

# Pickup design for arrival-time measurements at REGAE



TECHNISCHE  
UNIVERSITÄT  
DARMSTADT

A. Angelovski,<sup>1</sup> M. Hansli,<sup>1</sup> I. Dornmair,<sup>2,3</sup> B. Zeitler,<sup>2,3</sup> A. Penirschke,<sup>1</sup> F. Grüner<sup>2,3</sup> and R. Jakoby<sup>1</sup>

<sup>1</sup> Technische Universität Darmstadt, Institute for Microwave Engineering and Photonics

<sup>2</sup> Center for Free-Electron Laser Science, Hamburg

<sup>3</sup> University of Hamburg

- ❑ High quality electron bunches from **Relativistic Electron Gun for Atomic Exploration - REGAE** for laser-driven wakefield
  - ❑ Extremely short bunch lengths of approximately 10 fs
  - ❑ Wakefield structure on the order of a few 100 fs
  - ❑ Synchronization between the driving laser and the electron bunch in order of 10 fs necessary
- ❑ Very low bunch charges of 100 fC → Very low amplitude of the pickup signal
- ❑ Maximization of the induced voltage signal necessary
- ❑ Possible detection scheme
  - ❑ Broadband
  - ❑ Resonant

# Content

- Introduction
- Arrival-time measurement techniques
- Pickups for a broadband detection scheme
- Pickups for a resonant detection scheme
- Conclusion and future work

# Introduction

- ❑ Development of suitable Pickup structures for arrival-time monitors
  - ❑ Project application at the Federal Ministry of Education and Research (BMBF) starting from 01.07.2013
- ❑ Preliminary investigations of pickups as a part of the future arrival-time monitors for Laser-driven wakefield accelerators
  - ❑ Broadband and resonant

# Content

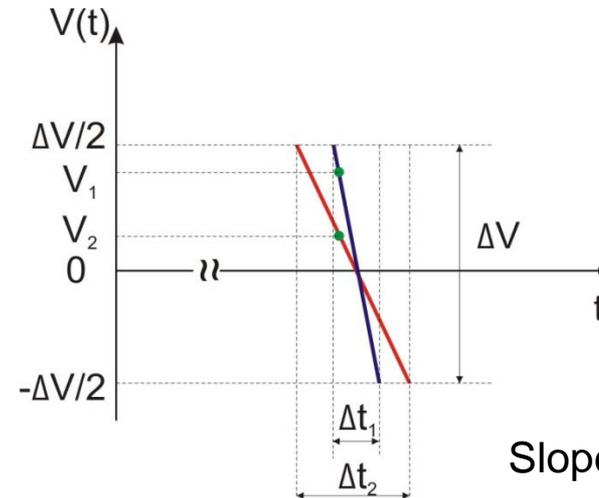
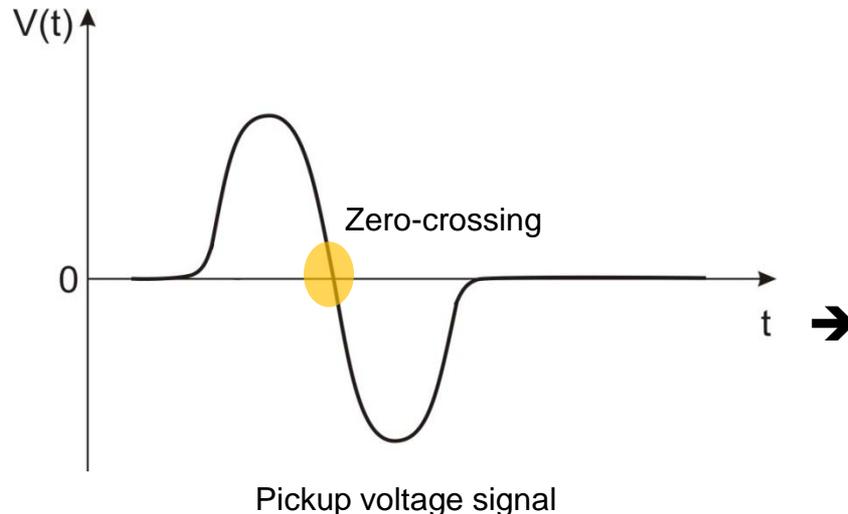
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# Arrival-time measurement techniques

## - BAMs at FLASH-

- ❑ Operation with low charged bunches (20 pC and less)
- ❑ The lower the charge the less the induced voltage in the pickup
- ❑ The time resolution of the BAM depends on the voltage slope at the zero crossing



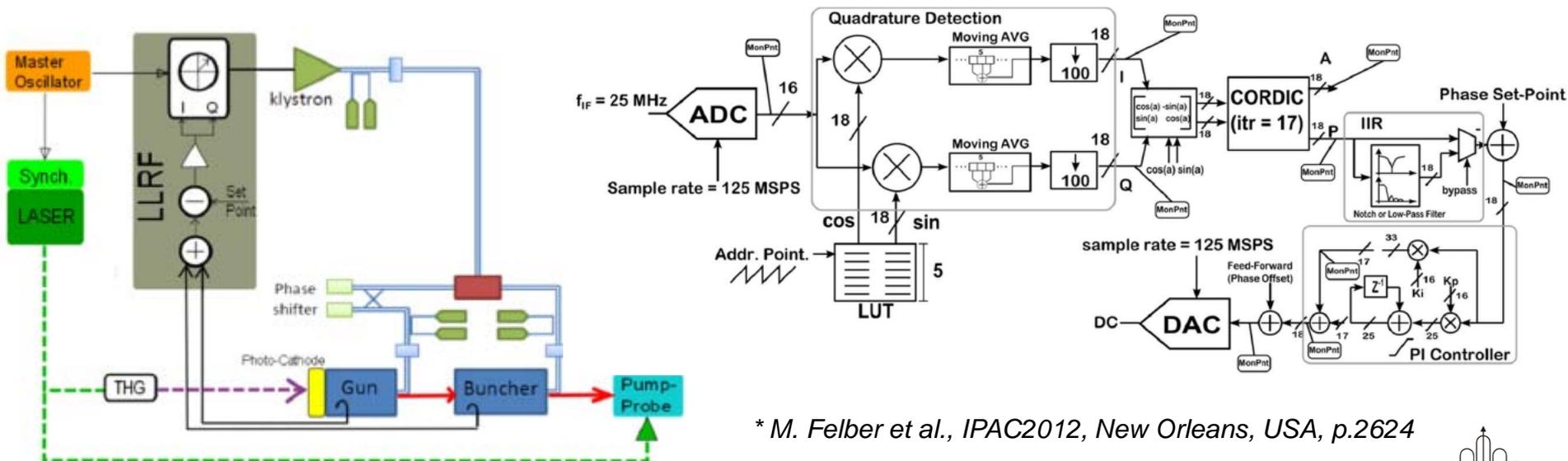
$$\text{Slope} = \Delta V / \Delta t$$

$t_s$  - sampling time

- ❑ Higher slope at zero-crossing increases the sensitivity of the BAM
  - ❑ Higher peak to peak voltage or
  - ❑ Larger bandwidth of the pickup signal

# Arrival-time measurement techniques - RF phase detection at IF for REGAE-

- ❑ One laser for the electron bunches and for pump-probe experiments
  - ❑ Timing jitter of approx. 10 fs between laser pulses and electron bunches
  - ❑ 10 – 20 fs synchronization was reported\* in terms of residual jitter between the laser and the 3 GHz master reference\* (*M. Felber et al., IPAC2012, New Orleans, USA, p.2624*)
- ❑ Resonant approach with an RF signal of 3 GHz extracted from the photo diode



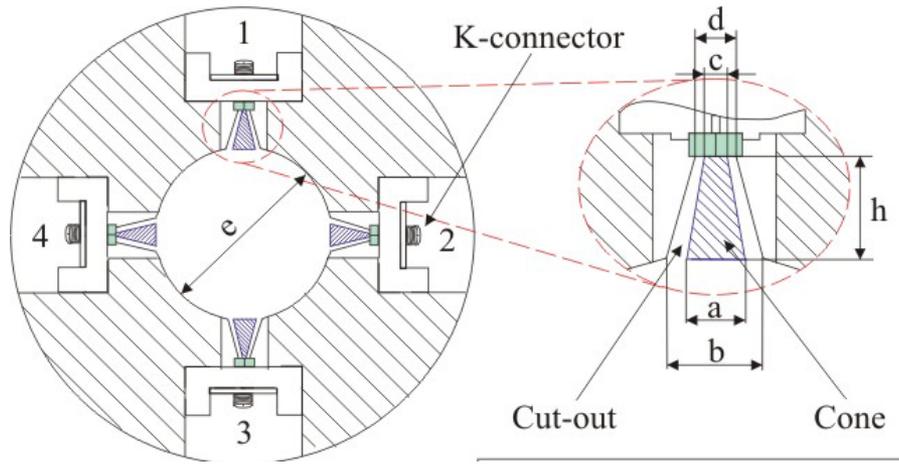
\* M. Felber et al., IPAC2012, New Orleans, USA, p.2624

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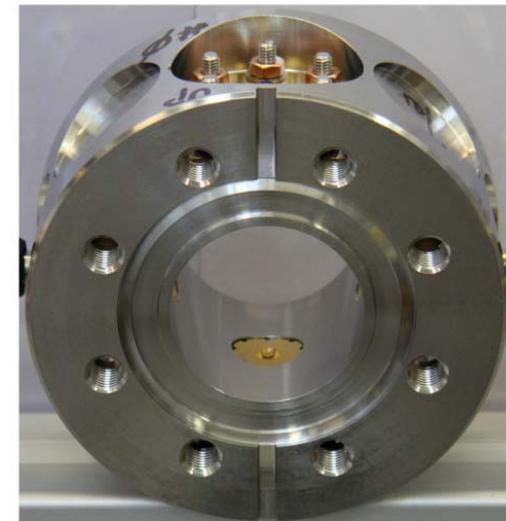
# Pickups for a broadband detection scheme at FLASH and XFEL

- Cone-shaped pickups with bandwidth up to 40 GHz (TU Darmstadt)



$a = 2.42 \text{ mm}$	$c = 0.70 \text{ mm}$
$b = 5.60 \text{ mm}$	$d = 1.62 \text{ mm}$
$e = 40.50 \text{ mm (XFEL)}$	
$e = 34 \text{ mm (FLASH)}$	
$h = 6 \text{ mm}$	

Cone shape pickup dimensions for FLASH and XFEL

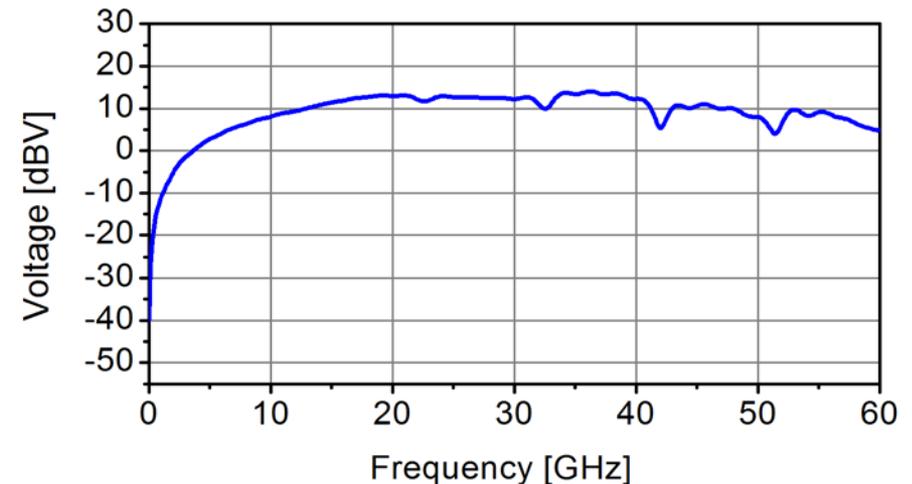
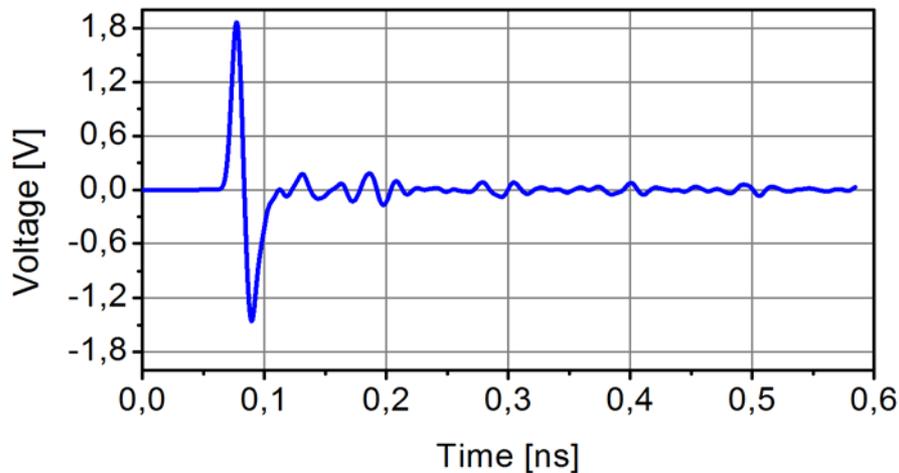
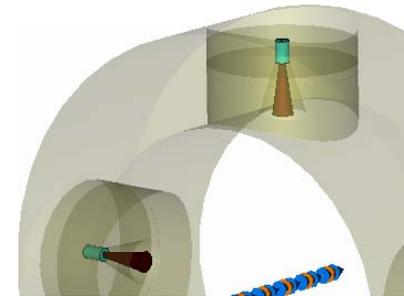


Manufactured cone-shape pickups

\* A. Angelovski et al., *Phys. Rev. ST Accel. Beams* **15**, 112803 (2012)

# Pickups for a broadband detection scheme at FLASH and XFEL

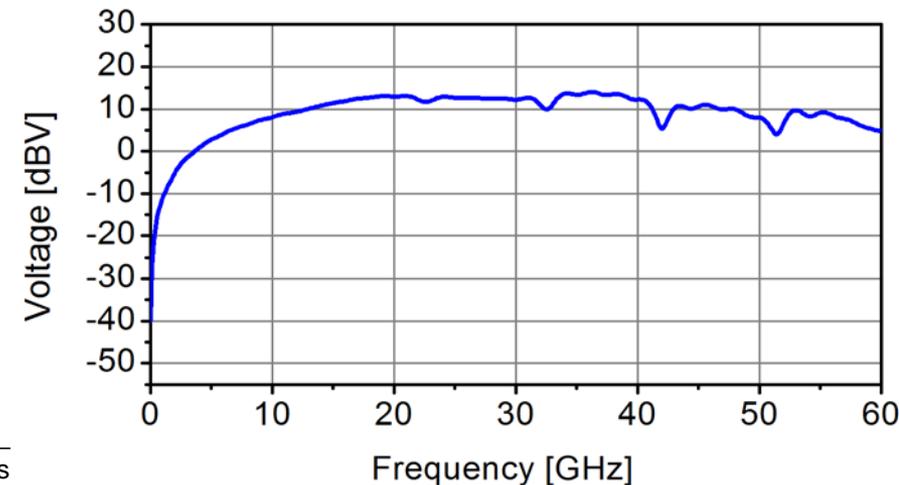
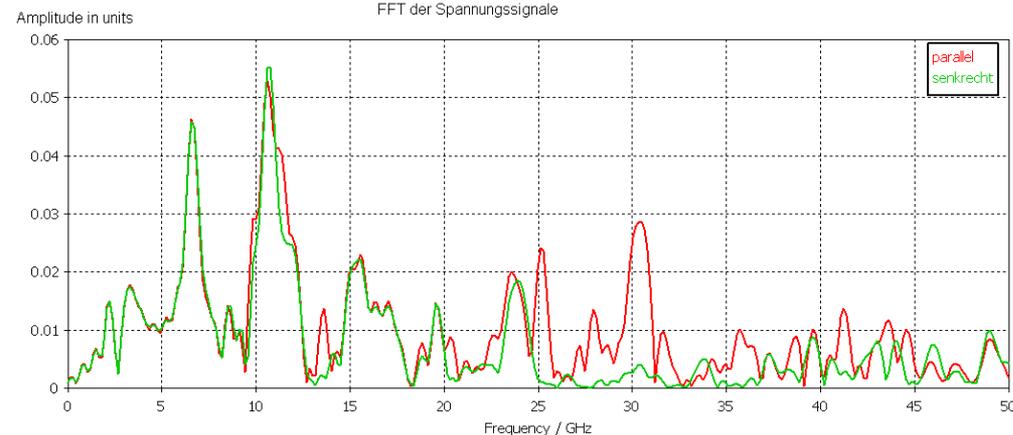
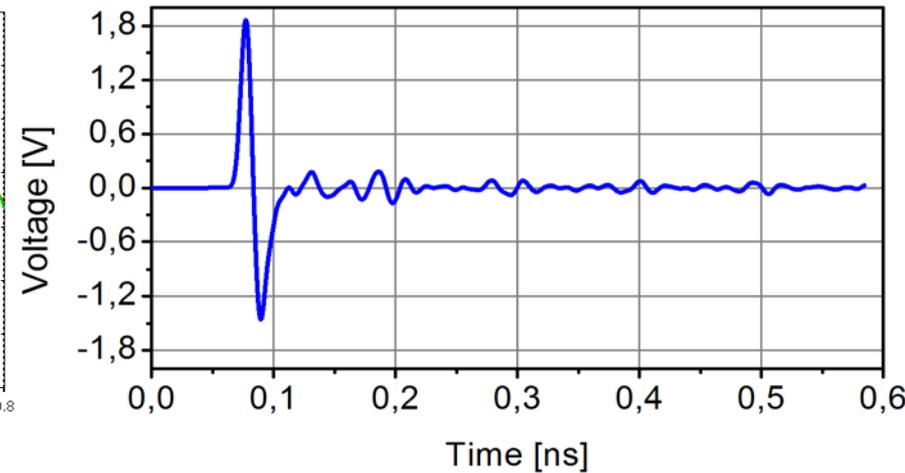
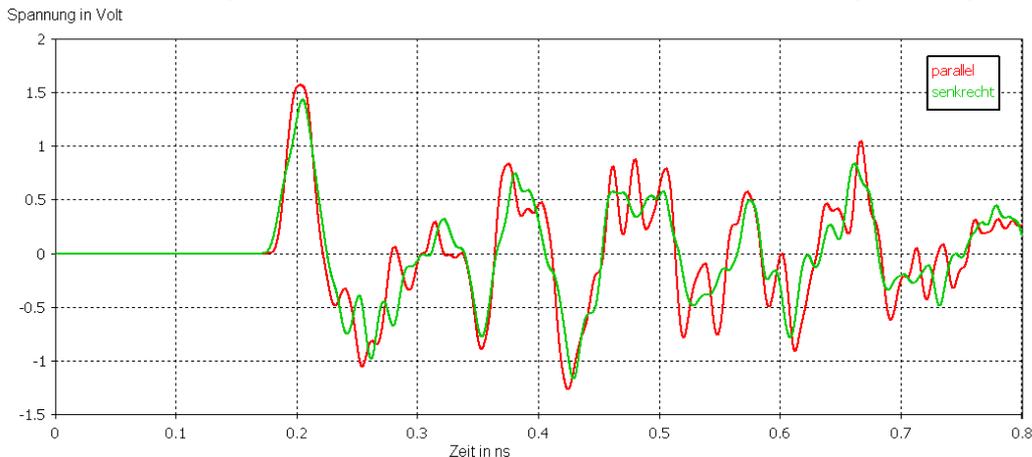
- ❑ No resonances at the pickup up to 40 GHz
- ❑ Fast voltage response
  - ❑ Reduced capacitance (smaller time constant)
- ❑ Tapered cut-out with constant ratio  $b / a = 2.3$  for  $50 \Omega$  matching



Pickup output signal. CST PARTICLE STUDIO simulation with bunch charge of 20 pC and bunch length of 1 mm.

# Pickups for a broadband detection scheme at FLASH and XFEL

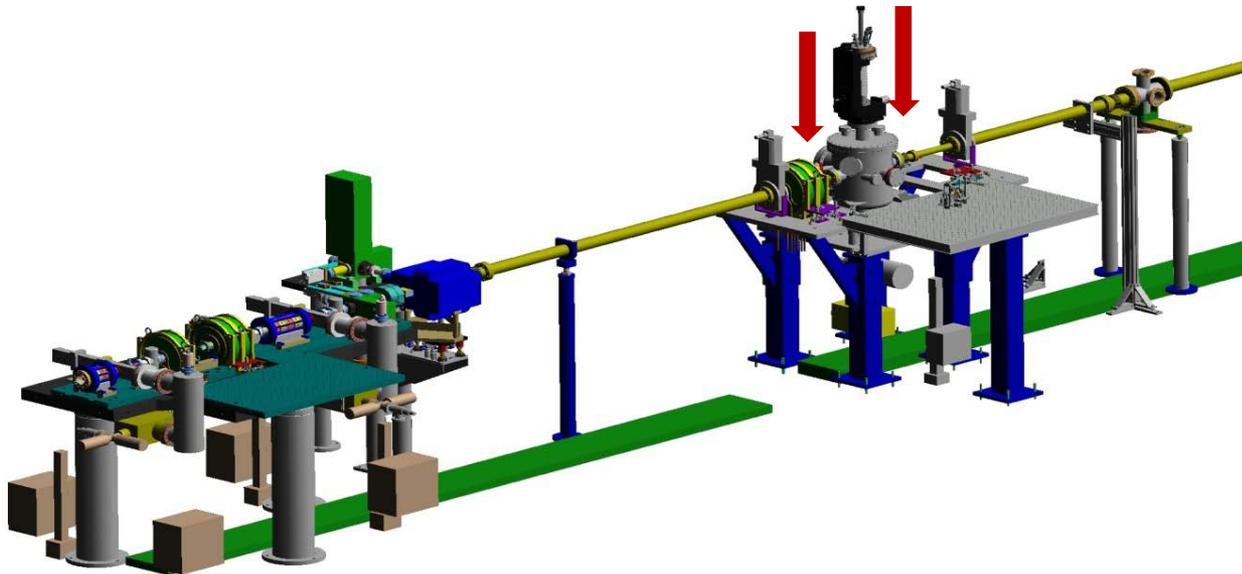
## Comparison to the state of the art pickups (up to 8 GHz)



\* Simulation of state of the art pickups, Courtesy to A. Kuhl

# Pickups for a broadband detection scheme for REGAE

- ❑ Two sets of pickups for the beam arrival time monitors
  - ❑ Before and after the chamber
  - ❑ Due to the extremely low bunch charge the expected pickup signal is very low
- ❑ Optimization the pickups for maximum peak voltage is necessary

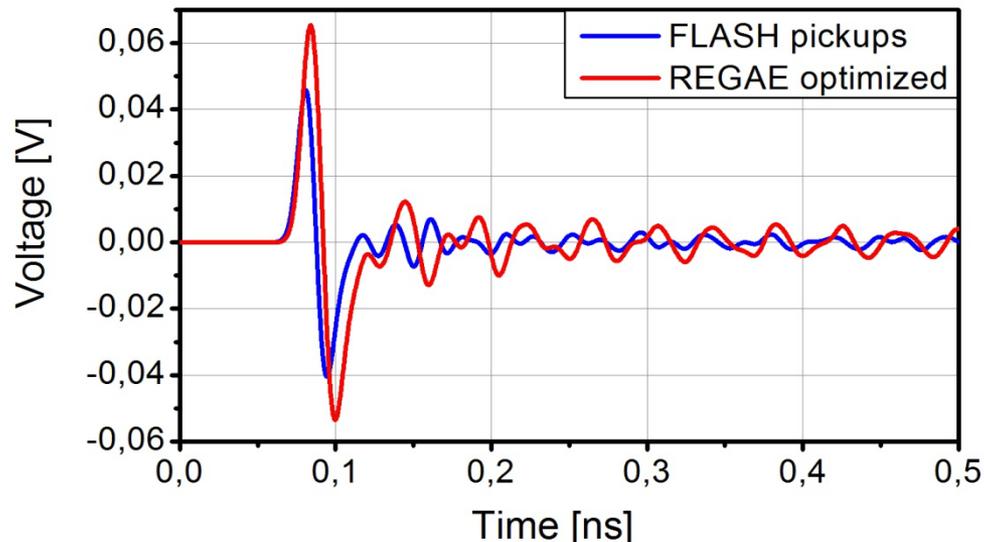
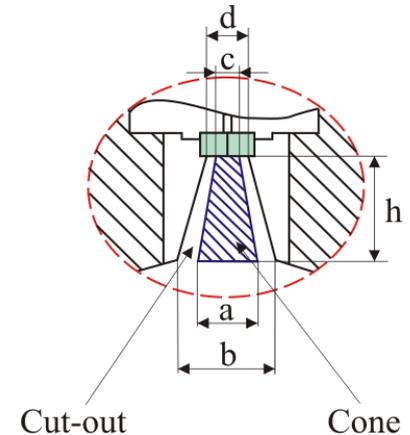


Position of the BAM pickups at REGAE , courtesy to B. Zeitler

# Pickups for a broadband detection scheme for REGAE

## ❑ Cone-shaped pickups for REGAE

- ❑ Bunch charge of 100 fC
- ❑ The pickups need to maintain the  $50 \Omega$  geometry,  $a/b = 2.3$
- ❑ Increased active surface of the pickups for higher induced signal
- ❑ Combined (mathematically) signal from four pickups



	FLASH	REGAE
Cone [mm]	5.60	<b>8.60</b>
Cut-out [mm]	2.42	<b>3.72</b>
V <sub>pp</sub> [V]	0.085	<b>0.12</b>

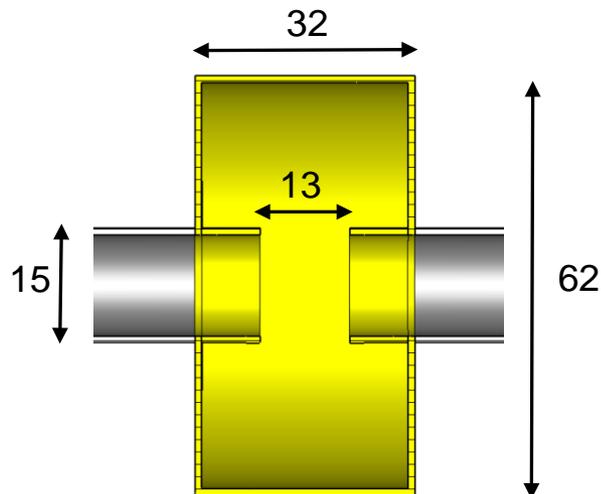
**41 % increased peak voltage !**

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# Pickups for a resonant detection scheme for REGAE

- ❑ Cavity with a resonant frequency of the monopole mode of 3 GHz
- ❑ Design of a pill box cavity
  - ❑ Maximum R/Q value
  - ❑ Coupling optimization for maximum pickup signal
- ❑ Two sets of simulations with CST Studio Suite
  - ❑ Eigenmode solver
  - ❑ Particle studio (wakefield solver)



Cavity parameters in mm (M. Hansli)

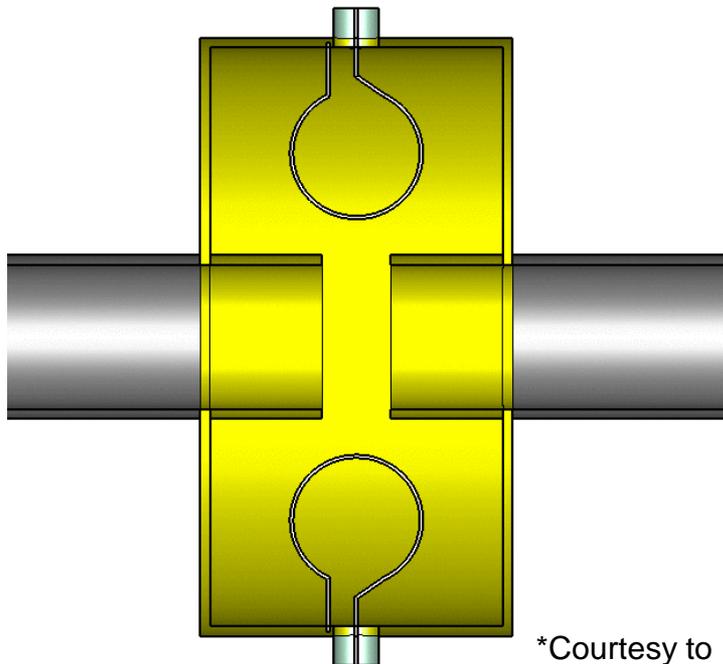
Cavity parameter	Value
Resonant frequency [GHz]	3
R / Q [ $\Omega$ ]	250.6
Q factor	10.343

Courtesy to M.Hansli

# Pickups for a resonant detection scheme for REGAE

## Simulation of the designed cavity with particle beam

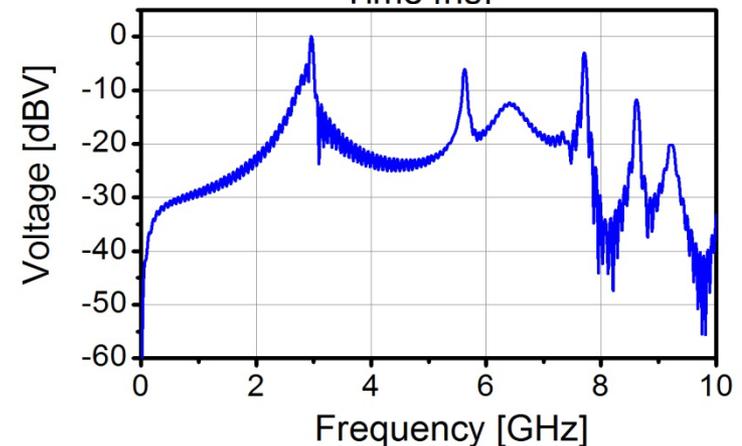
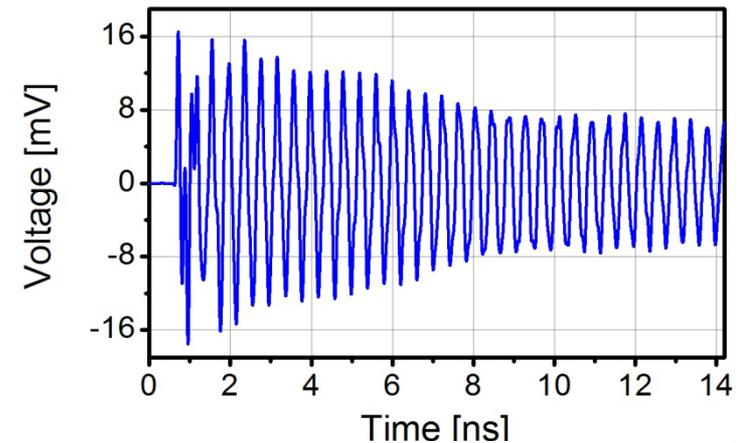
- Bunch charge of 100 fC
- Two coupling loops for signal extraction



\*Courtesy to M.Hansli

## □ Combined signal from both coupling loops

- Peak voltage depends on the coupling strength (optimization)



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# Conclusion and future work



- New Arrival time monitors need to be developed for REAGE
  - Preliminary investigations are shown in this talk
- Two detection schemes are under observation
  - Broadband
  - Resonant
- The pickups need to be optimized for maximum peak voltage due to the extremely low bunch charge of 100 fC
  
- Future work :
  - Selection and development of arrival time monitors for REGAE
  - Design of pickups according to the selected detection scheme
  - Design of RF and electronic front-end