

MOTIVATION

The all-optical synchronization system implemented in the European X-ray free-electron laser (EuXFEL) is to receive an upgrade. The modifications are intended to allow operation with consistently high accuracy in a 1 pC mode, which is required for various user experiments. The lower charges, e.g. a factor of 20, lead to a reduced signal strength at the pickups and thus to a decreased resolution. A significant potential for improvement has been identified in a modified pickup structure and transmission network, which provide the transient voltage signal to subsequent parts of the synchronization system. One solution for a broadband pickup structure with short signal paths, large active surfaces and minimum aperture diameter could be achieved by connecting rod-shaped pickups to a combination network on a printed circuit board, which will be mounted in the beamline.

In this contribution the proposed design is introduced and analyzed by electromagnetic field simulations.

BUNCH ARRIVAL-TIME MONITOR

RF unit:

- Pickups couple to the bunch's electric fields
- Bipolar voltage signal is induced
- Signal combination compensates for the beam position



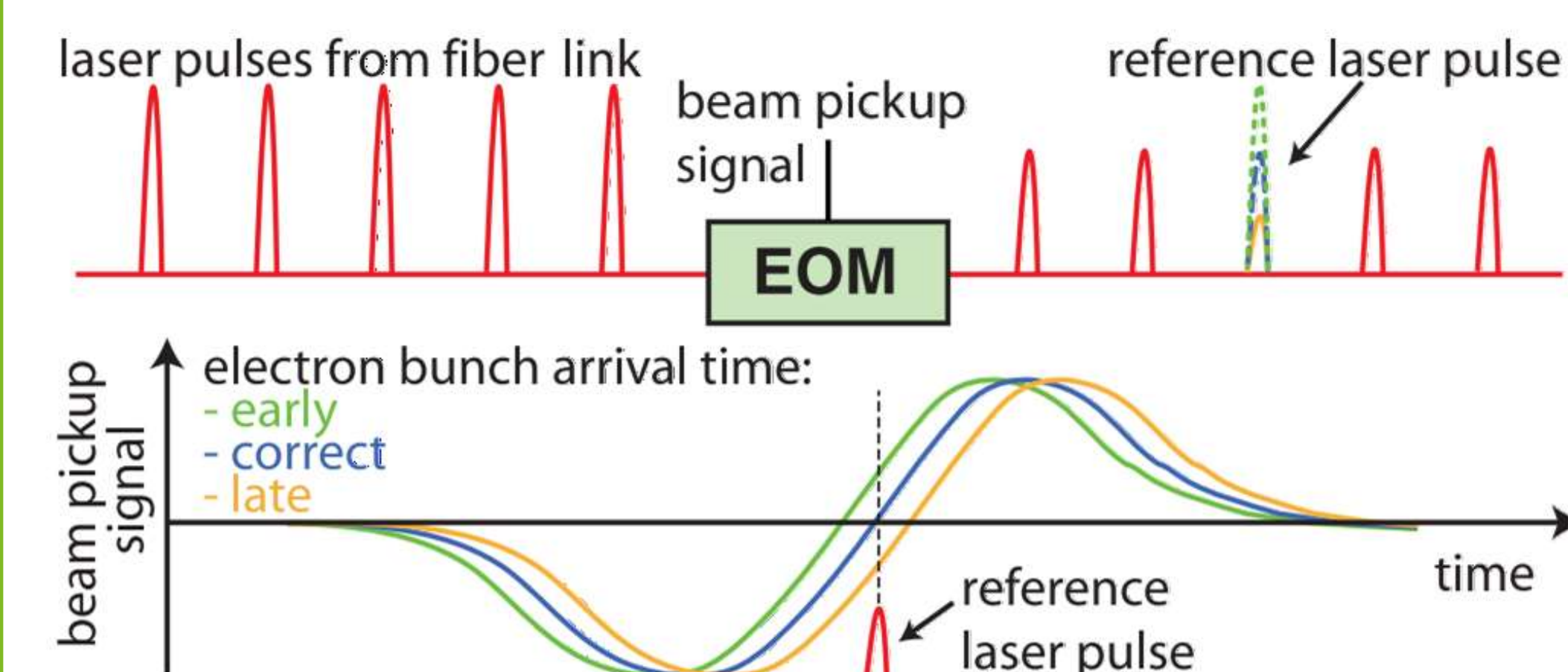
Single pickup of the non-hermetic prototype reprinted from [1].

Electro-optical unit:

- Electro-optic modulator
- Reference laser samples signal
- Amplitude modulation \propto temporal offset

Data acquisition system (DAQ):

- Photodiode: Measures amplitude
- ADC: Digitalizes amplitude
- Relative timing information for feedback loop etc.



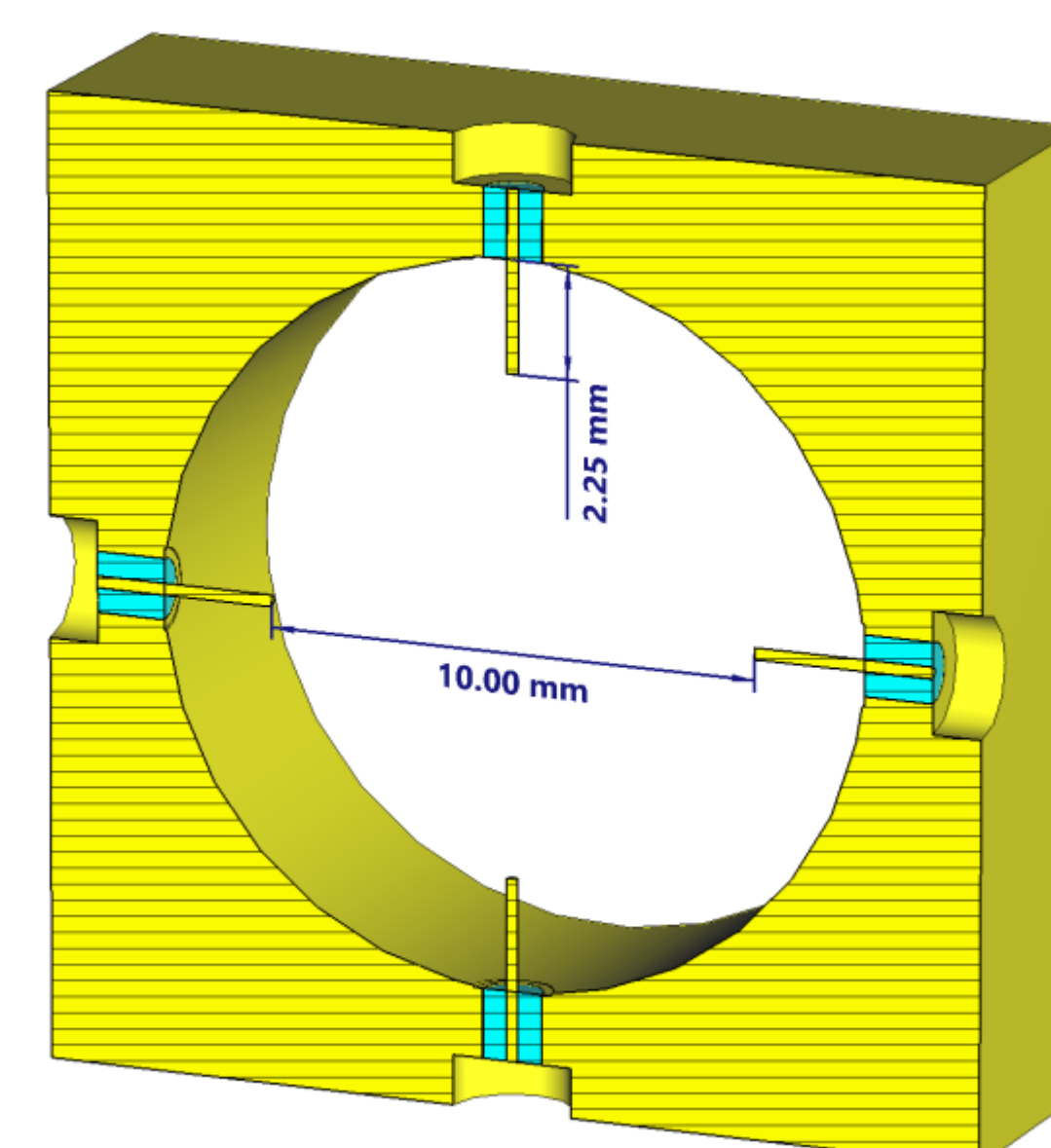
BAM working principle. Reprinted figure with permission from [2]. Copyright 2010 by the American Physical Society.

ROD-SHAPED PICKUPS

Normalized signal slope:

- Old pickups: $15 \frac{\text{mV}}{\text{ps pC}}$
- Required: $150 \frac{\text{mV}}{\text{ps pC}}$
- Achieved:**

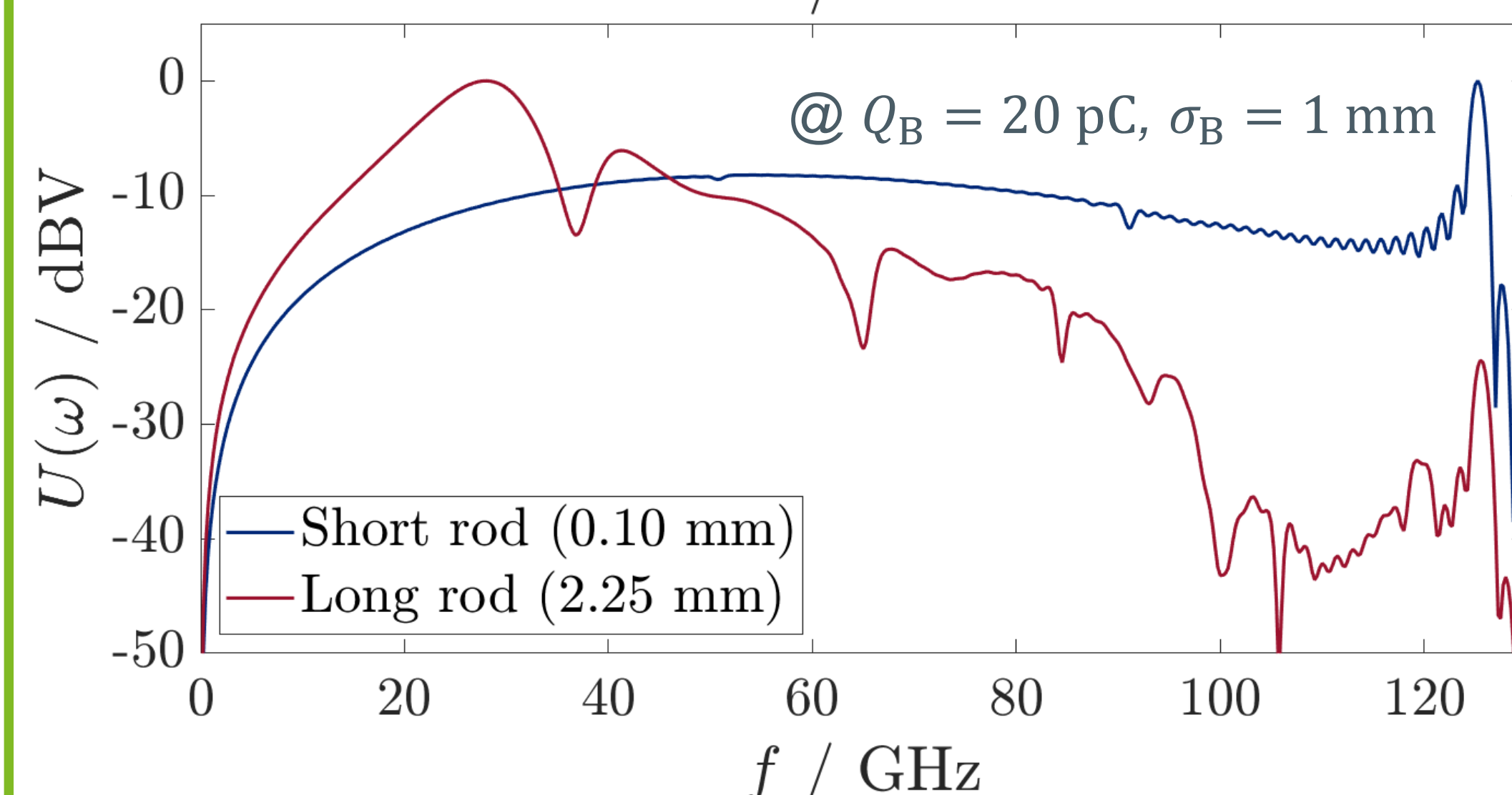
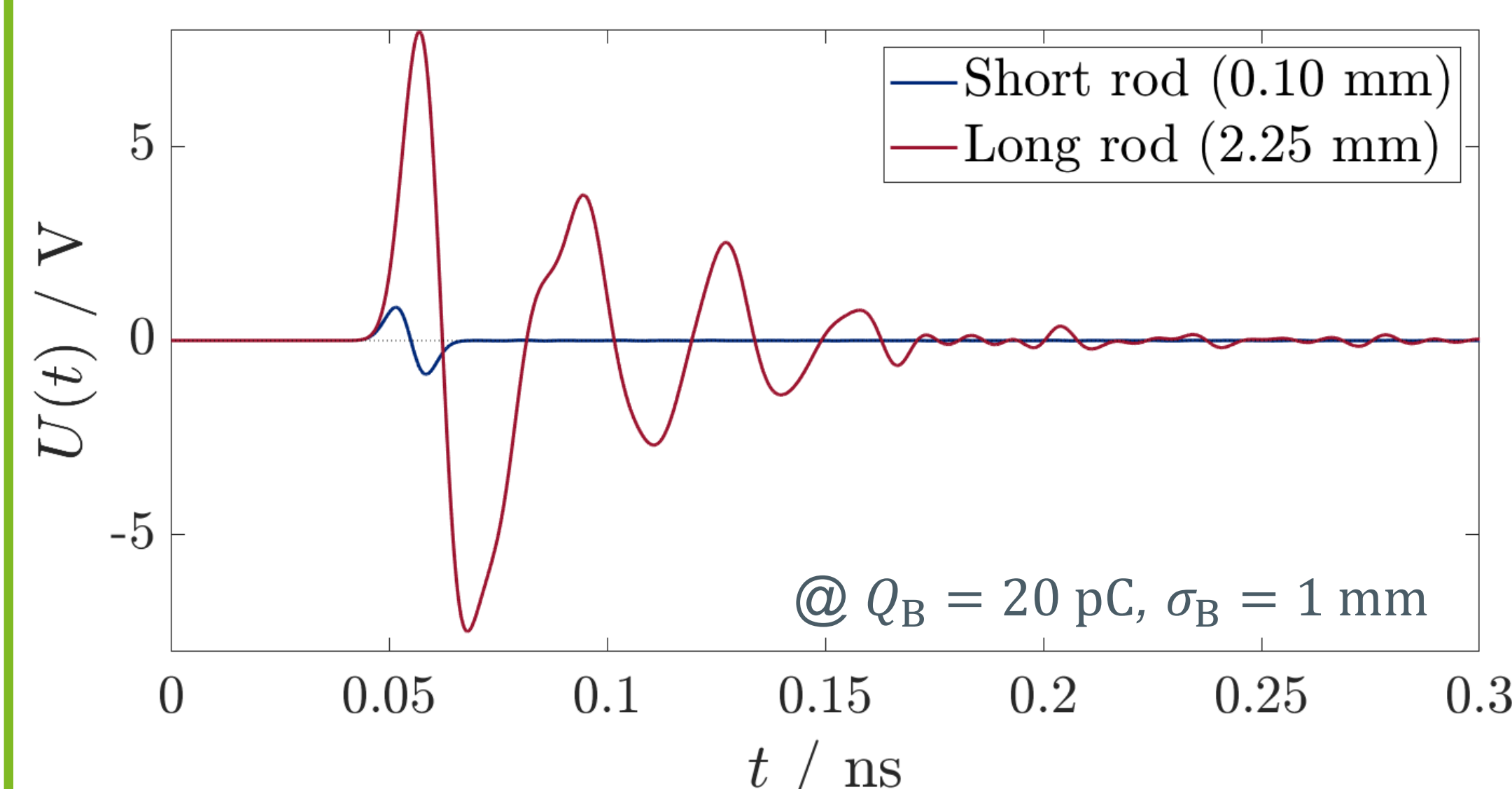
$$120 \frac{\text{mV}}{\text{ps pC}}$$



Cross-section of the CST model

Advantages:

- Close to the bunch
- Large effective area
- Low wakefields
- High bandwidth (with a short rod)
- Low ringing (with a short rod)



Simulated output voltage in time domain (top) and its normalized shifted spectrum (bottom) with two different pickup lengths and constant tip-to-tip distance of 10 mm.

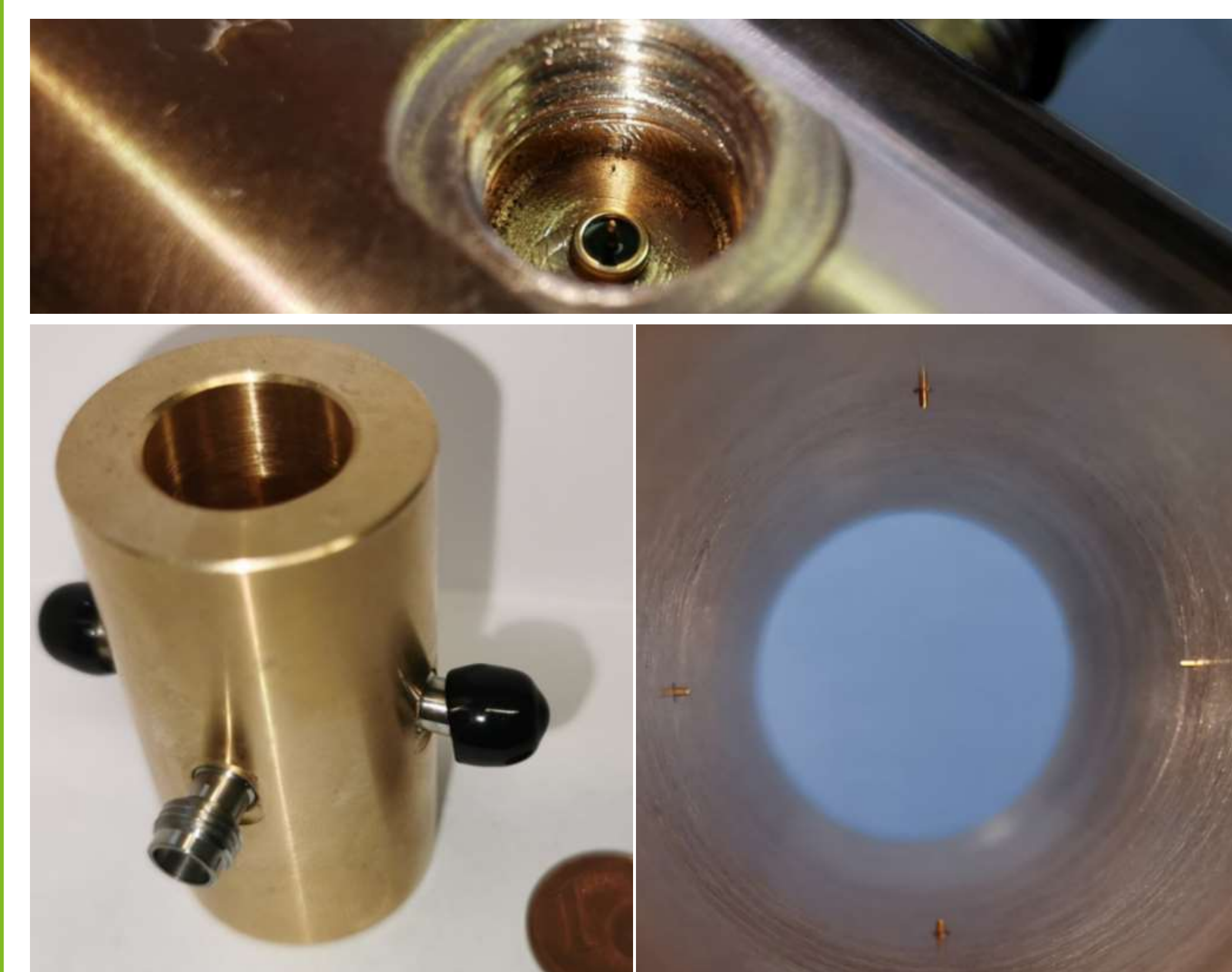
ACKNOWLEDGMENTS

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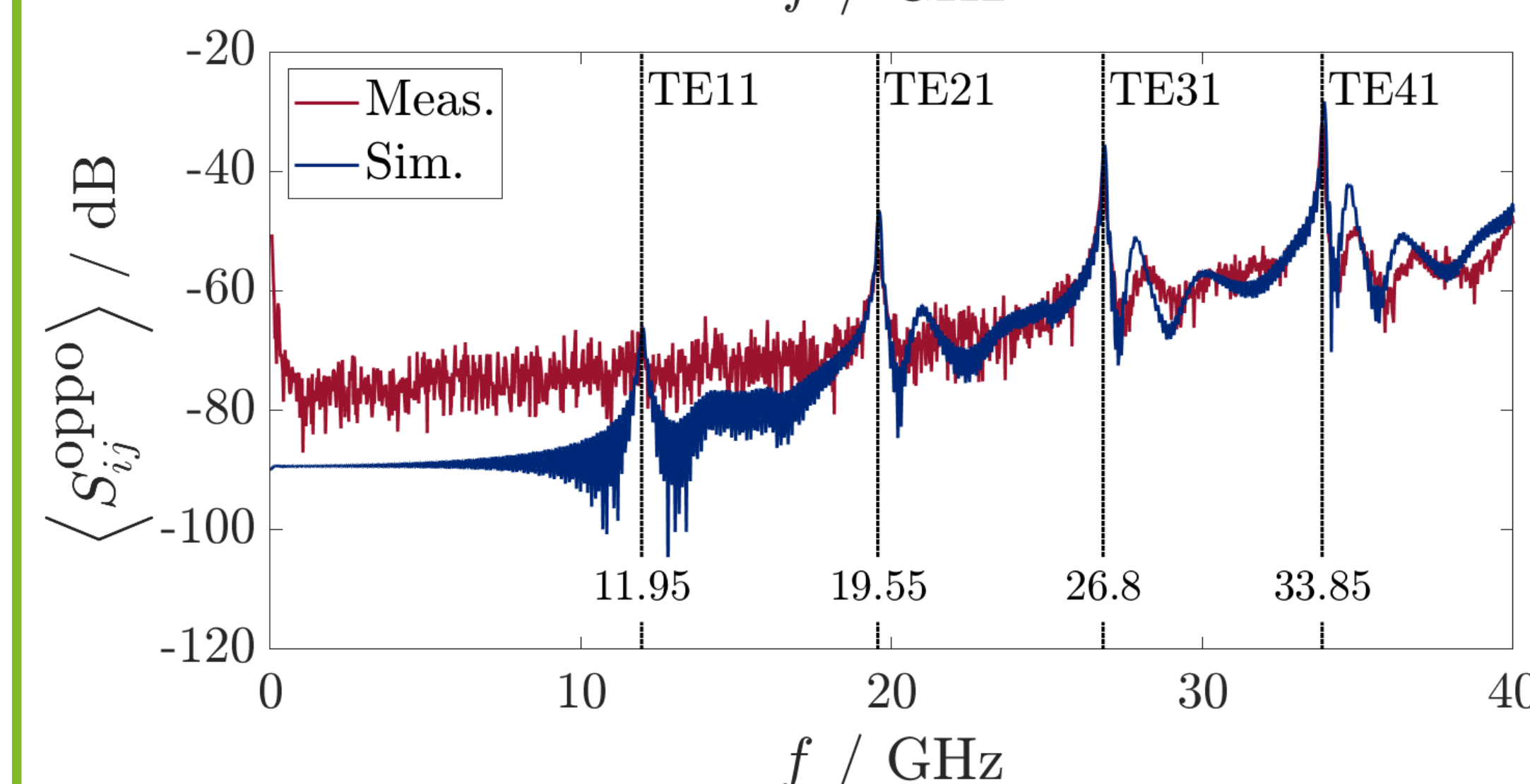
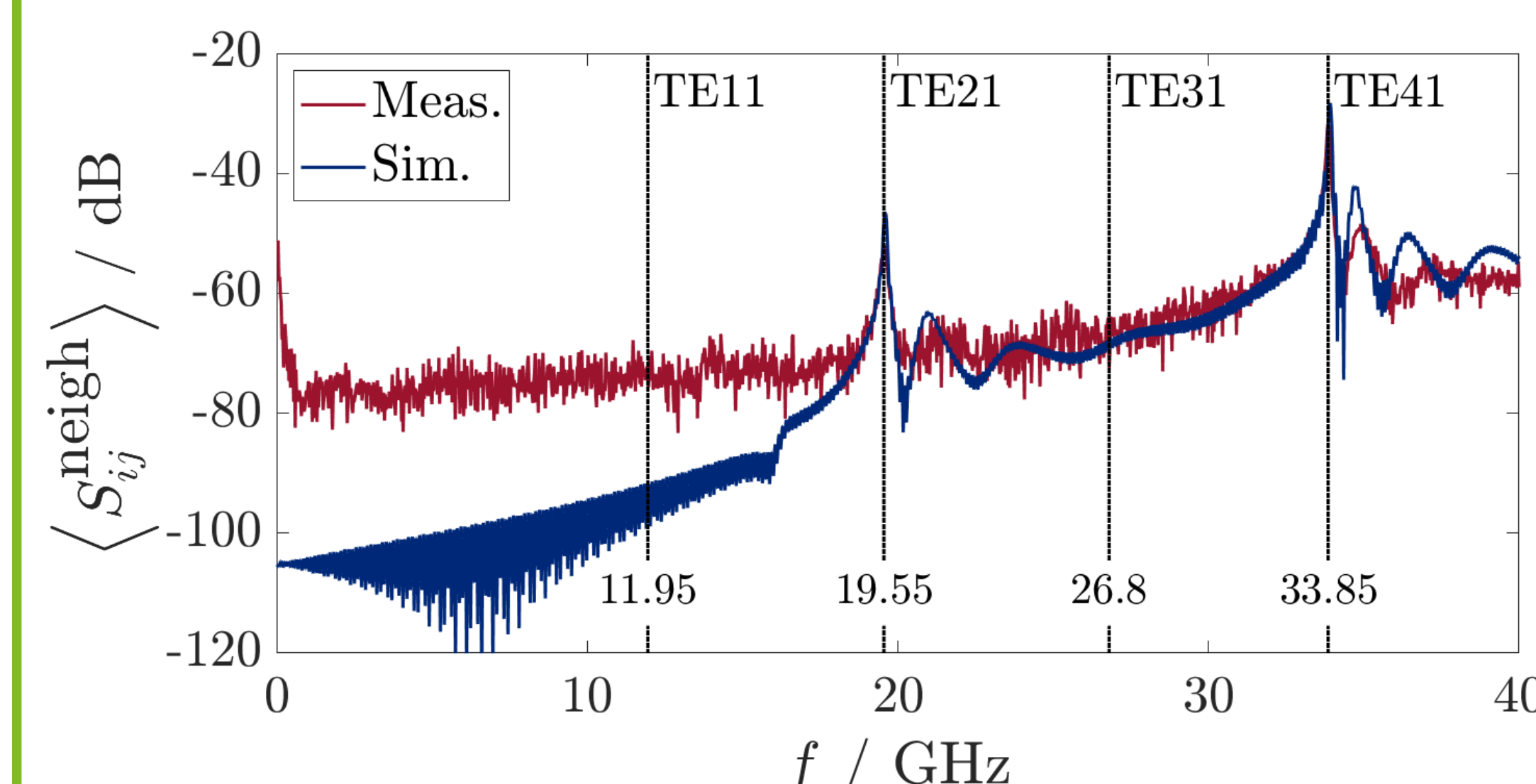


Bundesministerium für Bildung und Forschung

NON-HERMETIC DEMONSTRATOR



Photographs of the non-hermetic demonstrator of a rod-shaped pickup.



Mean measured (red) and simulated (blue) transmission parameters between opposite (top) and neighboring (bottom) pickups. Dashed vertical lines mark resonances in the filtered measurement data.

ROD-SHAPED PICKUPS ON A PCB

Normalized signal slope:

- Achieved:**

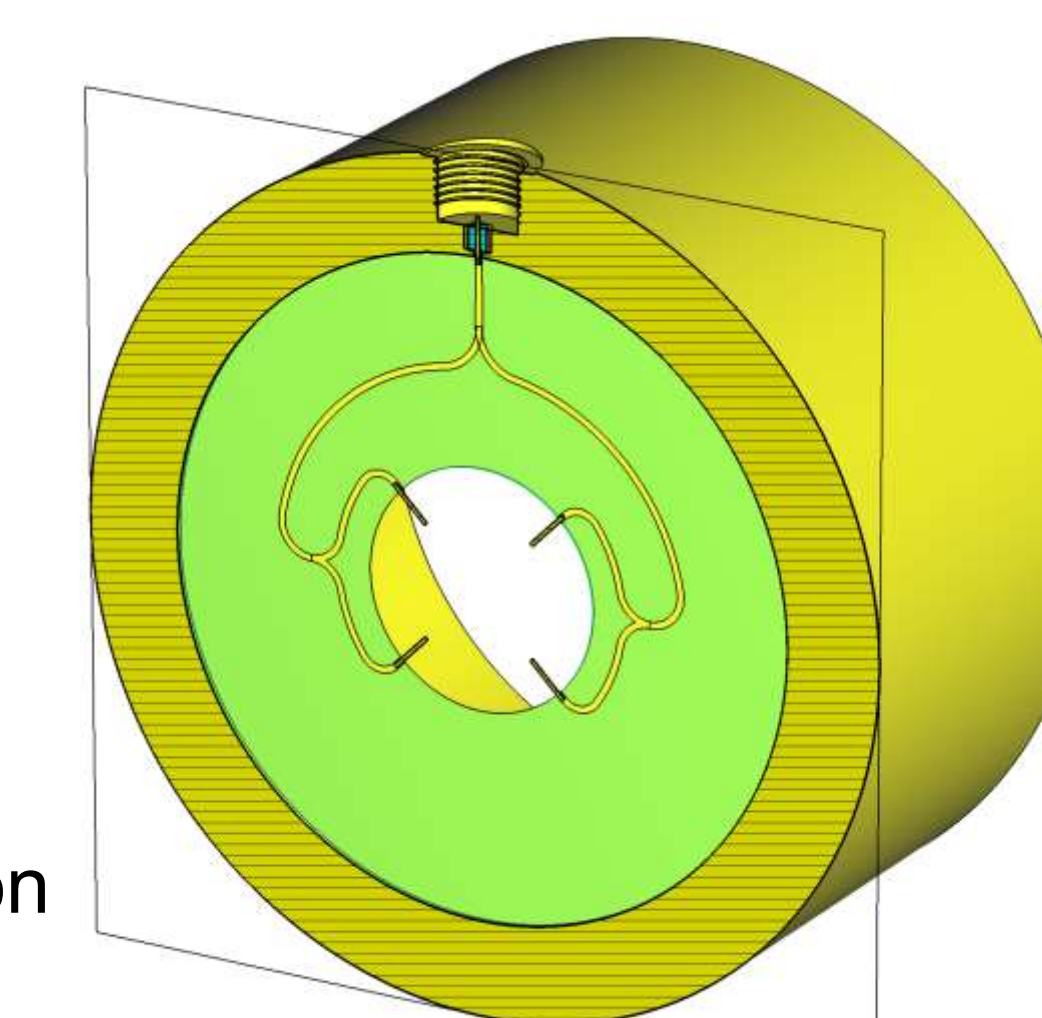
$$171.6 \frac{\text{mV}}{\text{ps pC}}$$

Advantages:

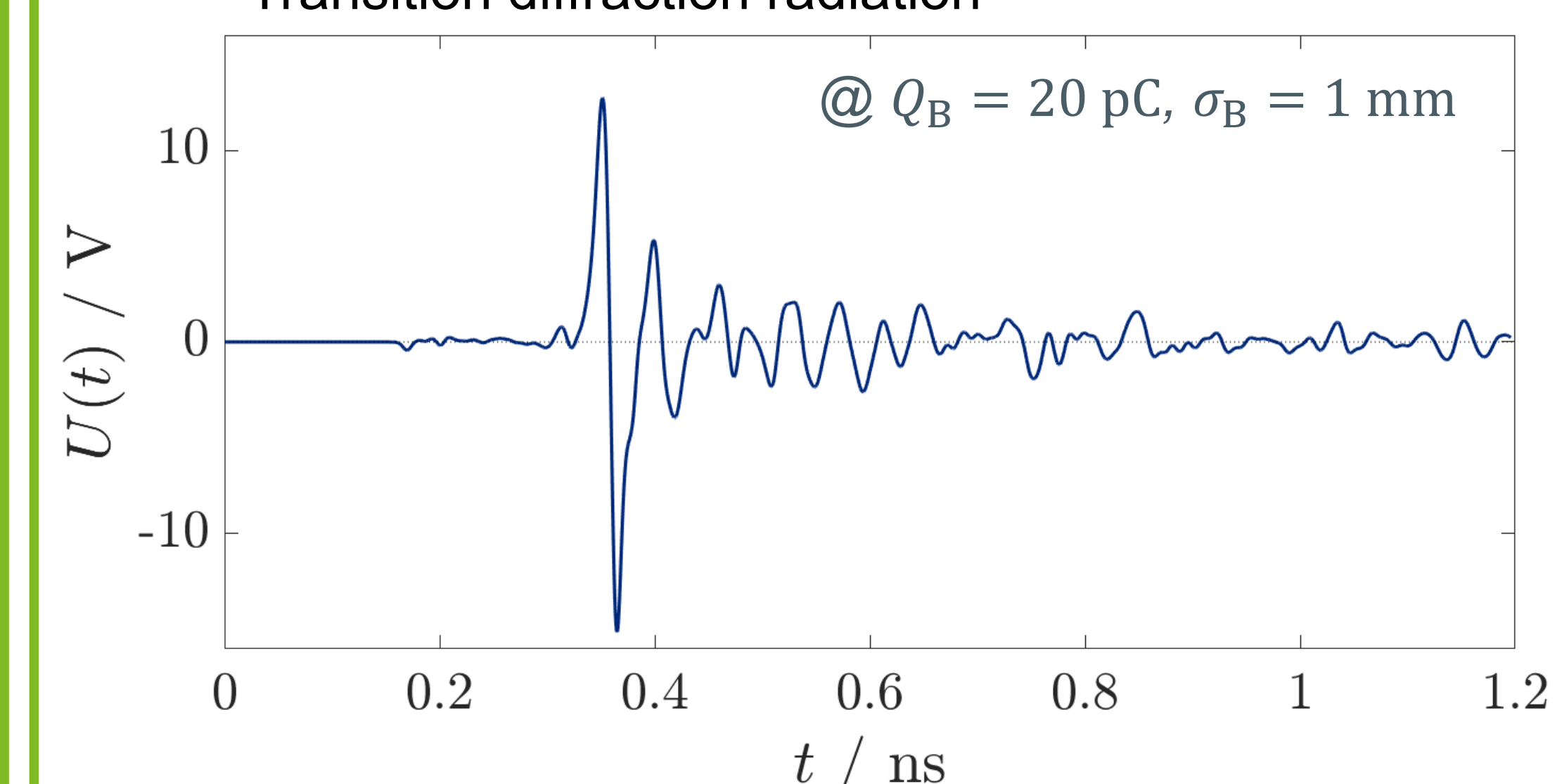
- Close to the bunch
- Large effective area
- Integrated combination network

Drawbacks:

- Strong ringing
- Transition diffraction radiation



Cross-section of the CST model.



Simulated output voltage after the feedthrough (v-type).

SUMMARY AND OUTLOOK

- 80 % of the project goal using rod-shaped pickups
- Simulations validated by S-parameter measurements
- 114 %** with integrated PCB combination network

Foreseen measurements:

- Use a 67 GHz VNA
- Build an hermetic demonstrator
- Use pulse generator or e.g. ARES
- Build PCB combination network

Further simulations:

- Wakefield treatment
- Optimization of pickup geometry and combination network

REFERENCES AND FURTHER READINGS

- A. Angelovski et al., "Pickup signal improvement for high bandwidth BAMs for FLASH and European - XFEL", IBIC'13, Oxford, Sep. 2013, paper WEPC40, pp. 778-781.
- F. Löhl et al., "Electron bunch timing with femtosecond precision in a superconducting free-electron laser", Phys. Rev. Lett., Vol. 104, No. 14, 2010. doi:10.1103/PhysRevLett.104.144801