

Pickup design for arrival-time measurements at REGAE



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- ❑ 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



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

- ❑ 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



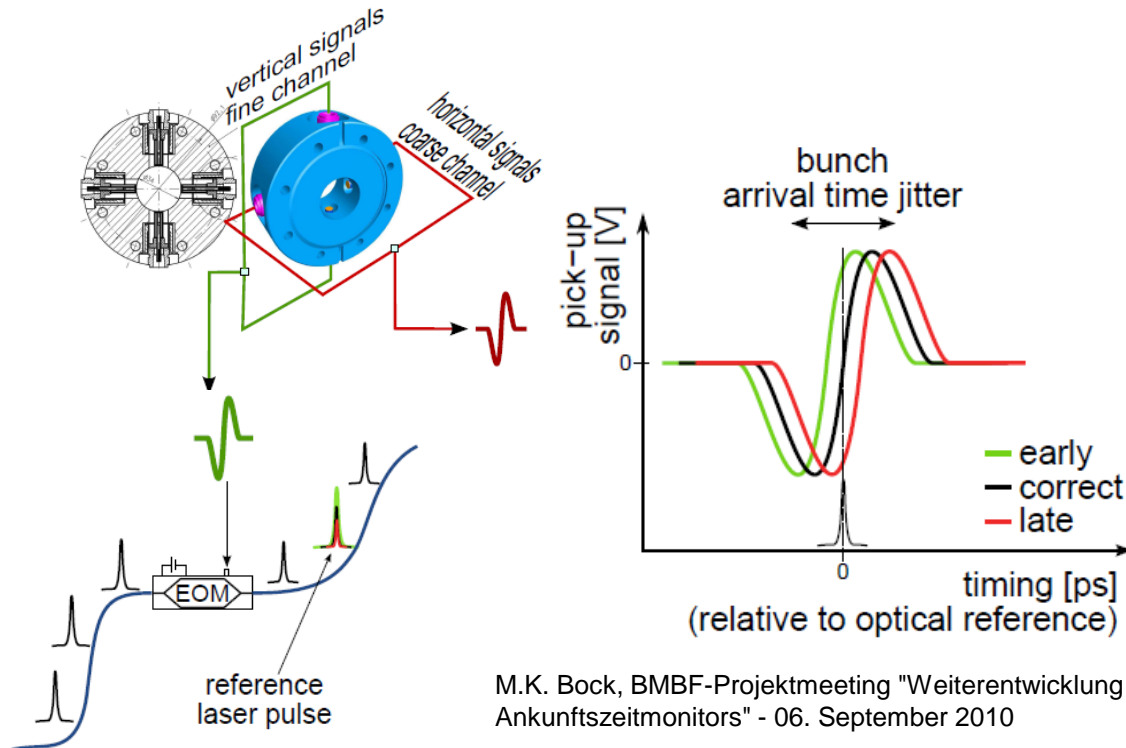
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Arrival-time measurement techniques

- BAMs at FLASH-

- ❑ Bunch Arrival-time Monitors (BAMs) at FLASH
 - ❑ Electro-optical detection scheme
 - ❑ Sub-10 fs time resolution for bunch charges higher than 100 pC



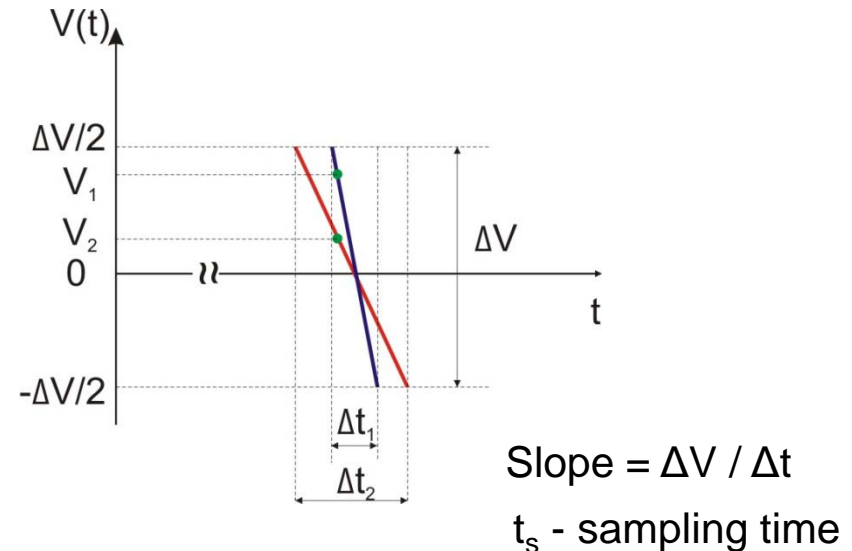
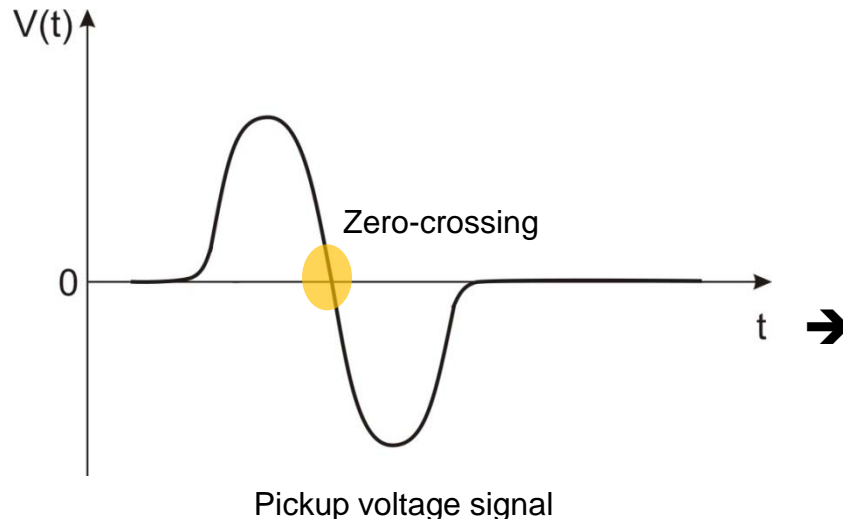
➔ The arrival-time of the electron bunch is encoded onto the laser pulse amplitude

M.K. Bock, BMBF-Projektmeeting "Weiterentwicklung eines Ankunftszeitmonitors" - 06. September 2010

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

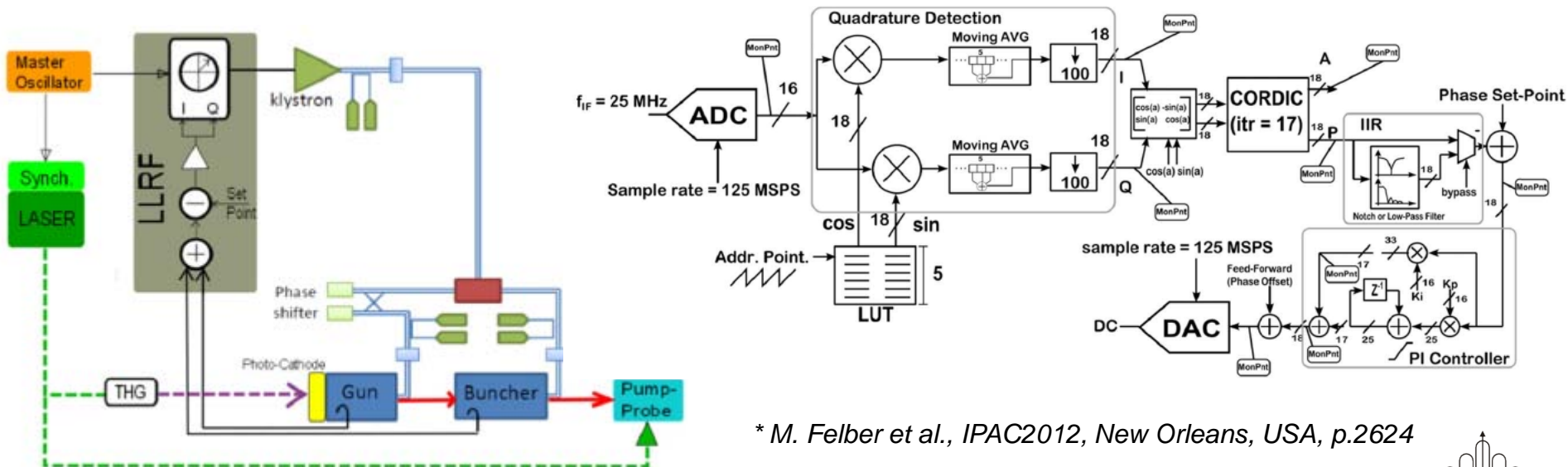


- ❑ Higher slope at zero-crossing increases the sensitivity of the BAM
 - ❑ Higher peak to peak voltage or
 - ❑ Larger bandwidth of the pickup signal

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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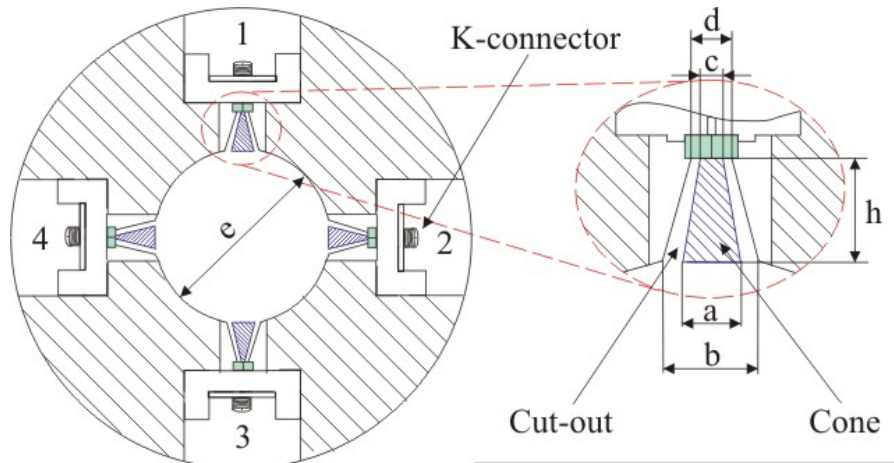


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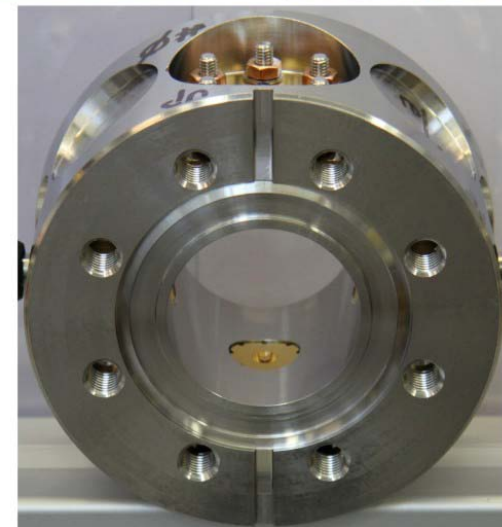
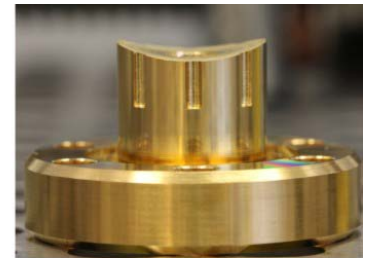
Pickups for a broadband detection scheme at FLASH and XFEL

❑ 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

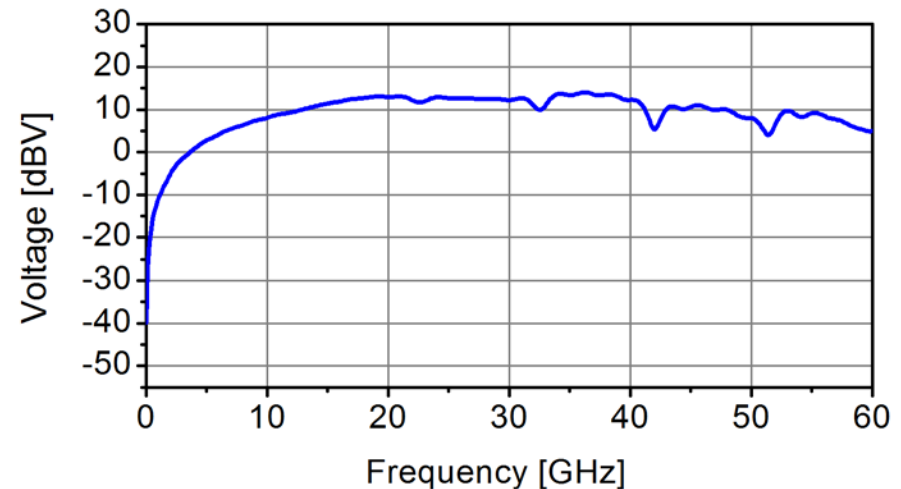
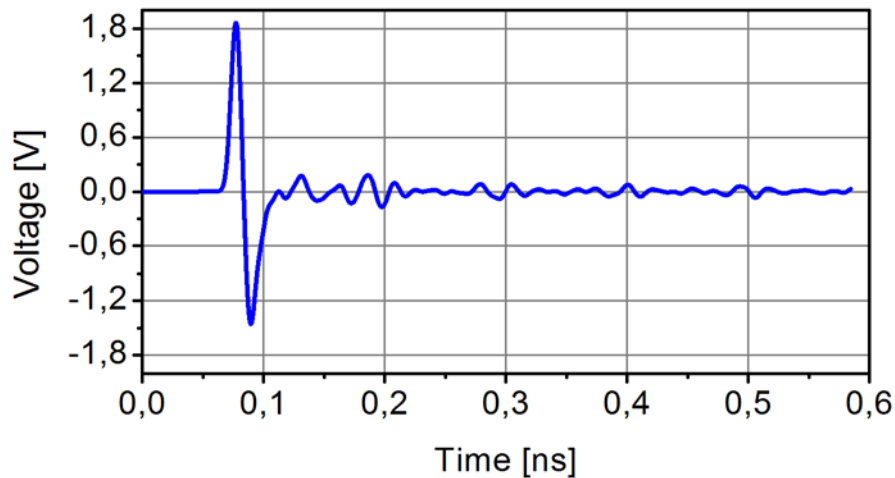
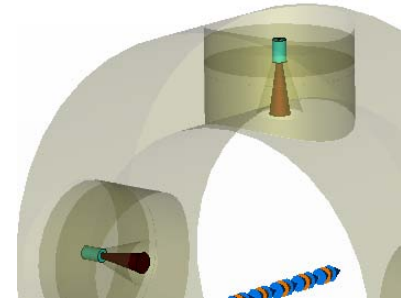


Manufactured cone-shape pickups

* 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 Ω matching

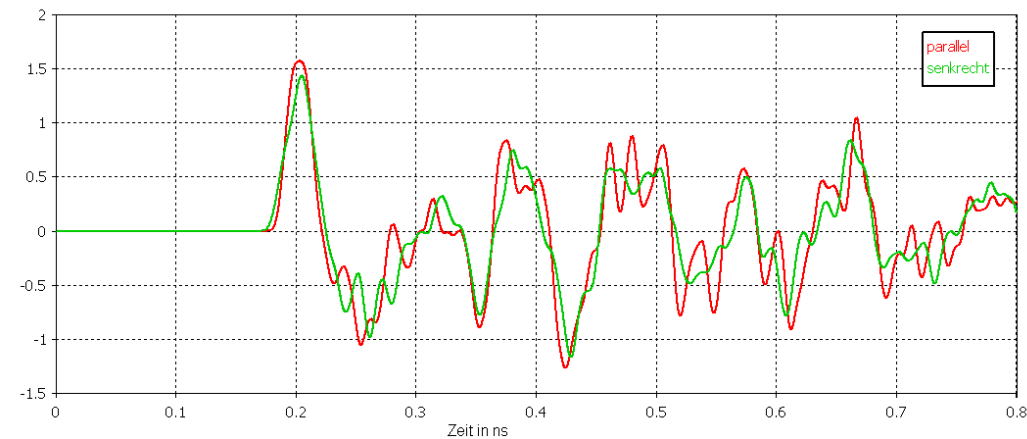


Pickup output signal. CST PARTICLE STUDIO simulation with bunch charge of 20 pC and bunch length of 1 mm.

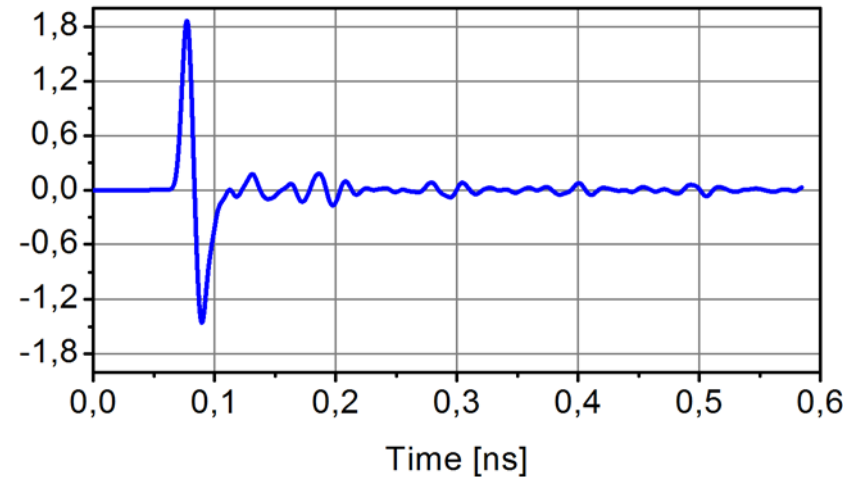
Pickups for a broadband detection scheme at FLASH and XFEL

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

Spannung in Volt



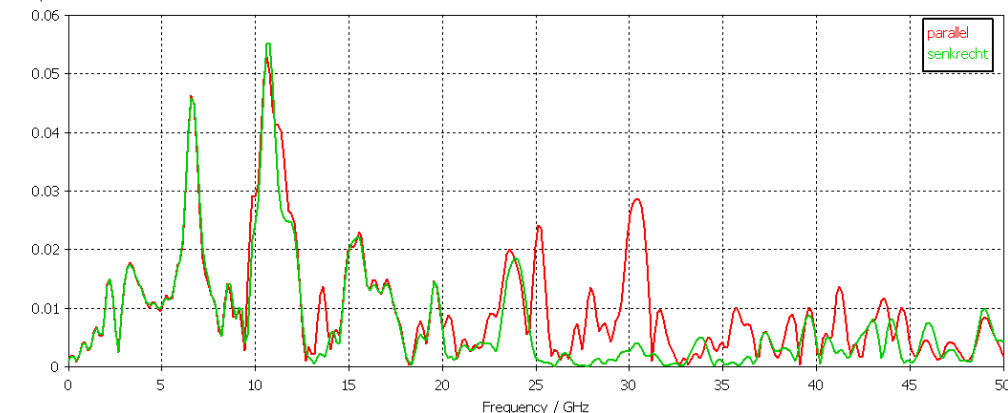
Voltage [V]



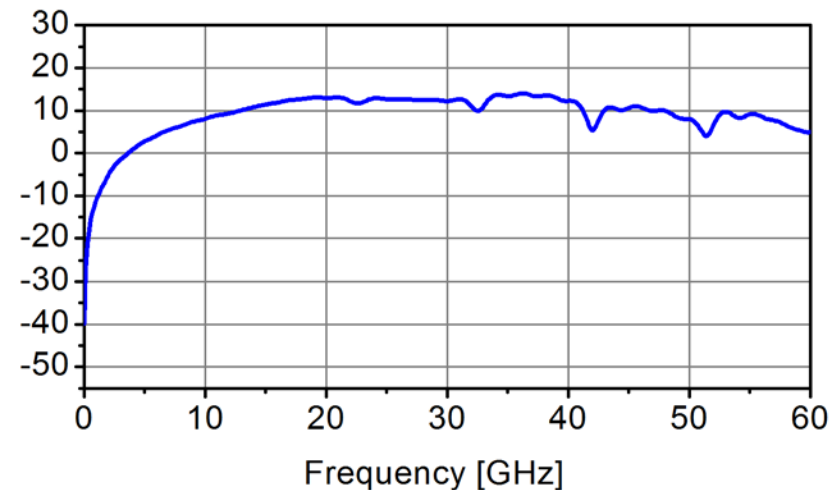
Time [ns]

Amplitude in units

FFT der Spannungssignale



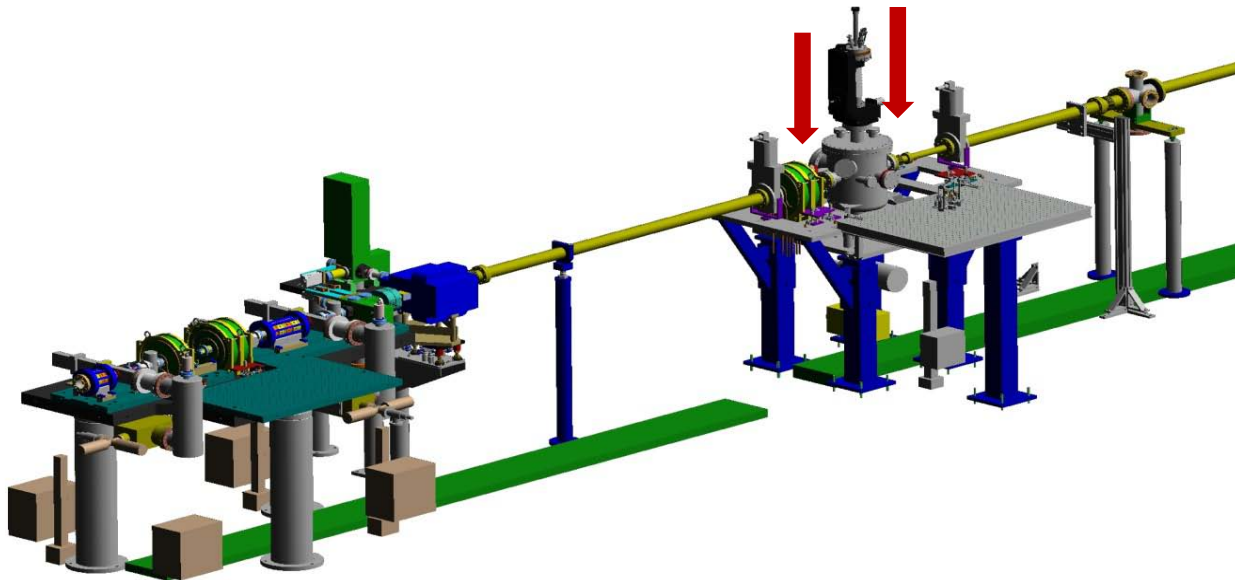
Voltage [dBV]



* 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

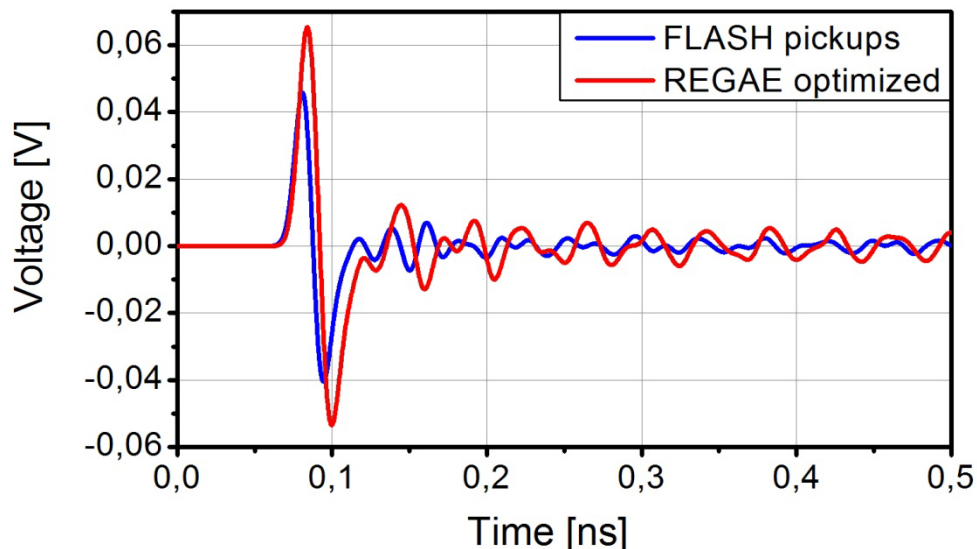
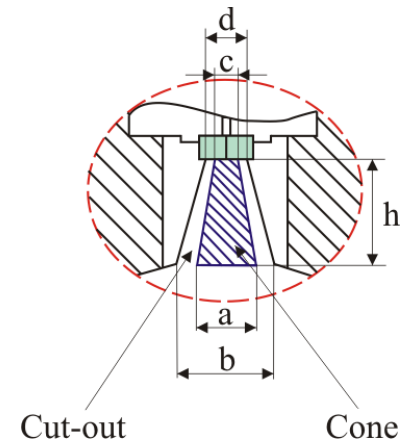
❑ Cone-shaped pickups for REGAE

❑ 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 | 8.60 |
| Cut-out [mm] | 2.42 | 3.72 |
| Vpp [V] | 0.085 | 0.12 |

41 % increased peak voltage !

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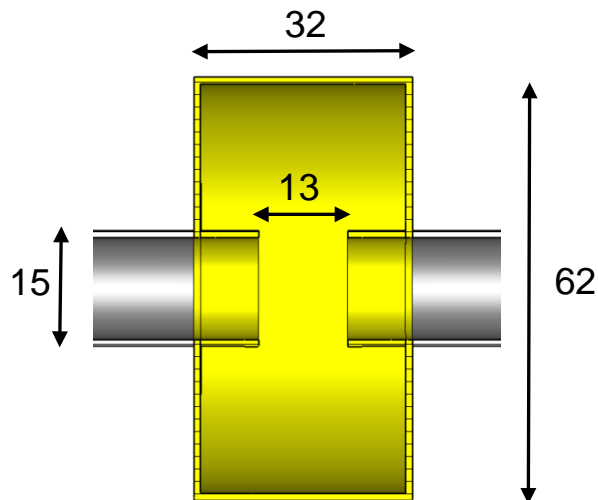


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Pickups for a resonant detection scheme for REGAE

- ❑ 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)

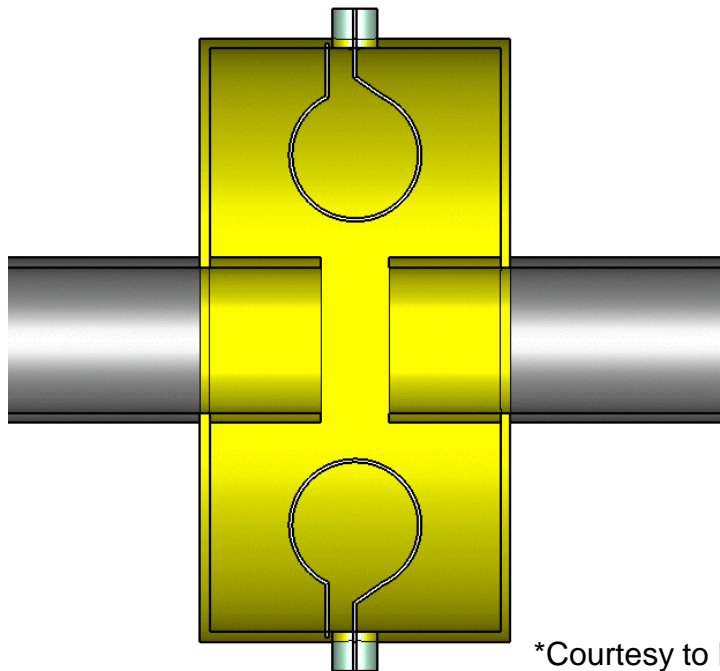
| Cavity parameter | Value |
|--------------------------|--------|
| Resonant frequency [GHz] | 3 |
| R / Q [Ω] | 250.6 |
| Q factor | 10.343 |

Courtesy to M.Hansli

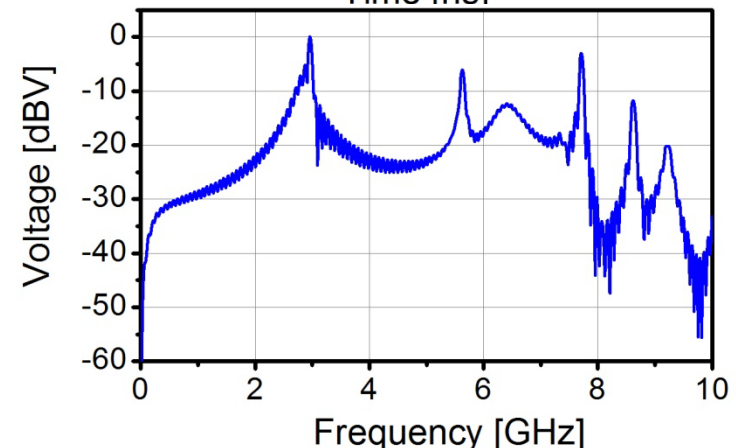
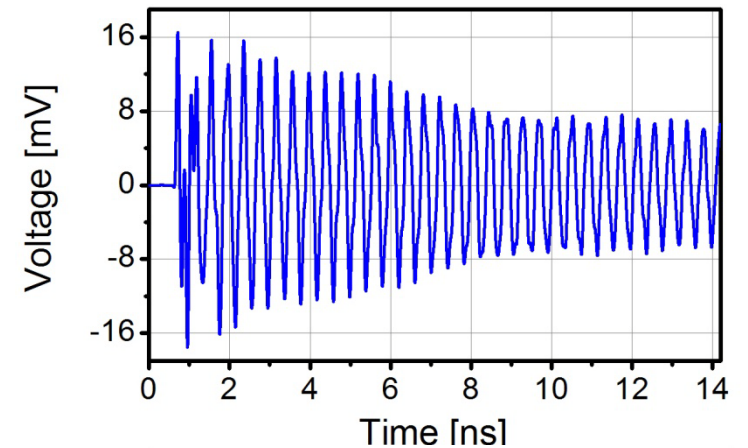
Pickups for a resonant detection scheme for REGAE

☐ 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