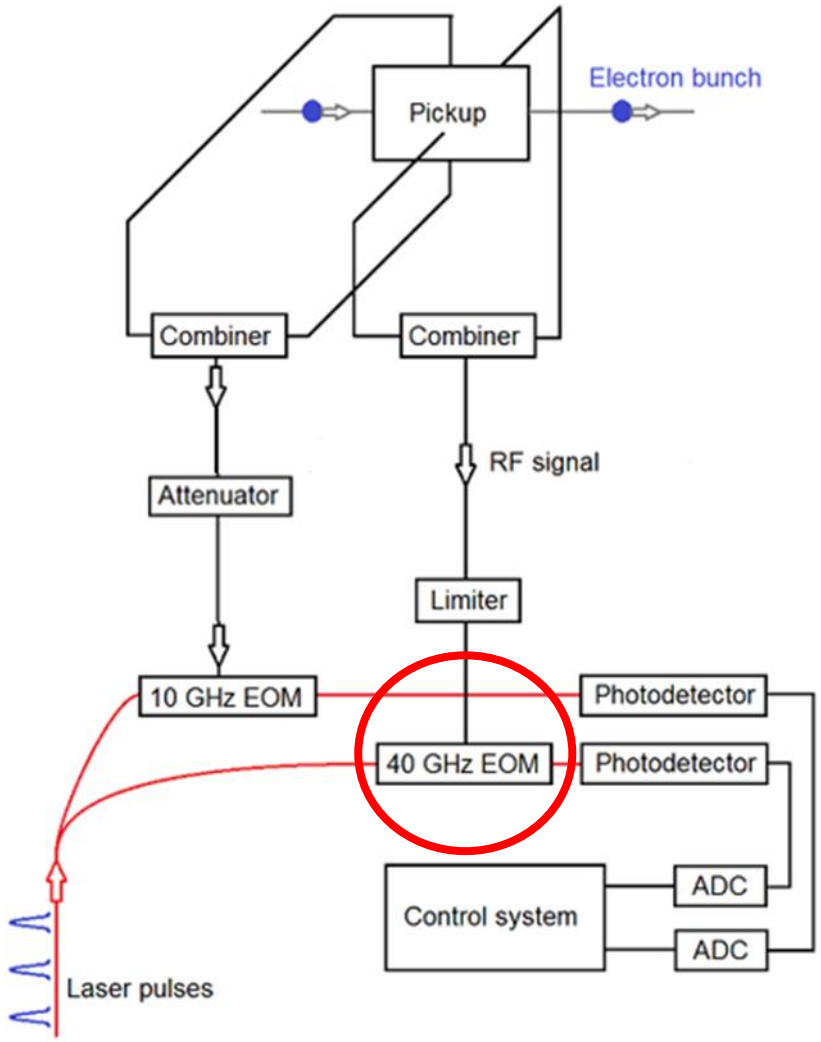
Signal extrapolated by using S-parameters
- Cable
- Combiner

IBIC 2012 - MOPA46
A. Angelovski et. al.

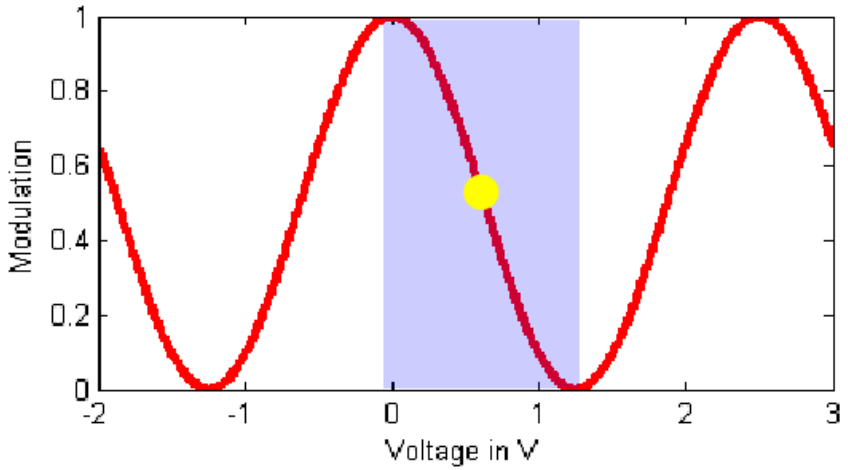
IBIC 2012 - MOPA43
A. Penirschke et. al.



Electro Optical Modulator (EOM)



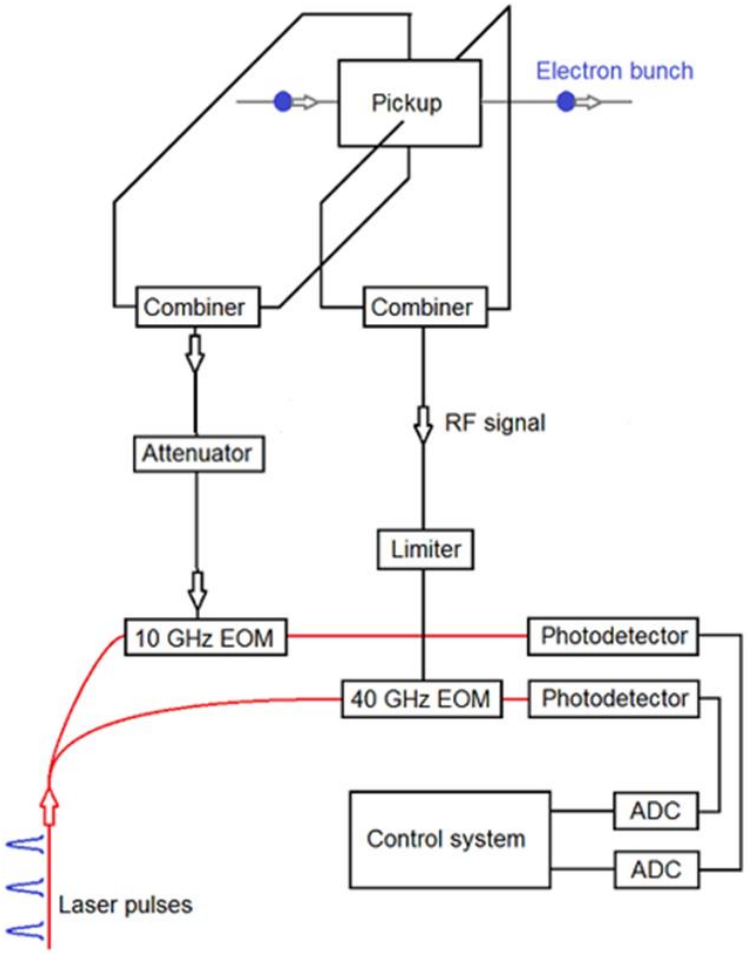
Modulation of the laser pulse



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

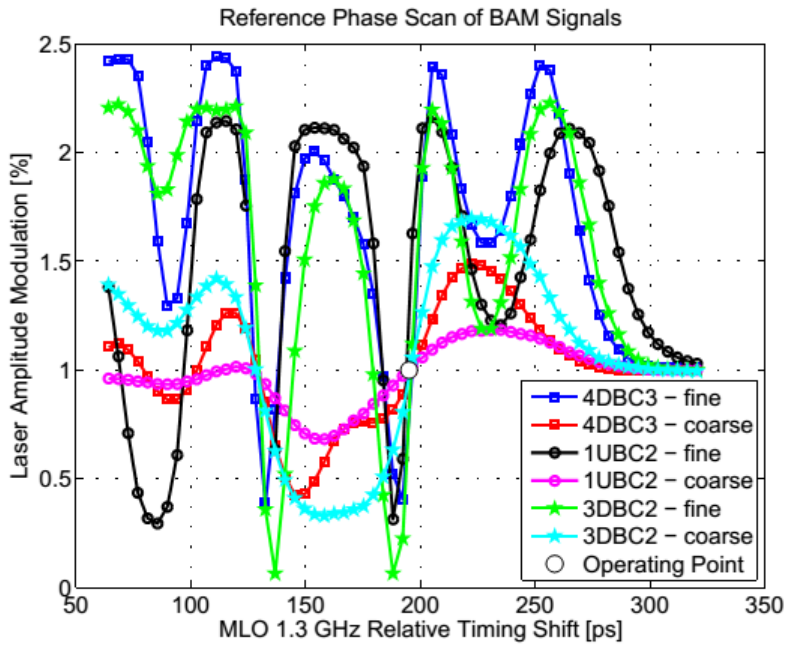
M = Modulation
I = Laser amplitude
δ_0 = intrinsic operation point
U_π = Voltage to change M from 0 to 1

Different Jitter Sources



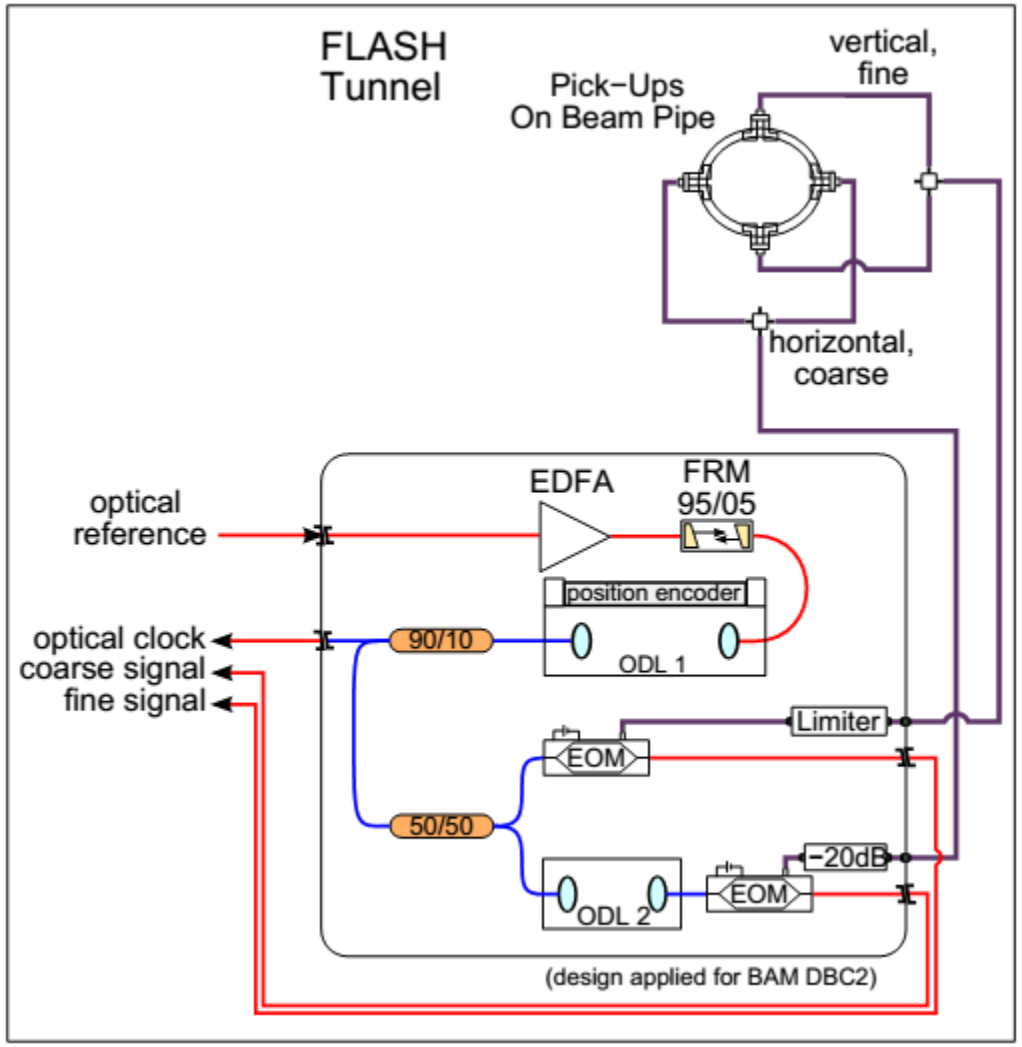
Influence of different jitter sources on the arrival time measurement

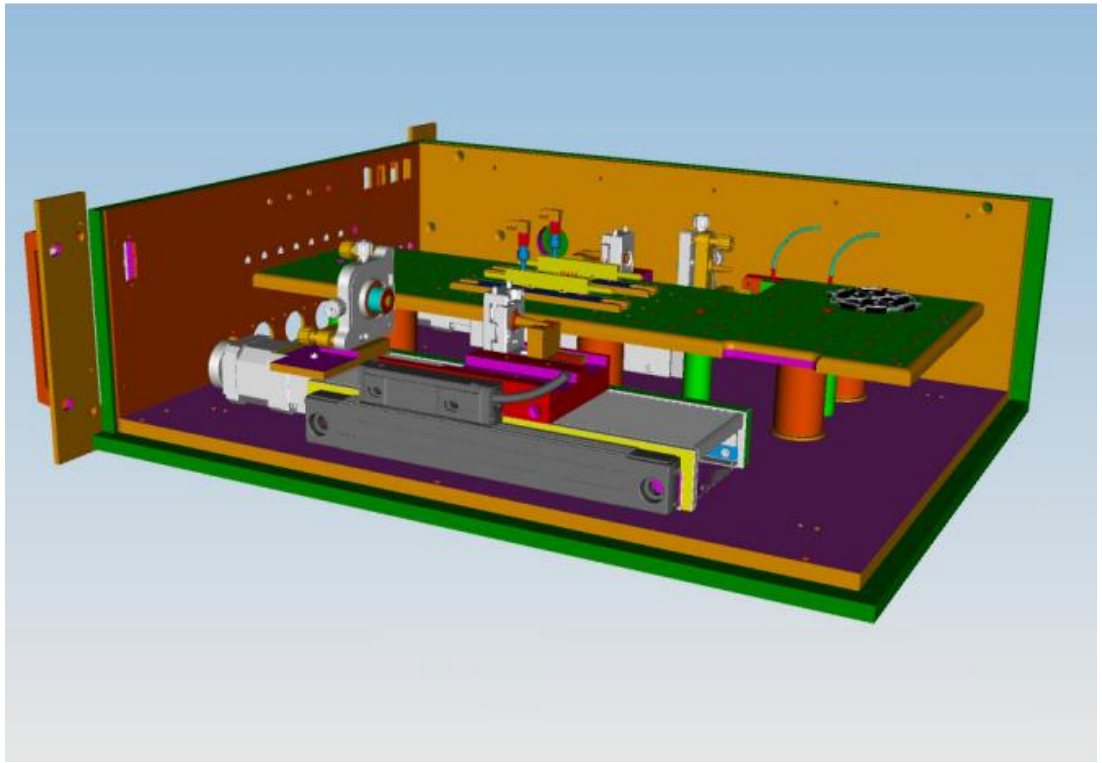
Parameter	Assumed RMS values
Bunch charge	1 %
Bias voltage	0.5 mV
RF voltage	0.5 mV
Laser amplitude	0.35 %
Laser timing	2.5 fs
ADC channel (16bit)	20



M. K. Bock et al.,WEOCMH02, IPAC'10

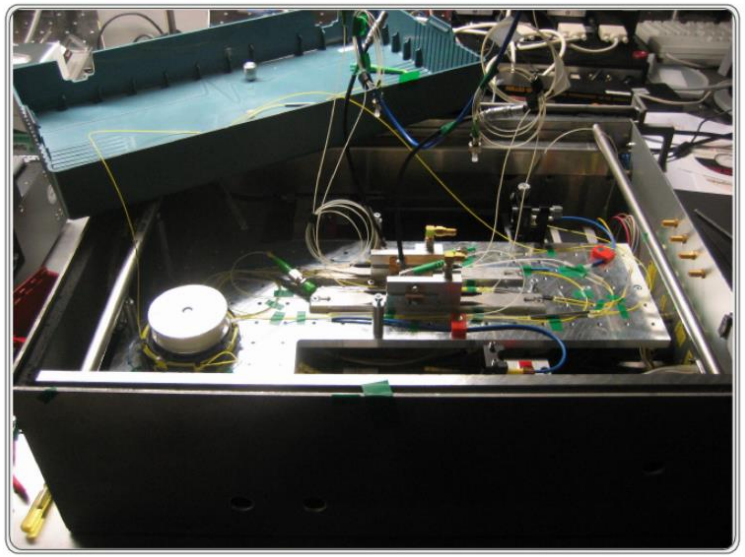
Opto-Mechanical Front-End

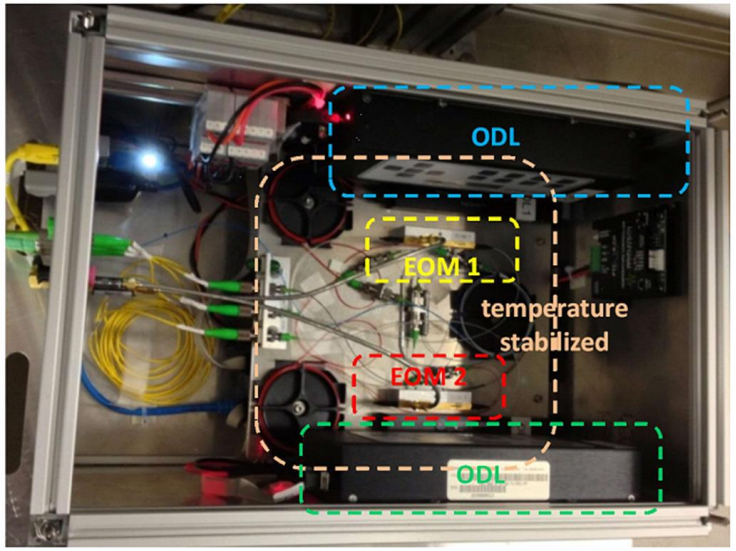




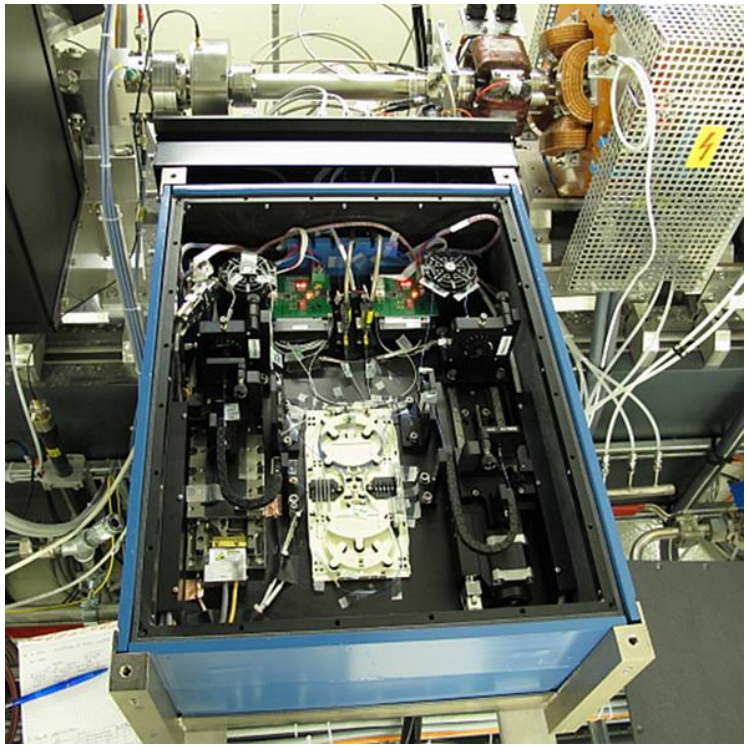
Schematic of the Opto-Mechanical Front-End and chassis

BAM front-end prototype

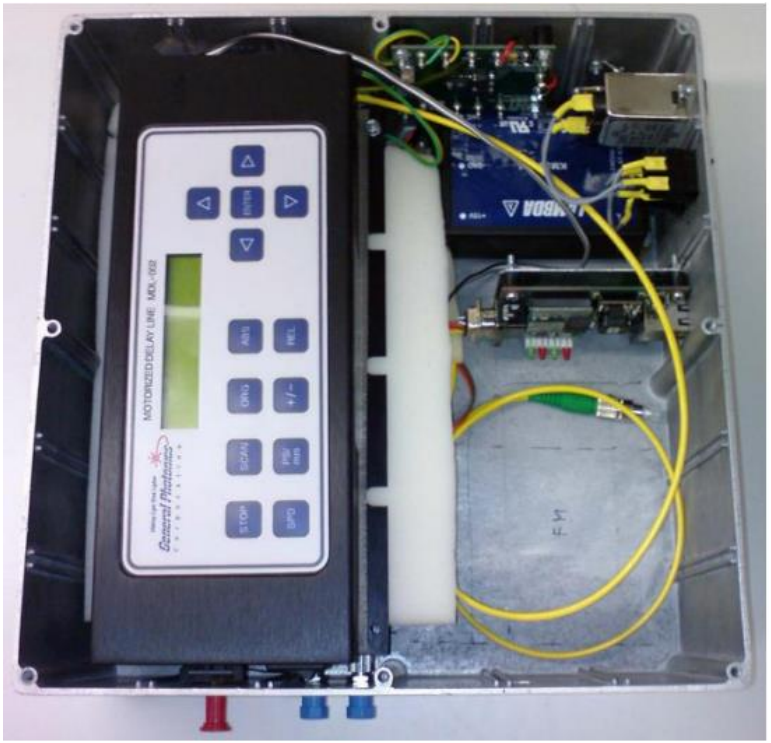




FLASH@DESY



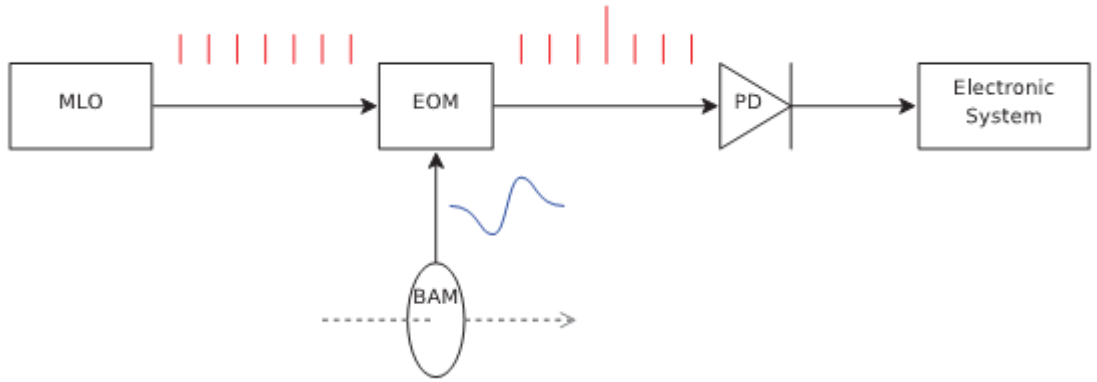
SwissFEL@Paul Scherrer Institute

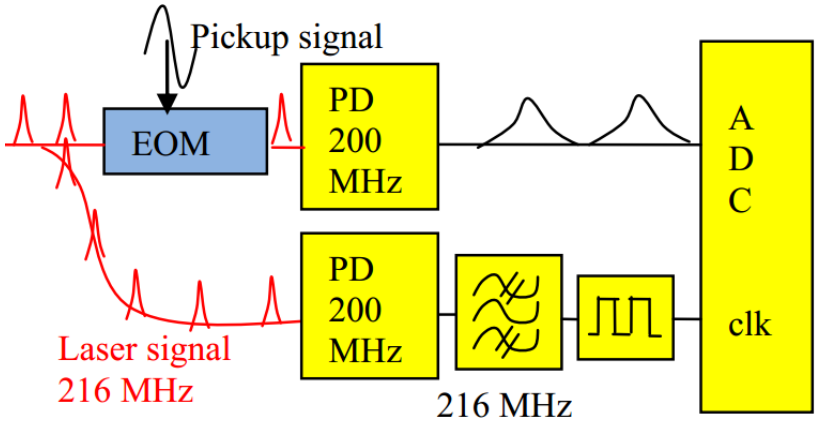


FERMI@Elettra

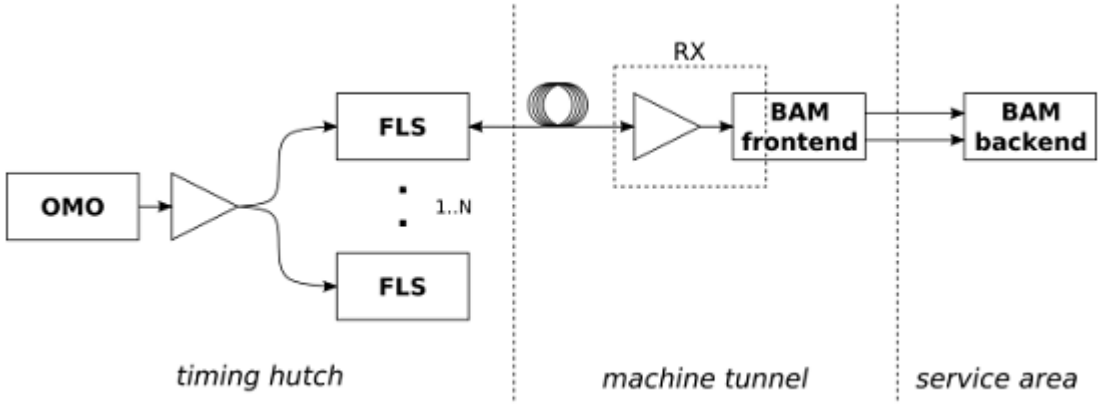
BAM Back End

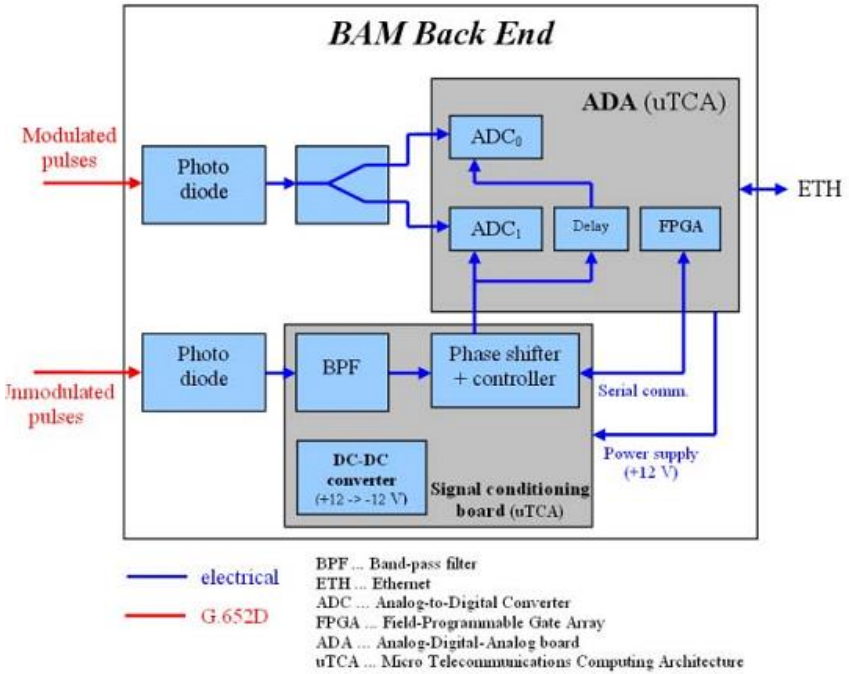
The general concept of the laser pulses modulation





Optical distribution used for the BAM

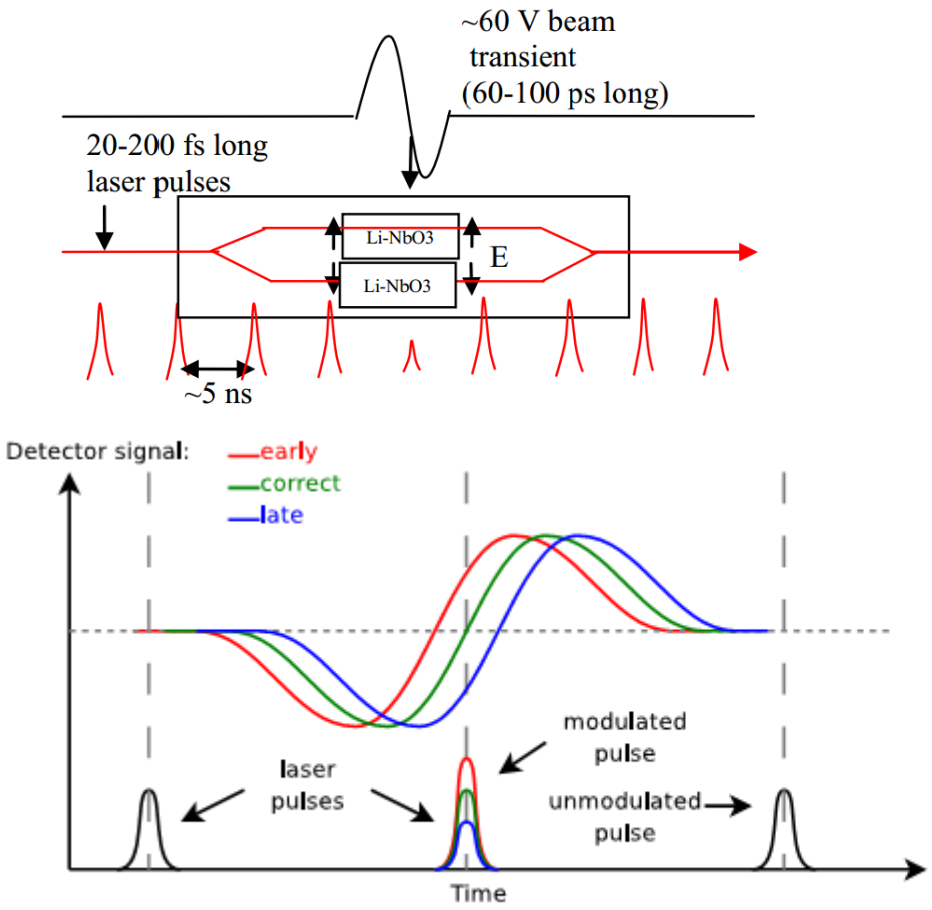


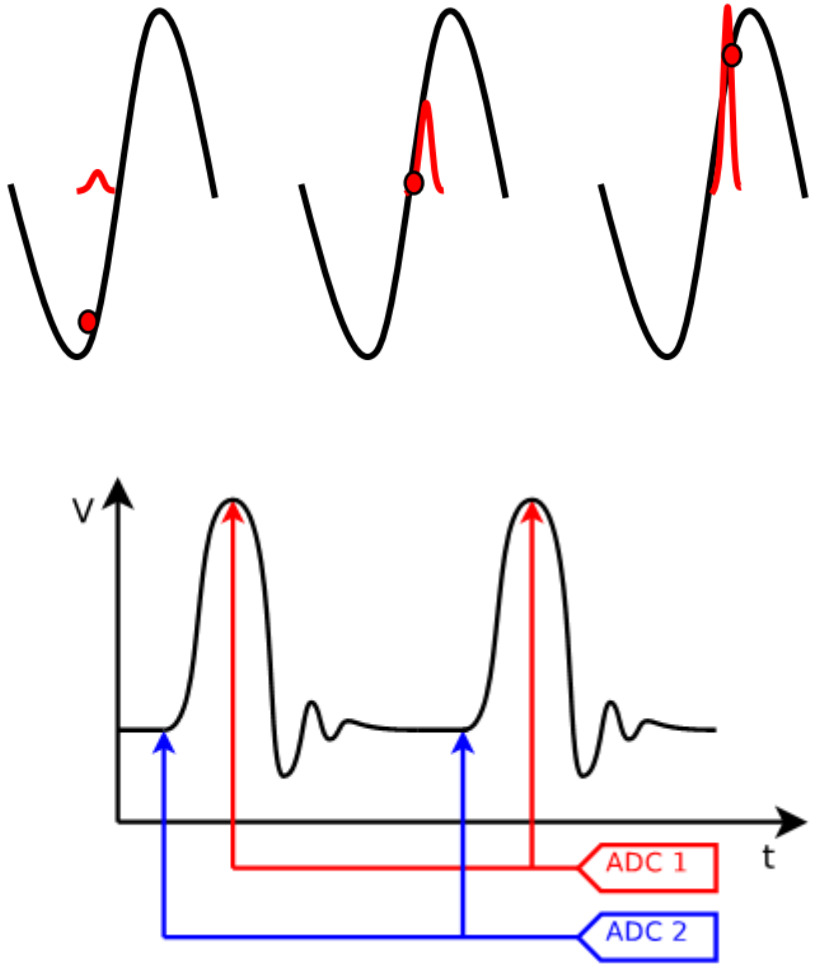


L.Pavlovic et al., BUNCH ARRIVAL MONITOR AT FERMI@ELETTRA, JACoW

Peak and baseline sampling

60ps/200fs=300(min);100ps/20ps=500(max);
5ns/100ps=50(min);5ns/60ps=83.3(max)



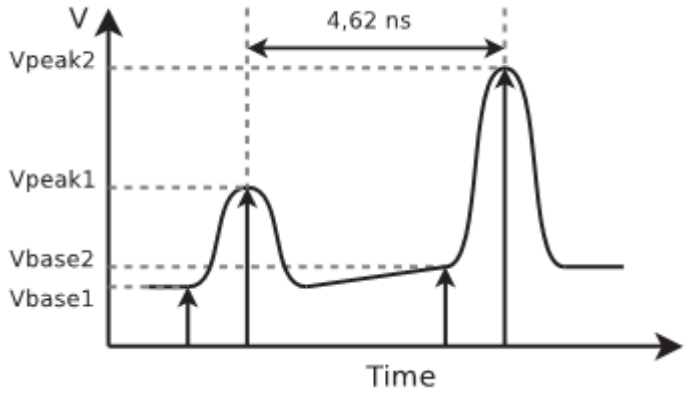


Modulation of the laser pulses by the signal from the BAM detector

Peak and baseline sampling principle with two ADCs with shifted clock phase

Amplitude correction

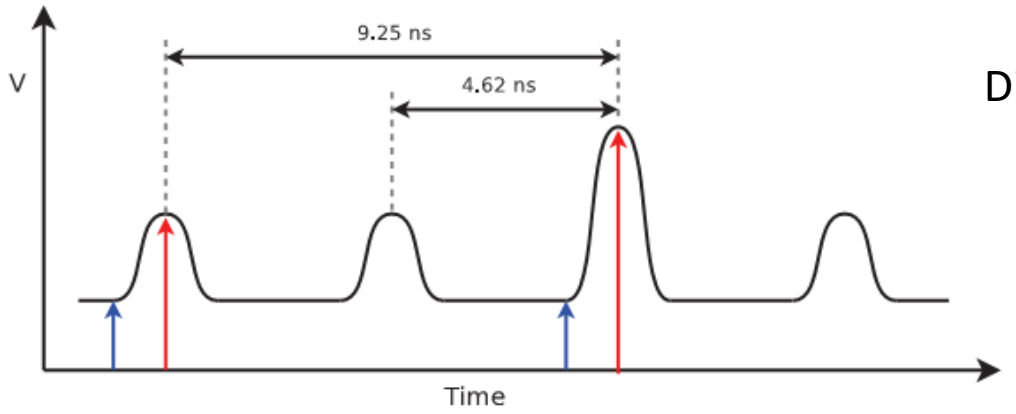
- The absolute height of the modulated pulse is not accurate enough, because of the drifts of the signal.
- Better results gives the relative height of the pulse.



$$A_{corr} = \frac{V_{peak2} - V_{base2}}{V_{peak1} - V_{base1}}$$

This method of amplitude correction gives the proper amplitude correction, proportional to the arrival time of the electron bunch

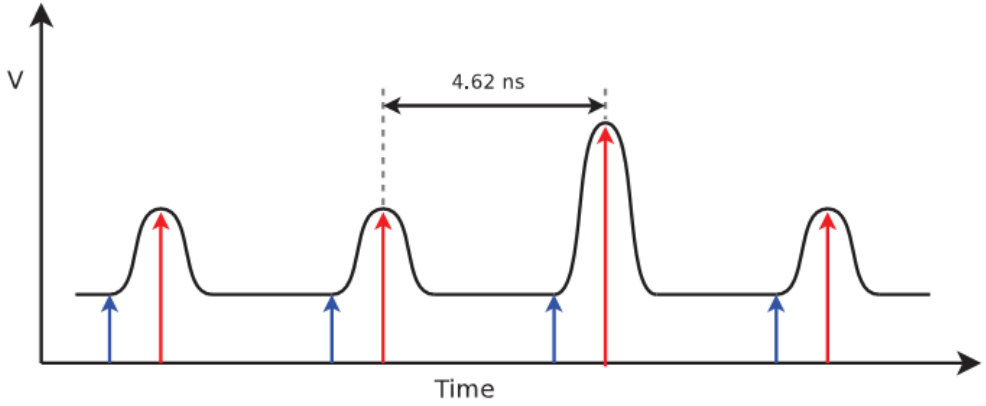
Improvement in the new uTCA system



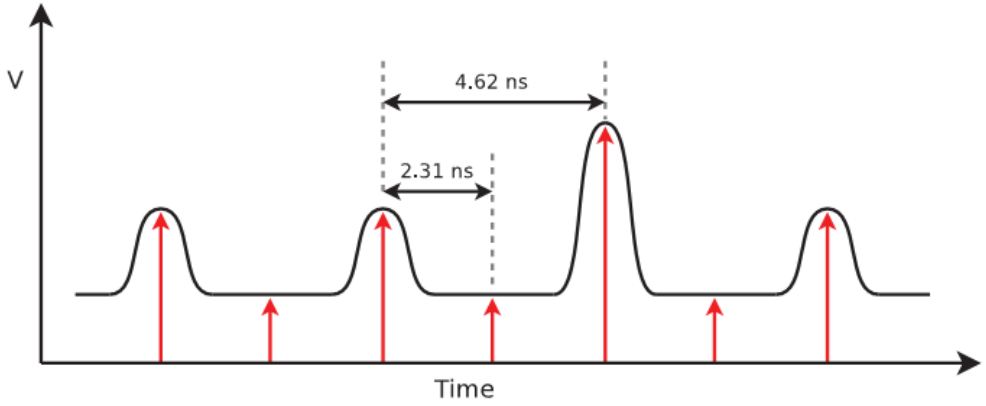
Sampling with 108 MHz and 2 ADCs

Disadvantage and Problem

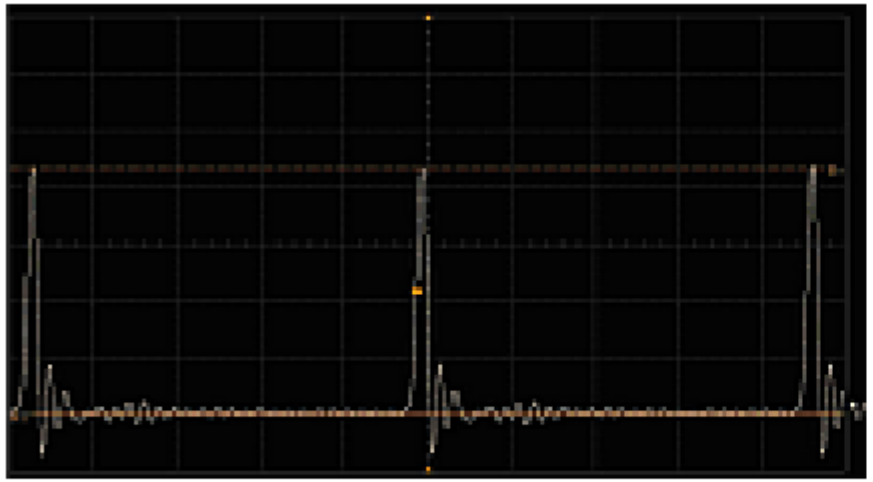
- **This method was that incorrect synchronization caused sampling wrong samples, that the modulated samples has not been seen.**
- **This kind of splitting may decrease the signal quality use two ADC.**



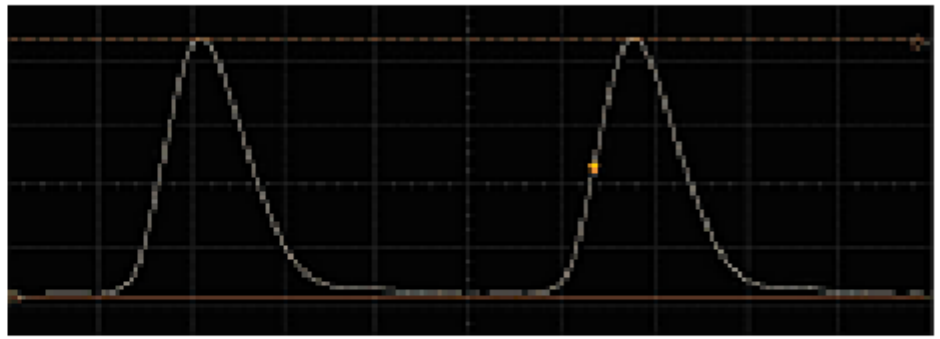
Sampling with 216 MHz and 2 ADCs



Sampling with 432 MHz and 1 ADC



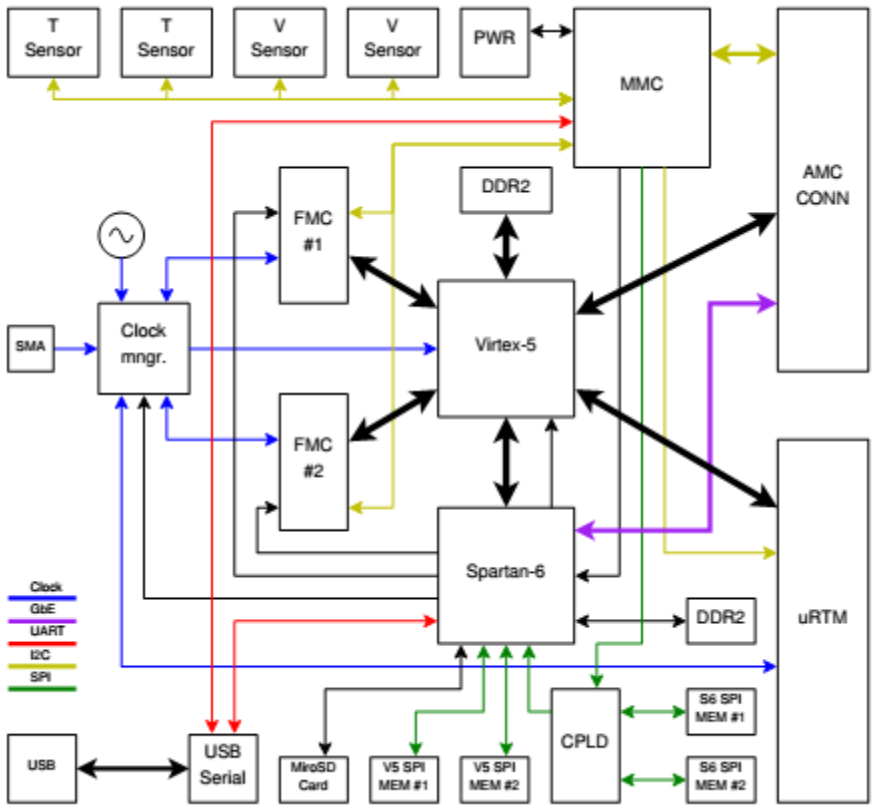
Raw photodiode signals at the BAM PRX input



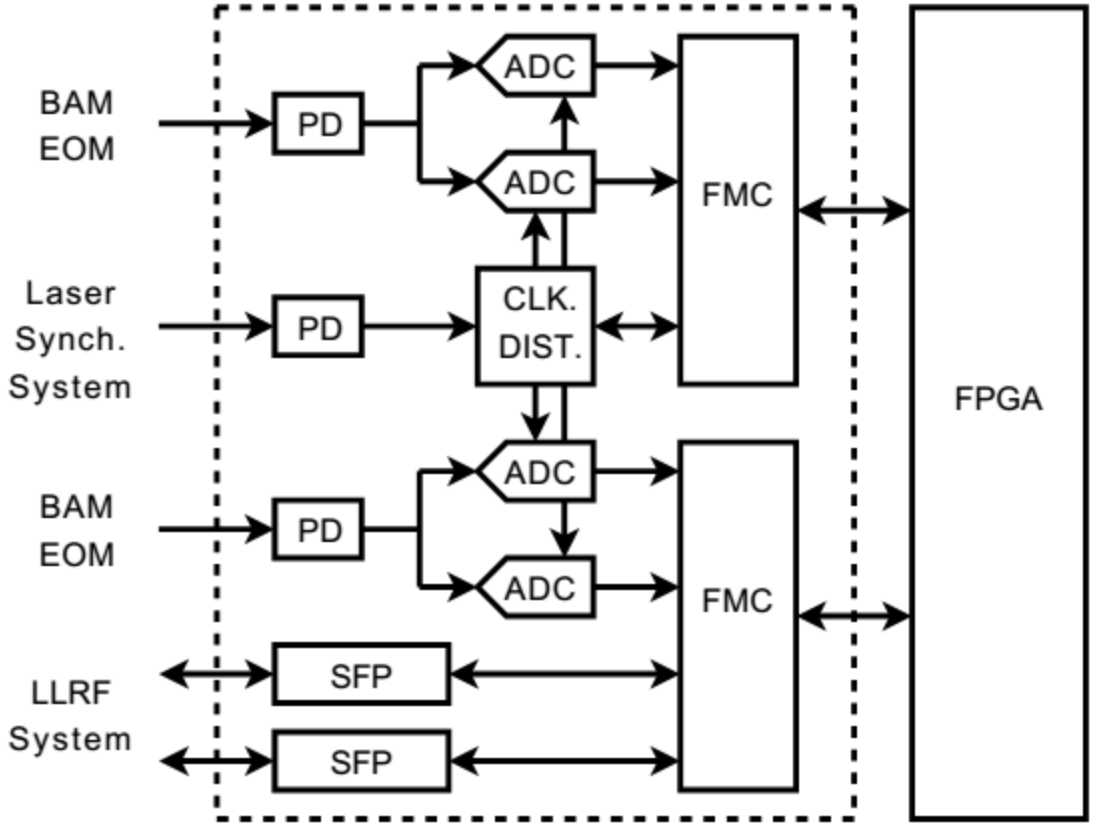
Pulse-shaped PRX signals fed to the ADC card

Photodiode signals

Prototype MTCA BAM Readout Devices

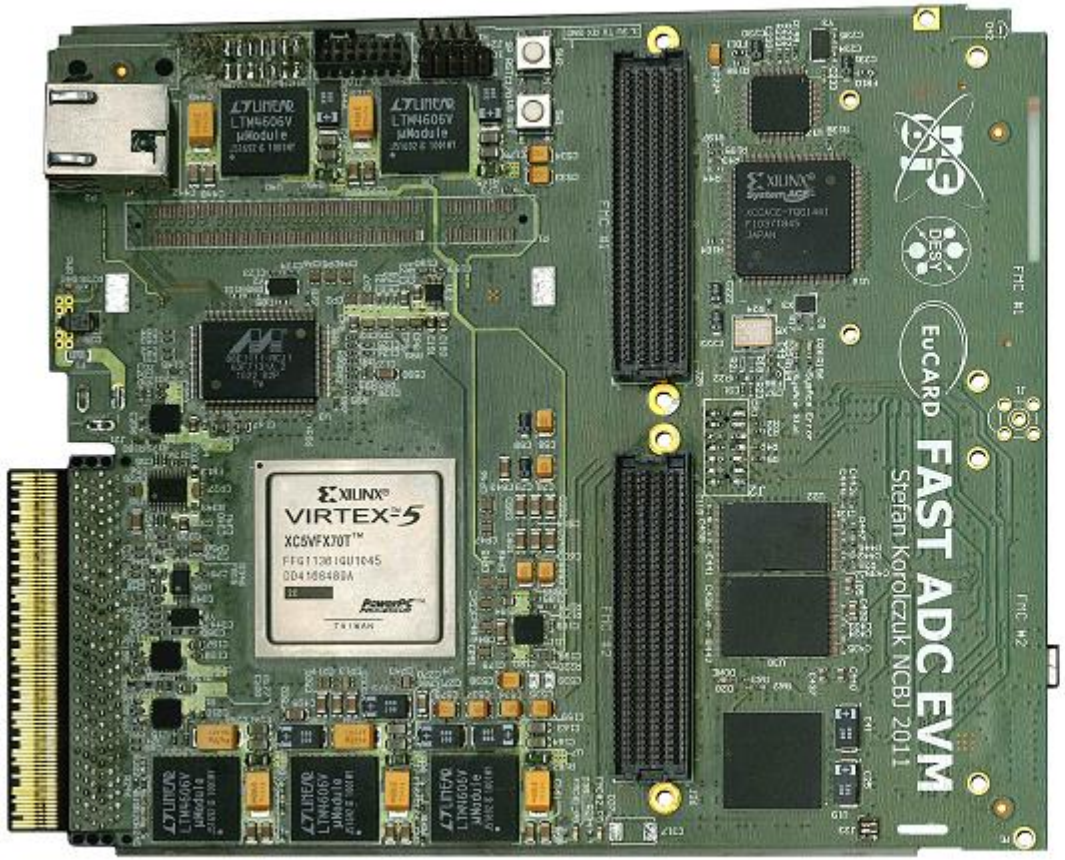


(a) Carrier block diagram

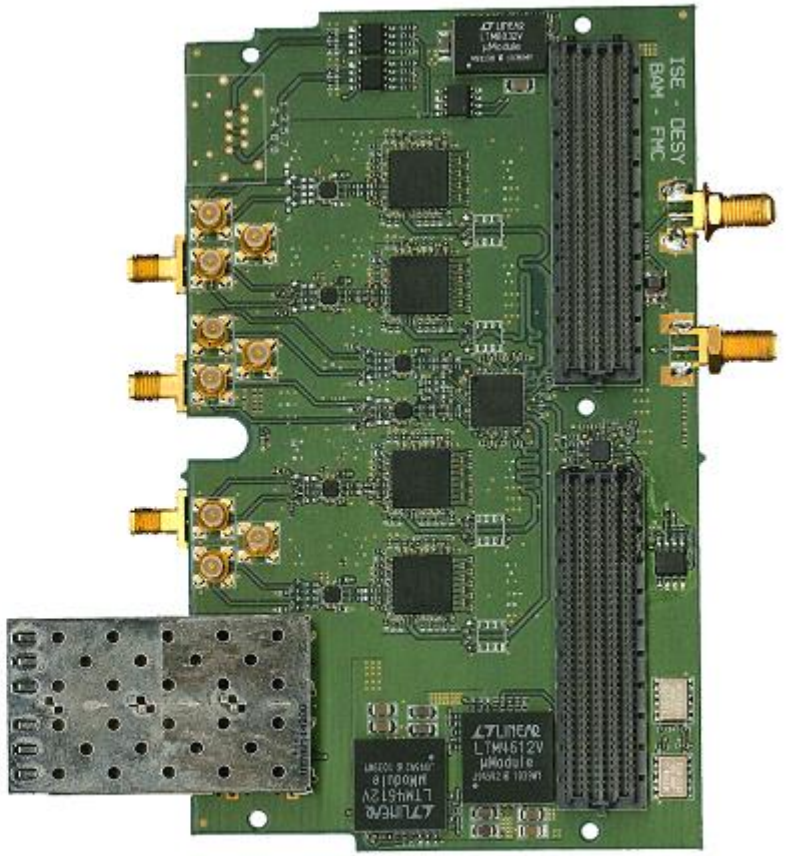


(b) Mezzanine block diagram

Prototype MTCA BAM Readout Devices



(a) Prototype FMC carrier



(b) Prototype FMC mezzanine with ADCs

Thank you for your attention!