Bio-Inspired Information Processing

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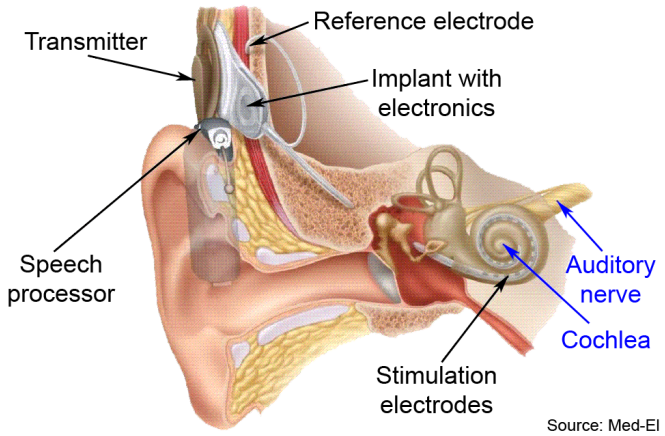
Bernstein Center for Computational Neuroscience Munich

IMETUM Zentralinstitut für Medizintechnik

TECHNISCHE UNIVERSITÄT MÜNCHEN

Modeling:

- Neuronal sound processing in the auditory brainstem
- Sound localization
- Electrical- & optical stimulation of neurons
- Coding strategies for cochlear implants
- Automatic speech recognition



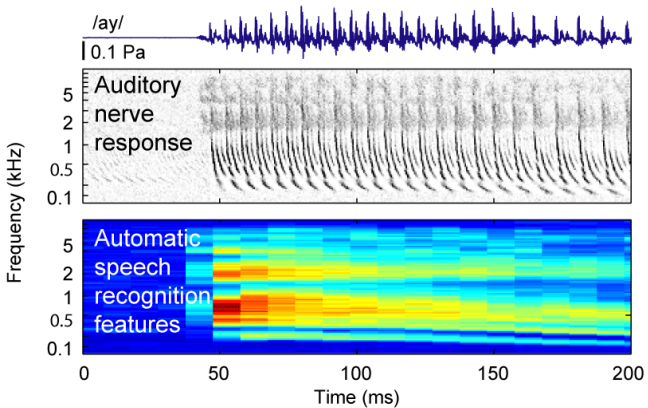
Source: Med-El

Experimental:

- Psycho“acoustical” investigations on patients with cochlear implants
- Reference measurements with normal hearing subjects

Technology:

- Objective measurements for cochlear implants: eCAP, eBERA, current spread in the inner ear
- Binaural synthesis
- Microsystemtechnology and micromechanics



Location: IMETUM, Garching **www.bai.ei.tum.de**

Mitarbeiter


Werner Hemmert


Dr. Sonja Karg


Dr. Florian Völk


Dr. Siwei Bai


Jörg Encke


Stefanie Keller


Christian Wirtz


Robin Weiss

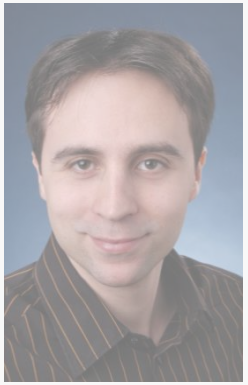

Miguel Obando


Andrej Voss

Alumni


Dr. Stefan Zirn


Michele Nicoletti


Michael Isik


Marek Rudnicki

Agenda

1. Einführung Neuroprothetik
2. Biophysikalische und physiologische Grundlagen
3. Das Membranpotential
4. Ionenkanäle
5. Das Aktionspotential
6. Extrazelluläre elektrische Stimulation eines Neurons
7. Kabelgleichung und Aktivierungsfunktion, EVALUATION
8. Das Hörorgan
9. Neuronale Verarbeitung entlang der Hörbahn
10. Aufbau eines Cochleaimplantats
11. Elektrochemie und Biokompatibilität
12. Prüfungsvorbereitung

Diplomarbeit: Messung der akustischen Eingangsimpedanz des Gehörs bei niedrigen Pegeln

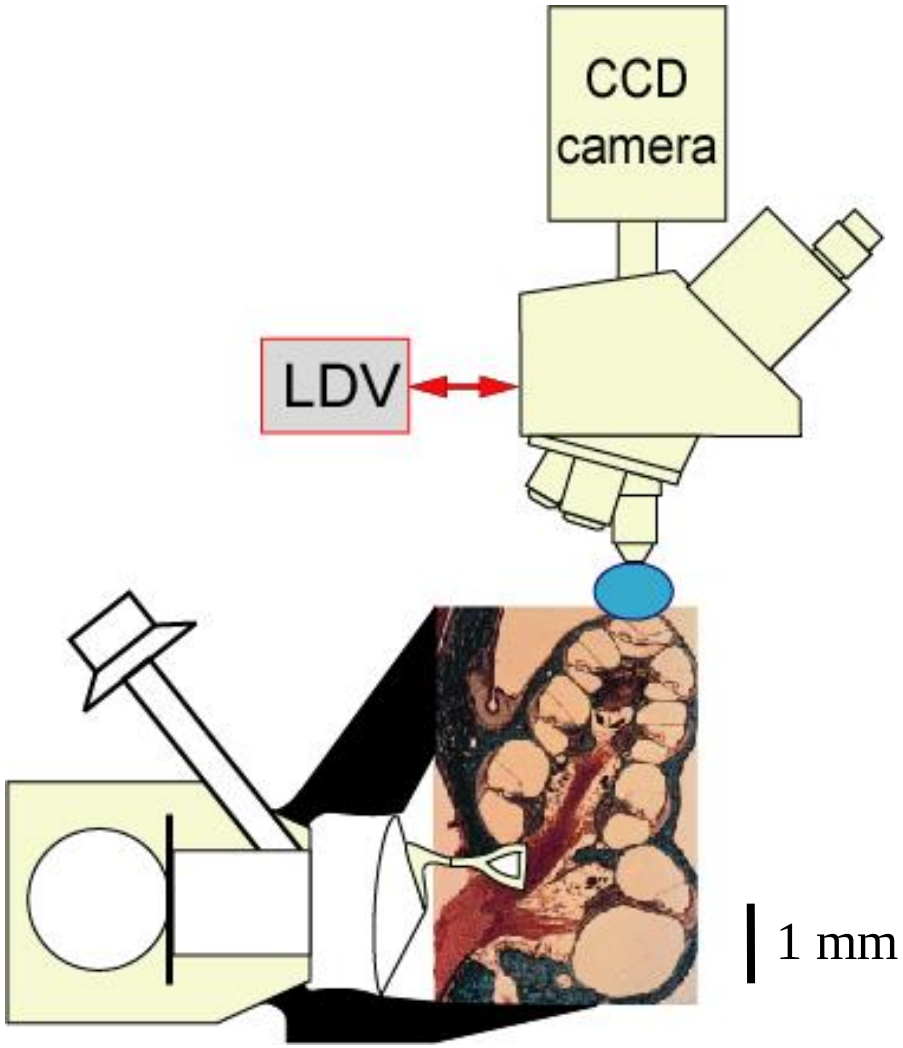
In memory of

Prof. Dr.-Ing. Eberhard Zwicker

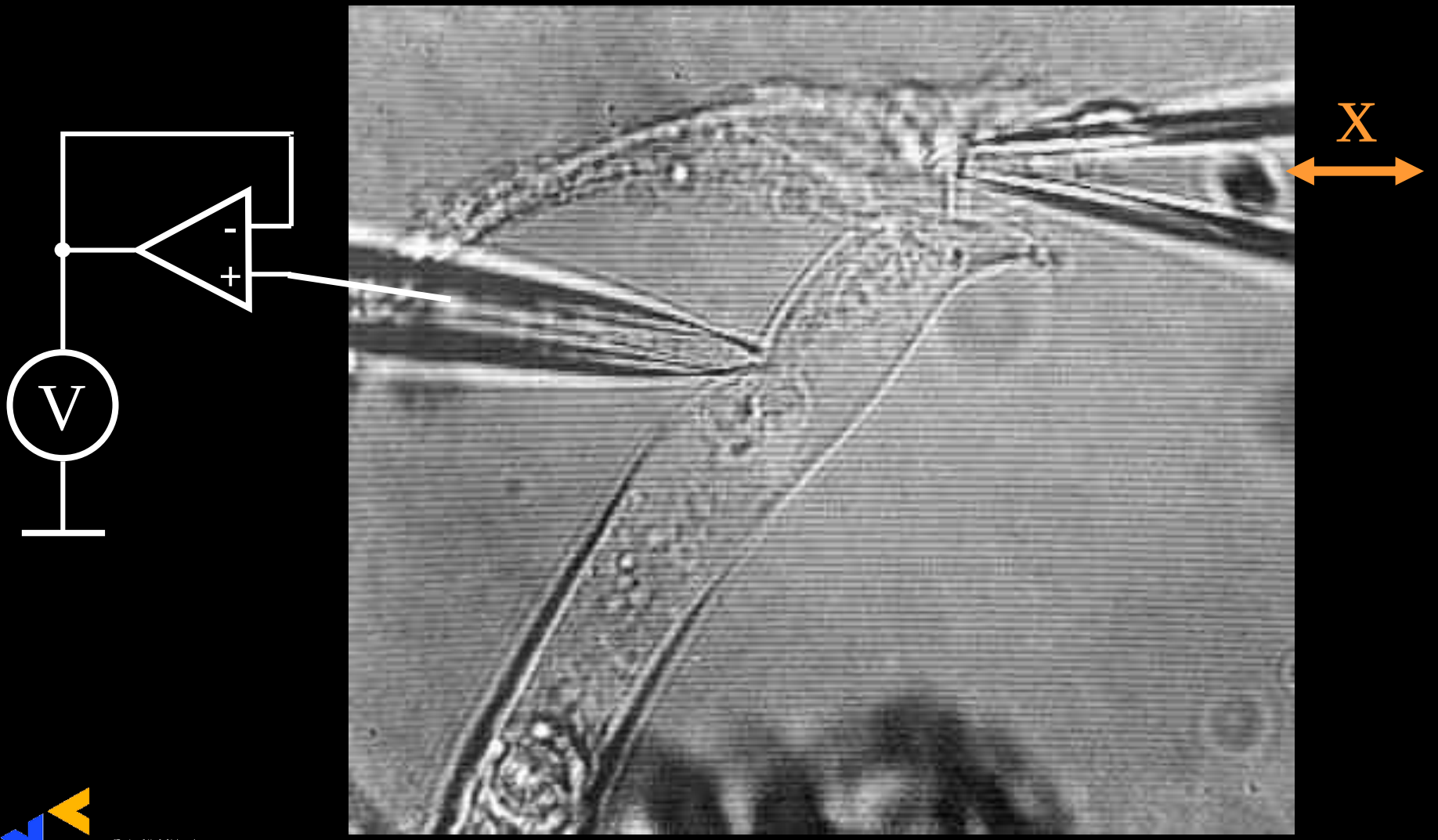
(Jan. 15 1924 - Nov. 24 1990),

my teacher, who loved to build models of the inner ear.

Vibration measurements

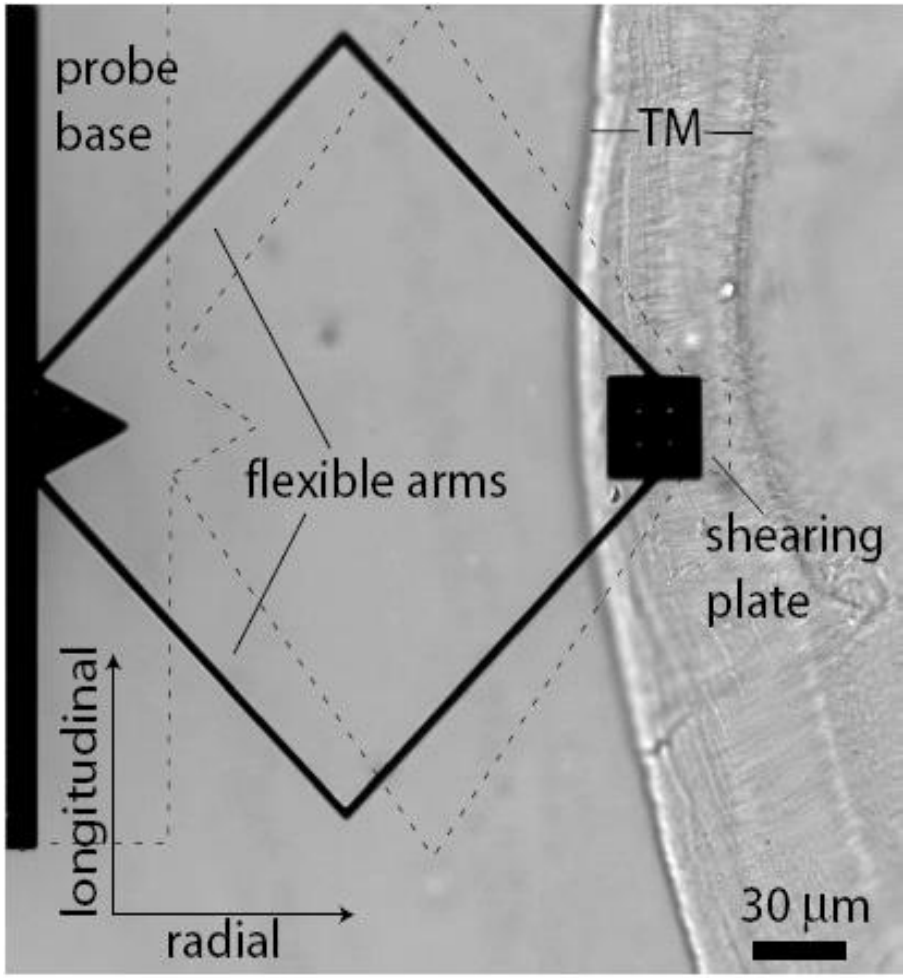


OHC Receptor Potential

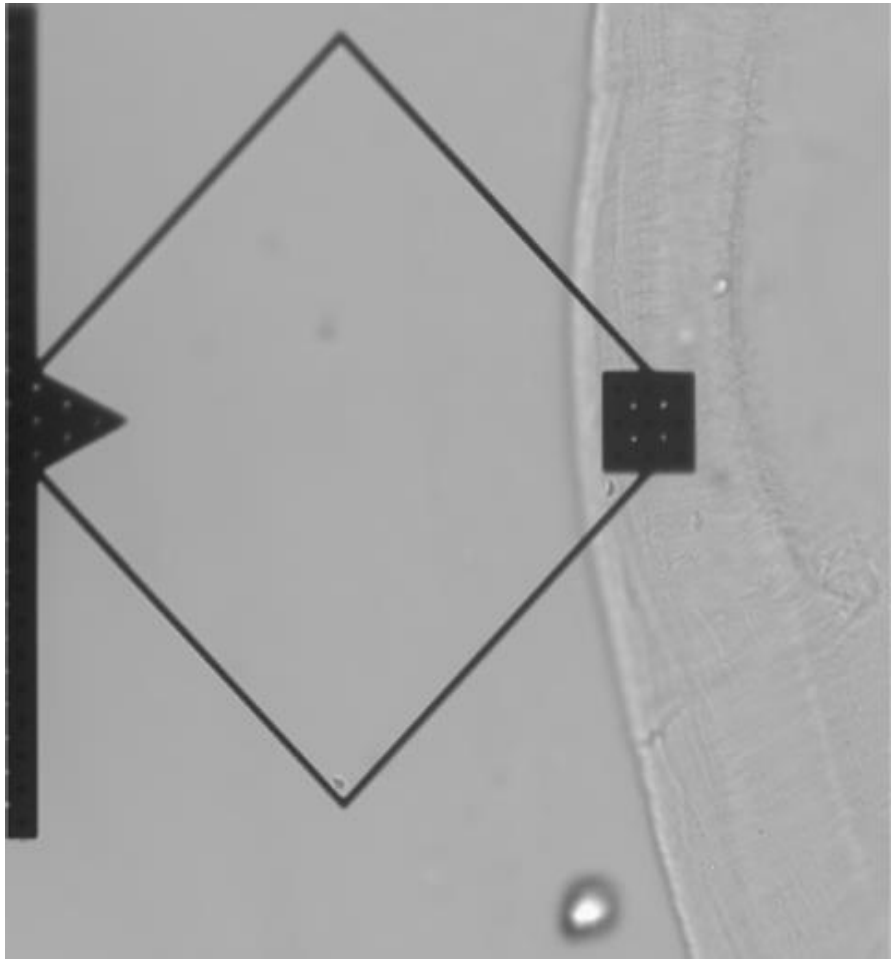


Preyer, Hemmert, Pfister, Zenner & Gummer, Hear.Res. 1994


MASSACHVSETTS INSTITVTE

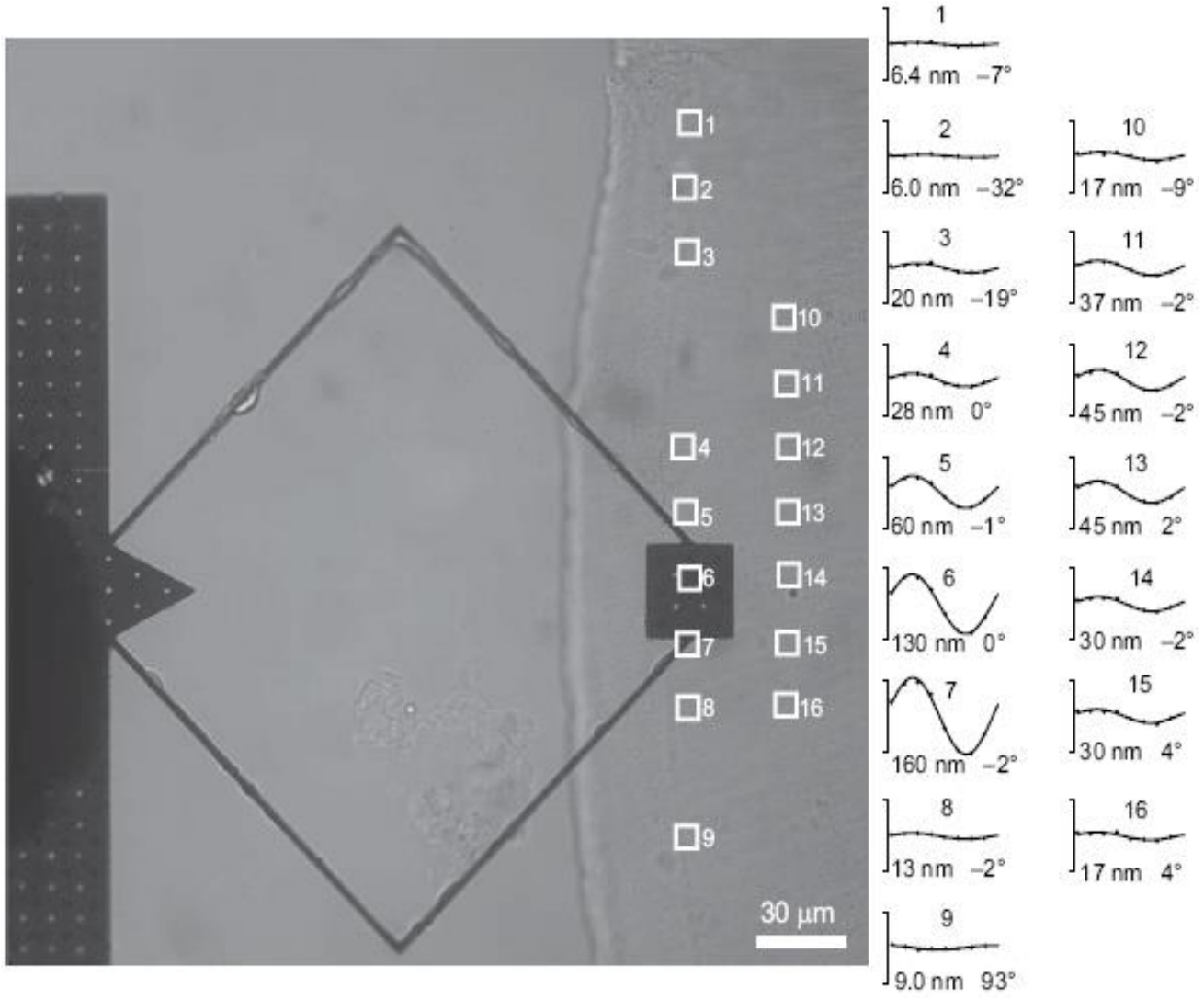


Gu, Hemmert, Freeman & Aranyosi J.Biophys. 2007



Micromechanics Group, M.I.T.

Gu, Hemmert, Freeman & Aranyosi J.Biophys. 2007



Gu, Hemmert, Freeman & Aranyosi J.Biophys. 2007

Micromechanical Cochlea - 1st Prototype

Werner Hemmert

IBM Zürich Research Laboratory

G. Retzius (1884)

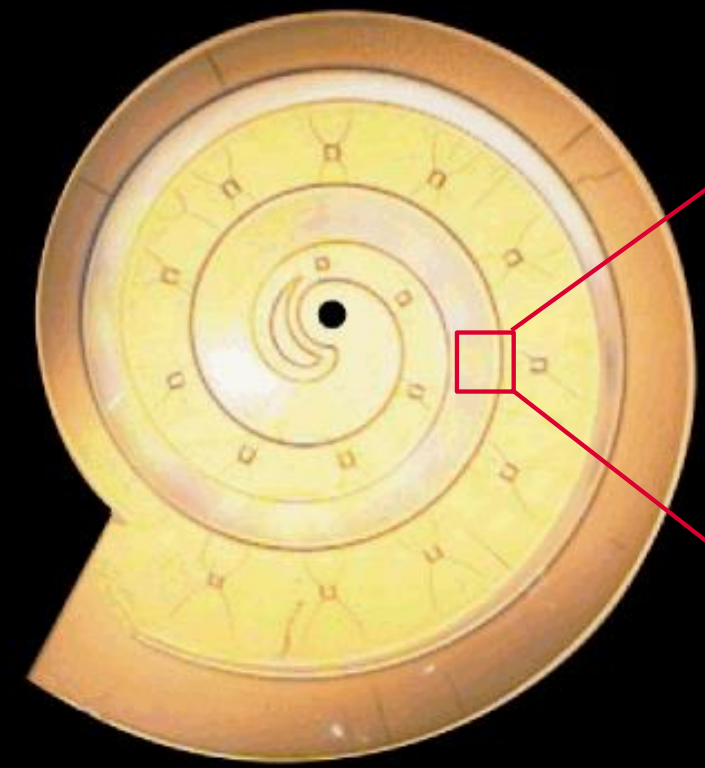
2 mm

Micromachined Cochlea

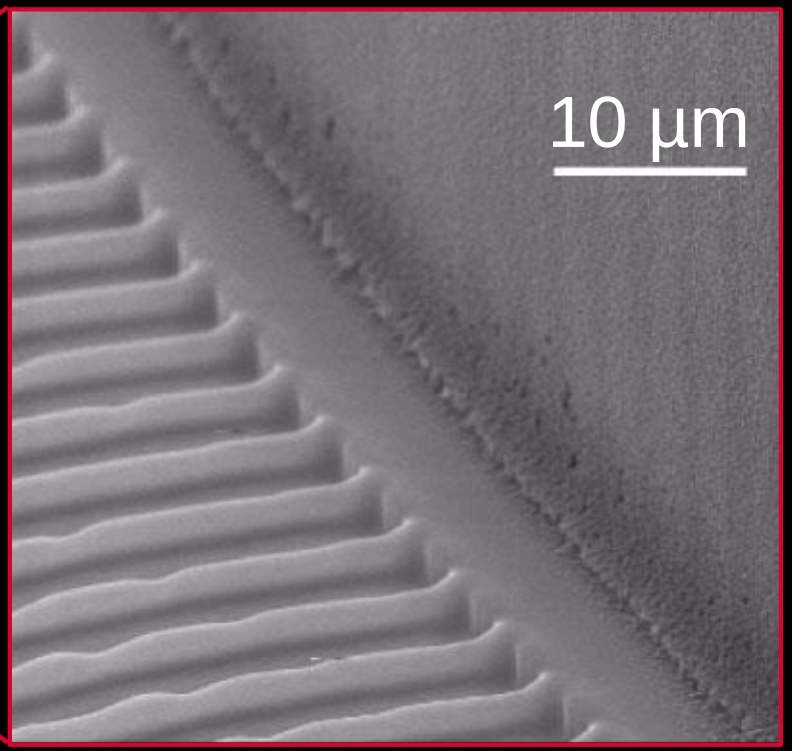
Micromechanical Cochlea - 1st Prototype

Werner Hemmert

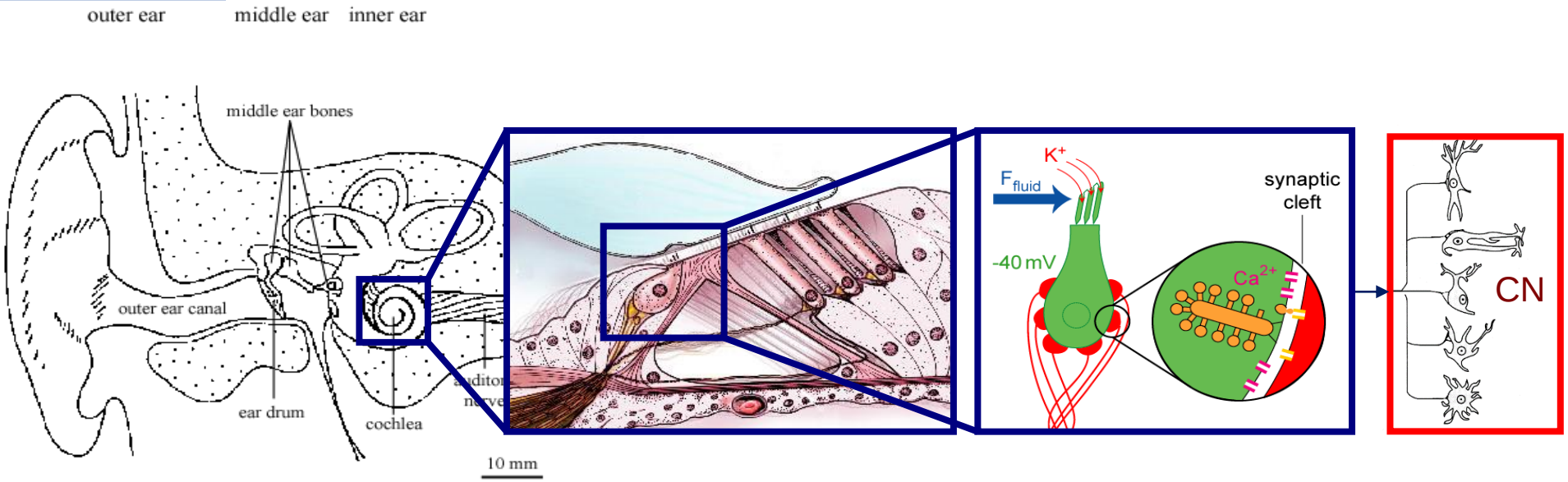
IBM Zürich Research Laboratory

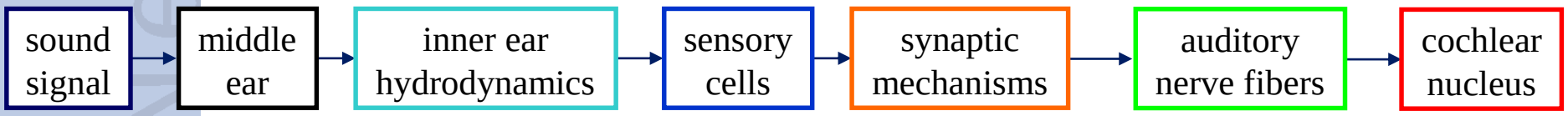


2 mm

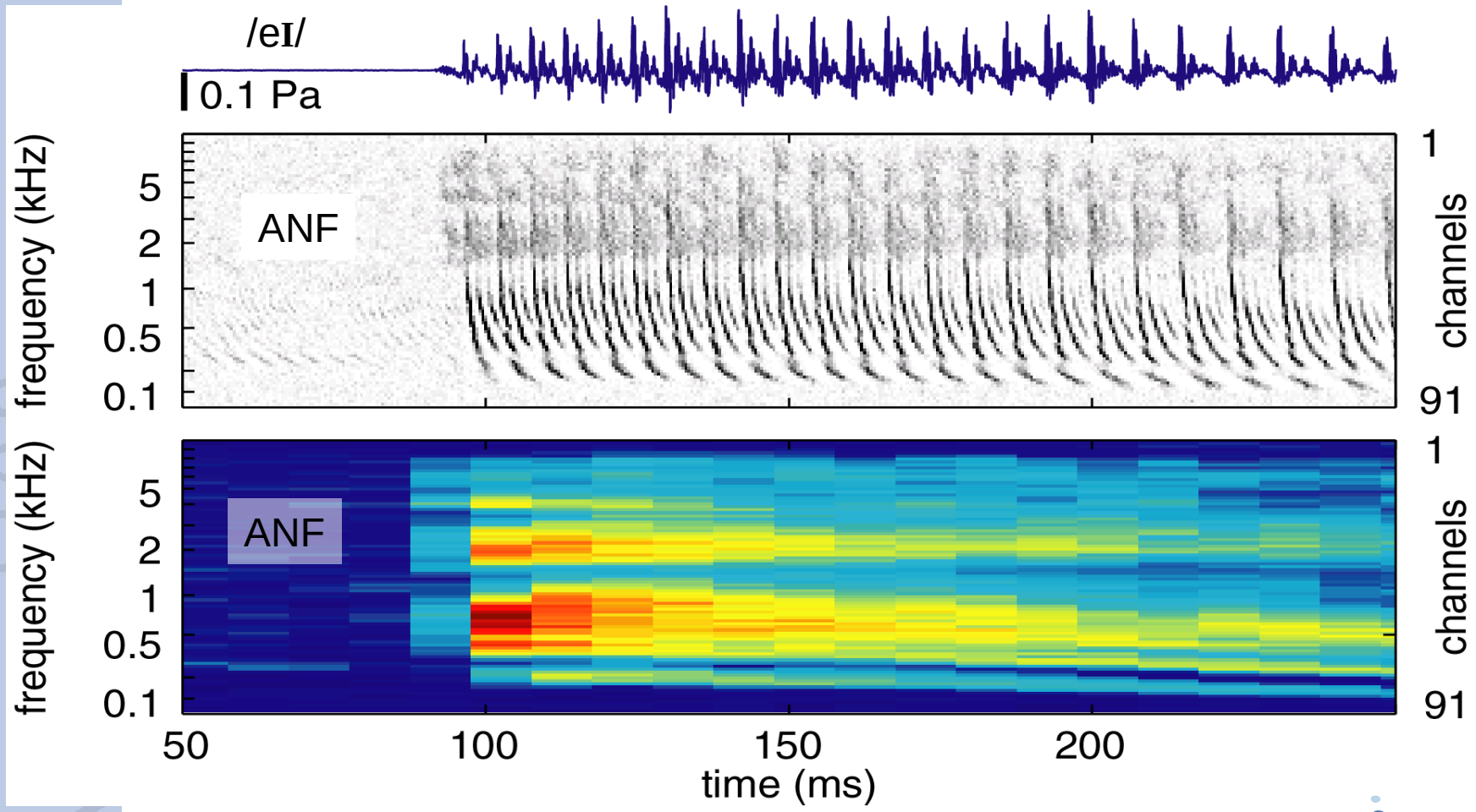


Model of auditory sound processing





Speech recognition with auditory nerve spike trains



Modeling the Auditory Pathway

Number of Neurons

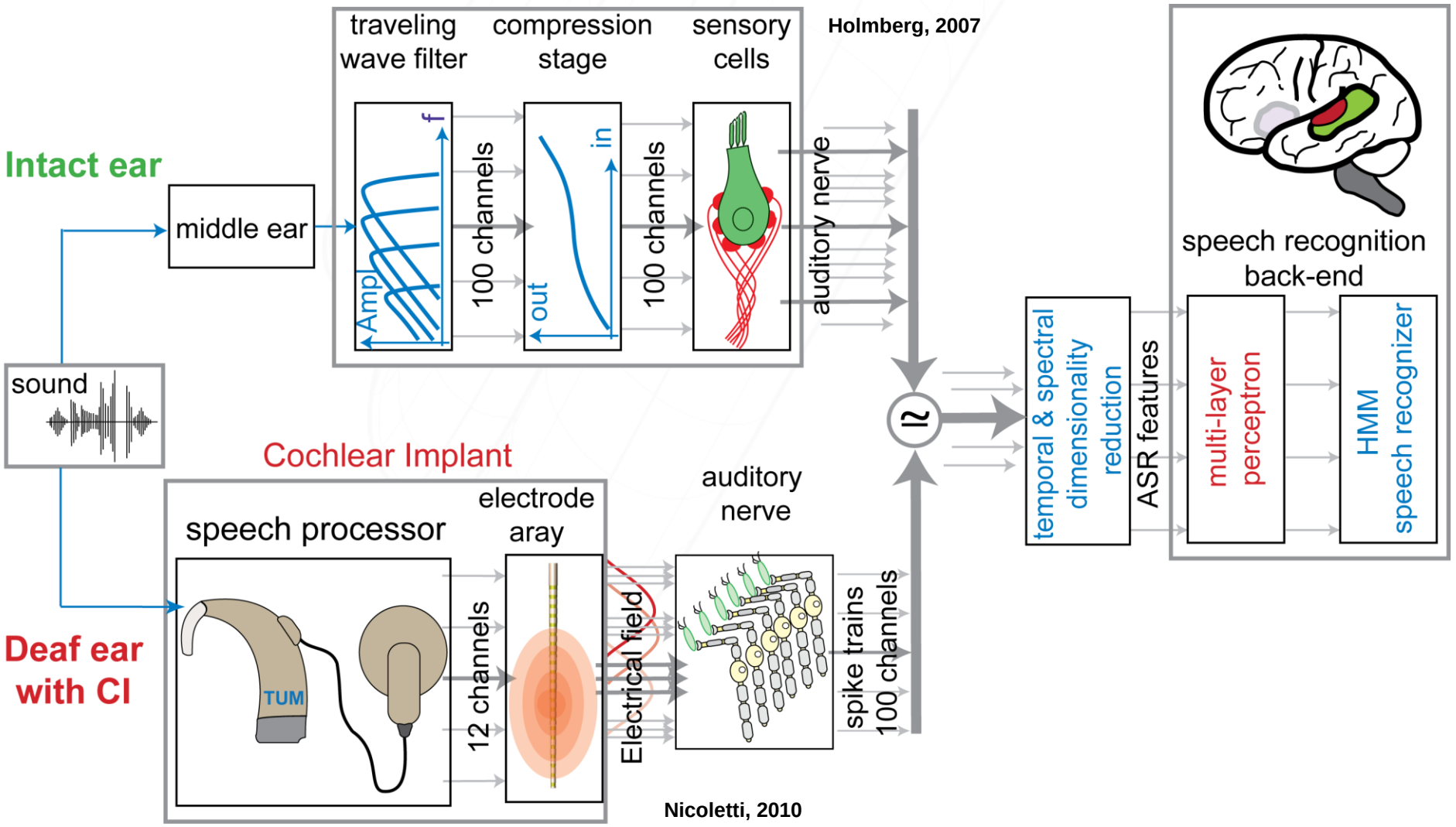
100.000.000

500.000

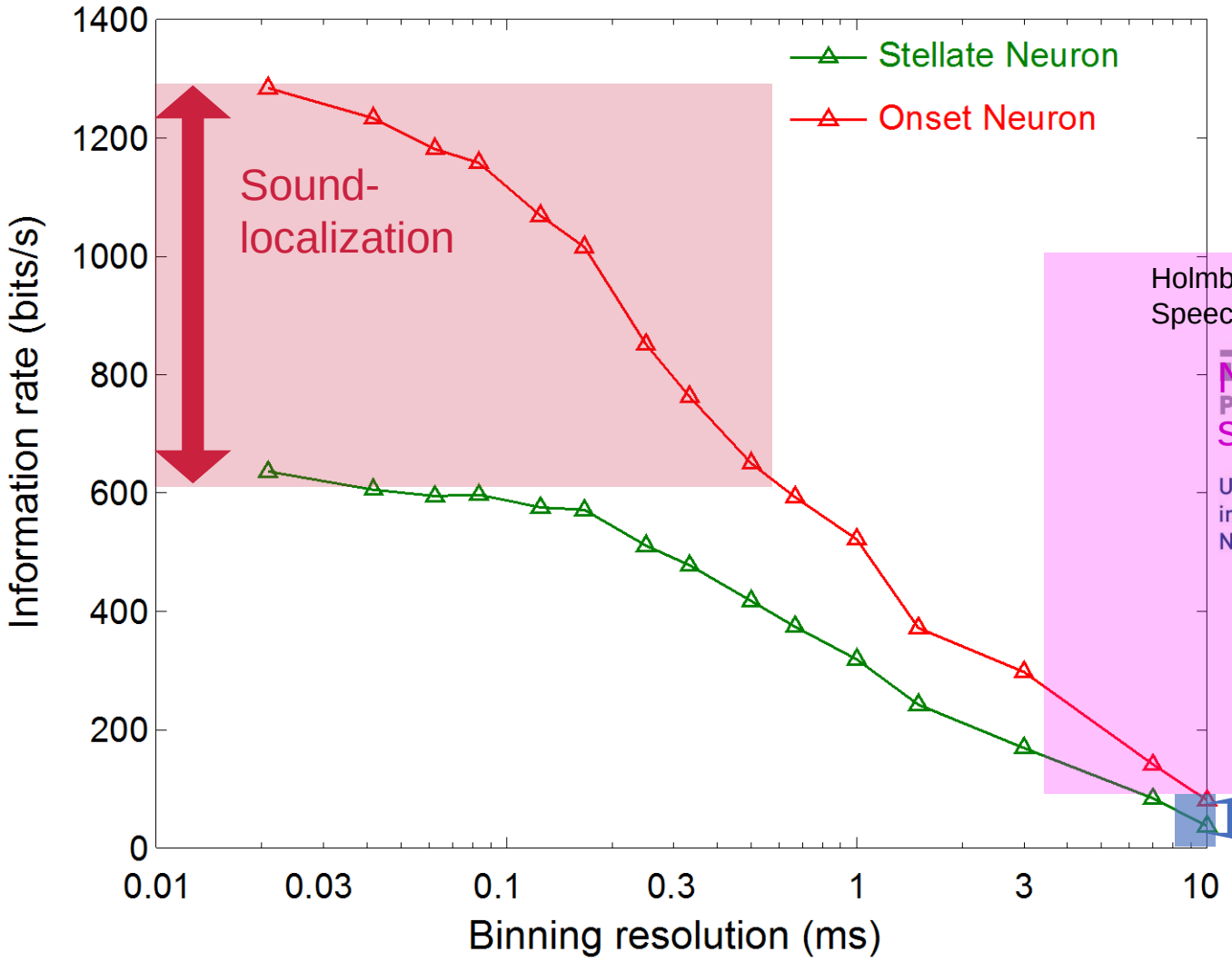
400.000

PhD Comics

Model of auditory sound processing



Temporal resolution of spike trains



BCCN Munich

Holmberg, Gelbart & Hemmert: Speech Comm. (2007)

DFG PP 1608

Noise-robust speech coding

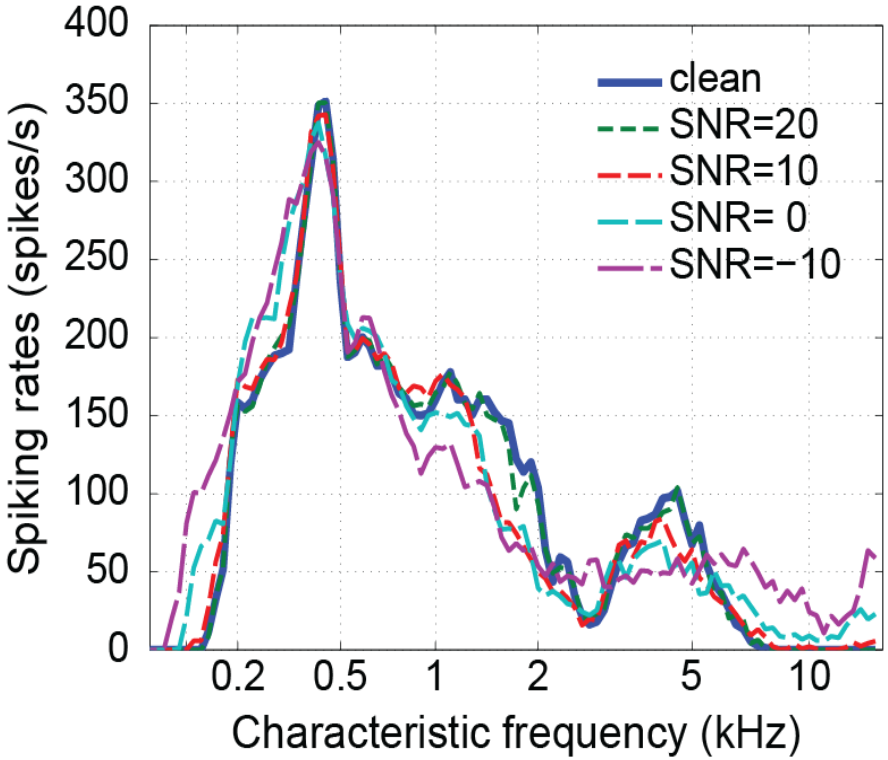
Ultrafast and temporally precise information processing: Normal and dysfunctional hearing

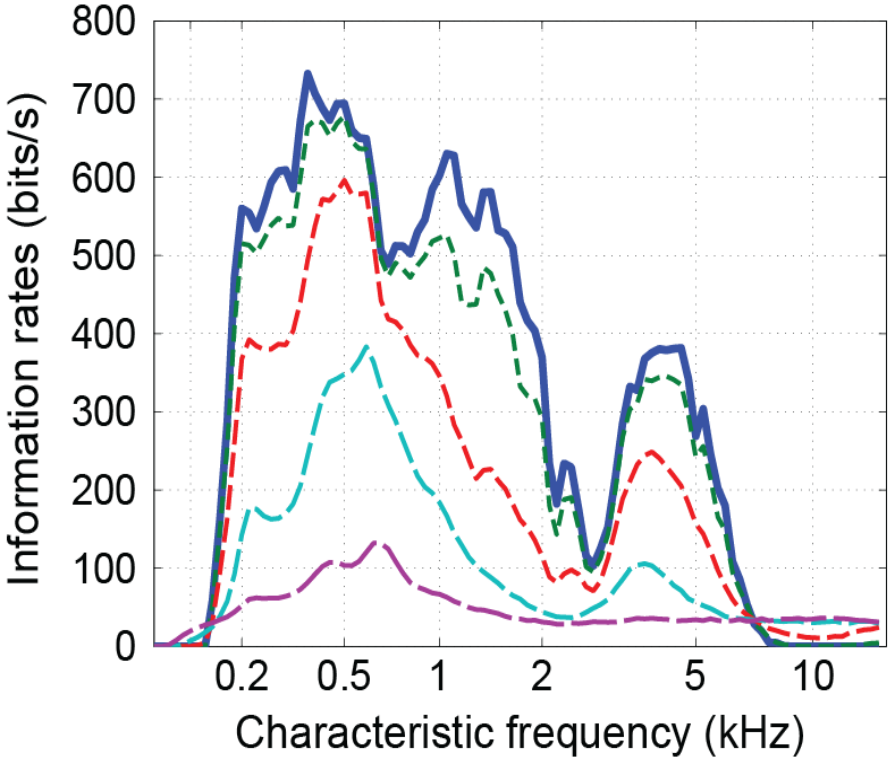
Speech-recognition

Wang, Holmberg and Hemmert: IEEE ICASSP (2006)

Wang, Isik, Borst & Hemmert: J.Comp.Neurosci. (2011)

Spectral information distribution and degradation in noise

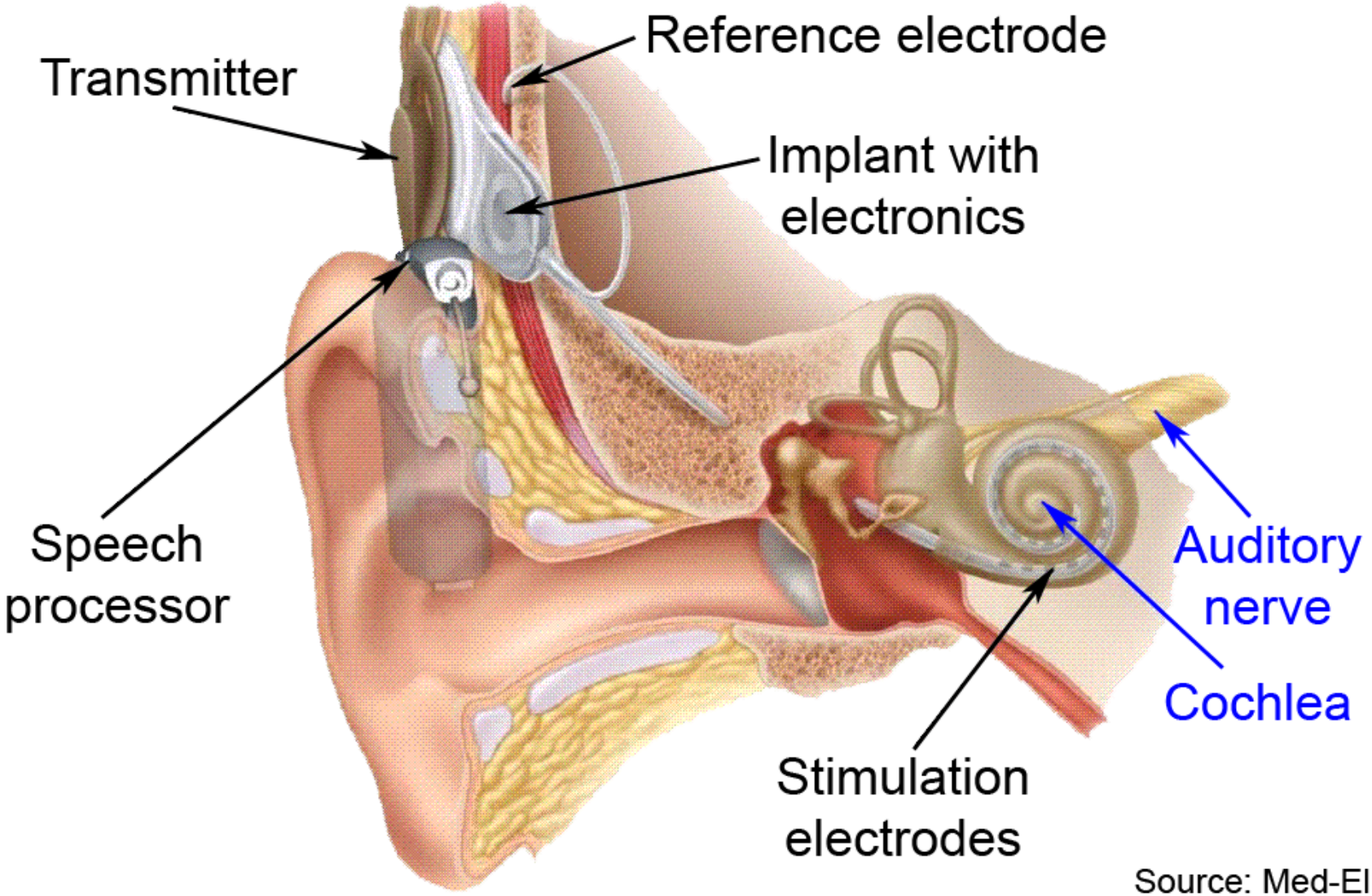




BCCN Munich

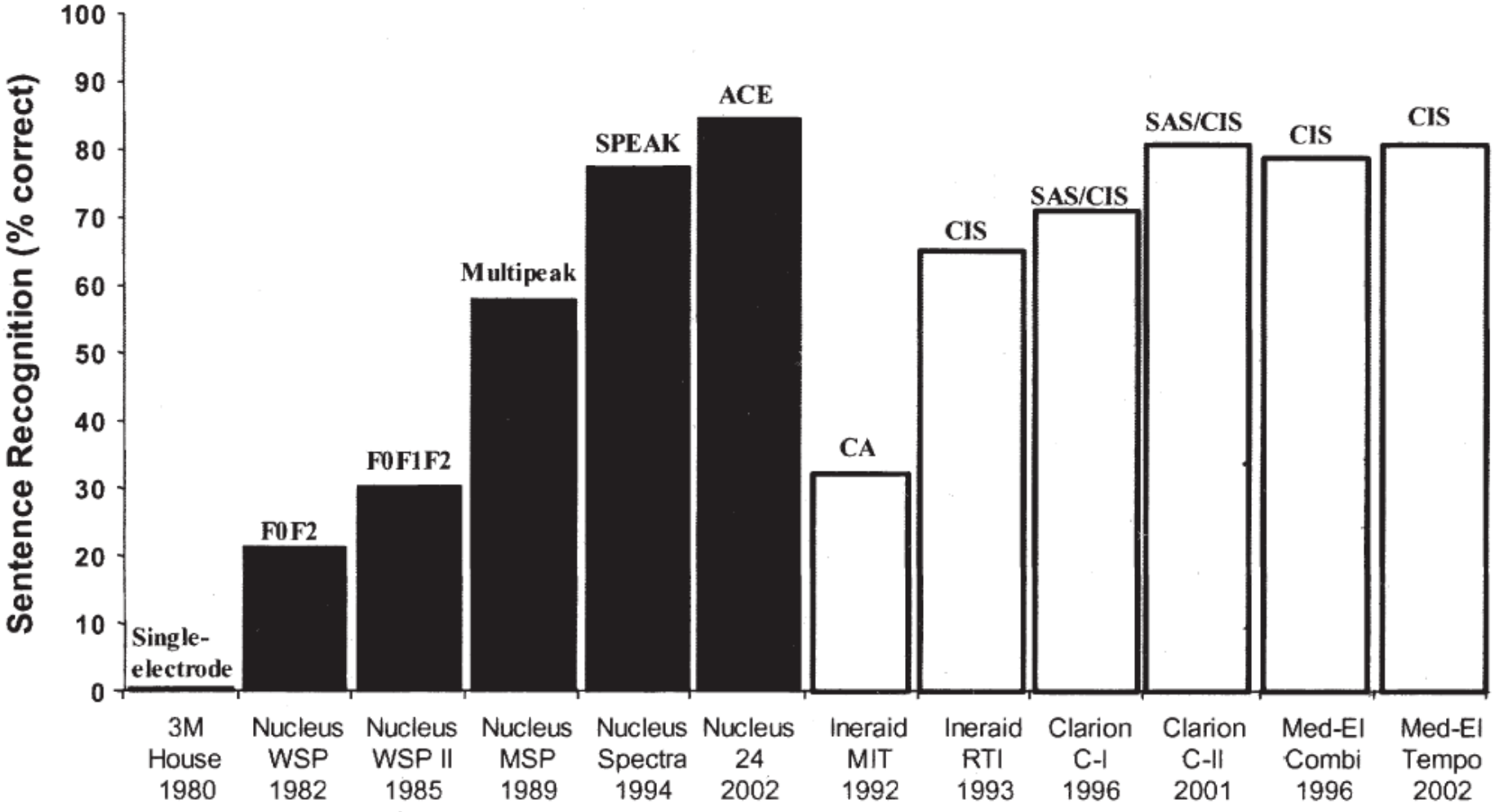
Wang, Borst & Hemmert
J.Comp.Neurosci. submitted

How does a Cochlear Implant work?



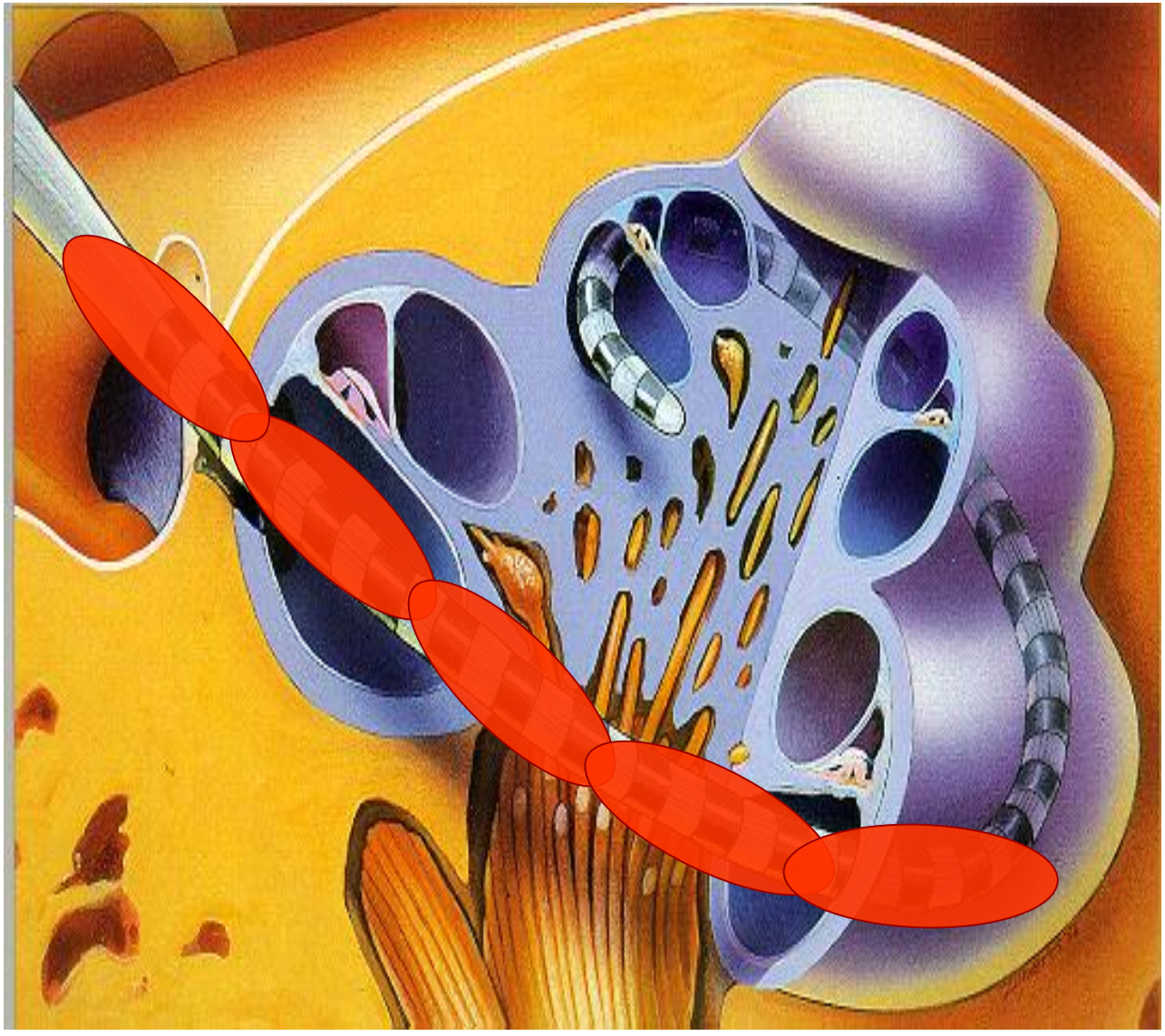
Source: Med-El

Sprachverständnis mit Cochlea Implantaten

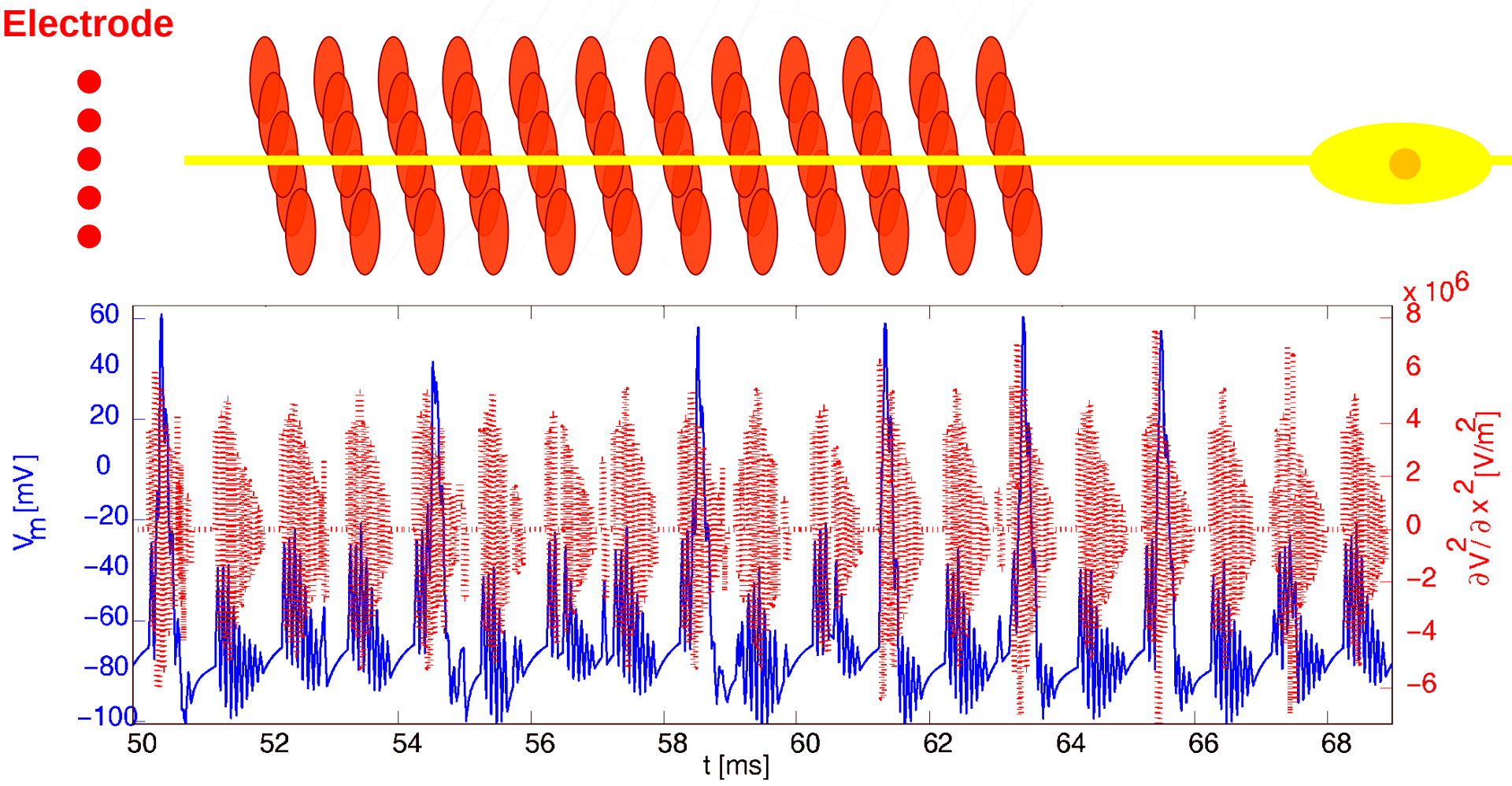


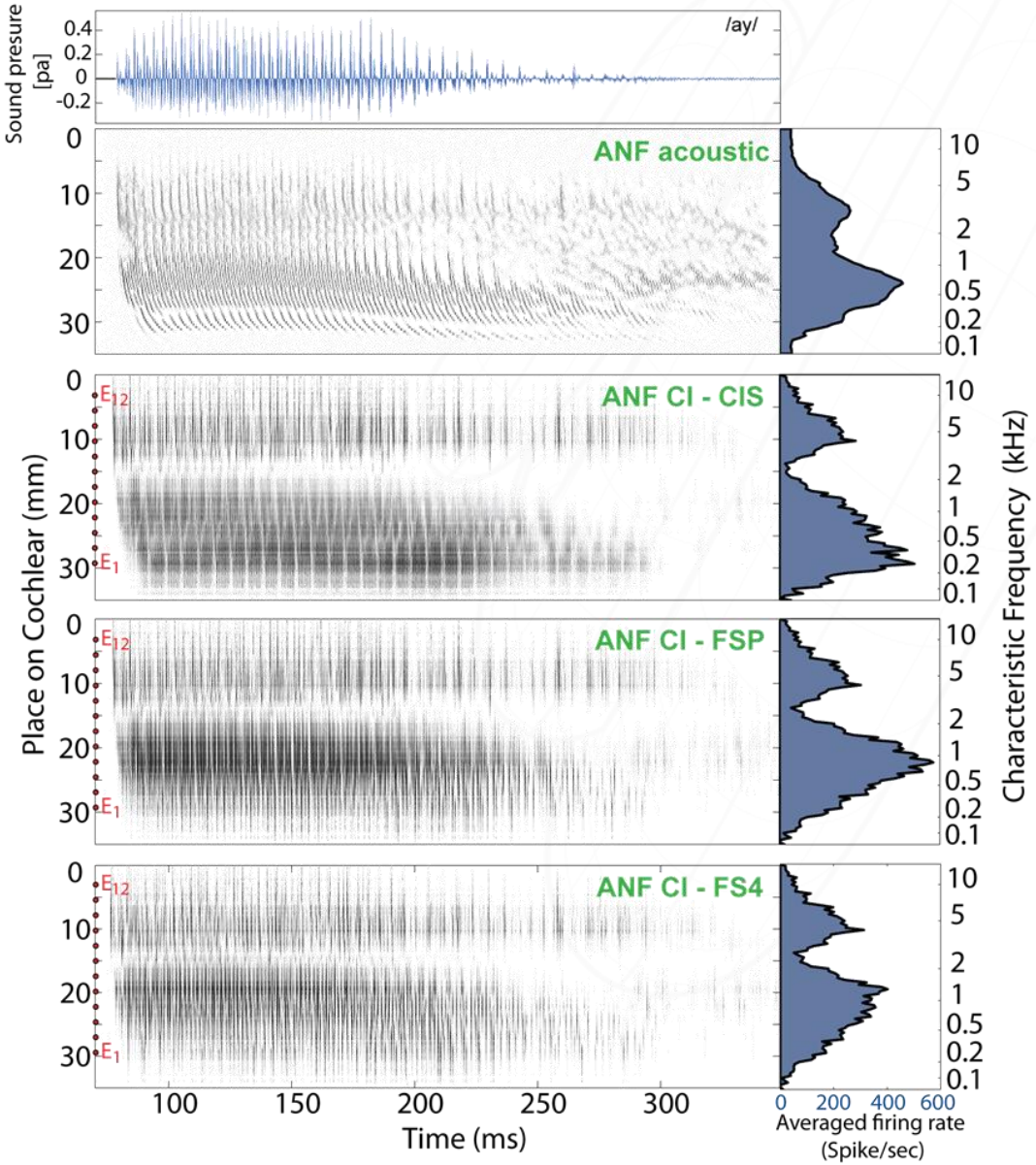
F.-G. Zeng (2004)

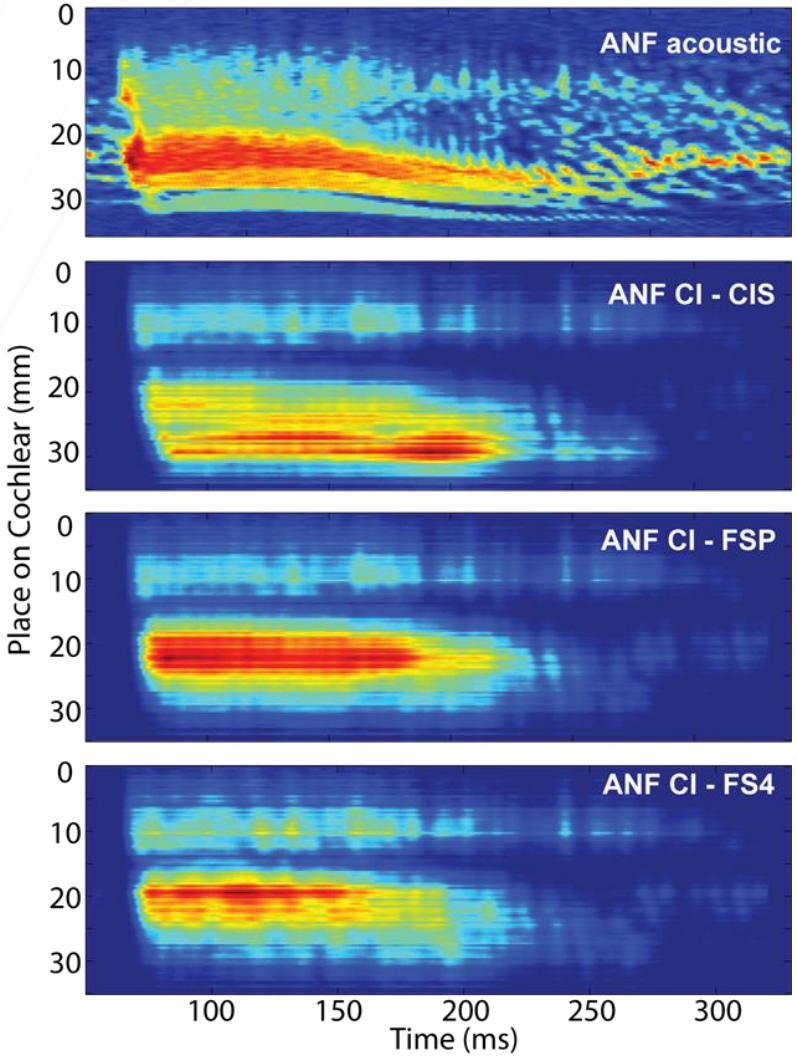
Channel Crosstalk and Interleaved Sampling



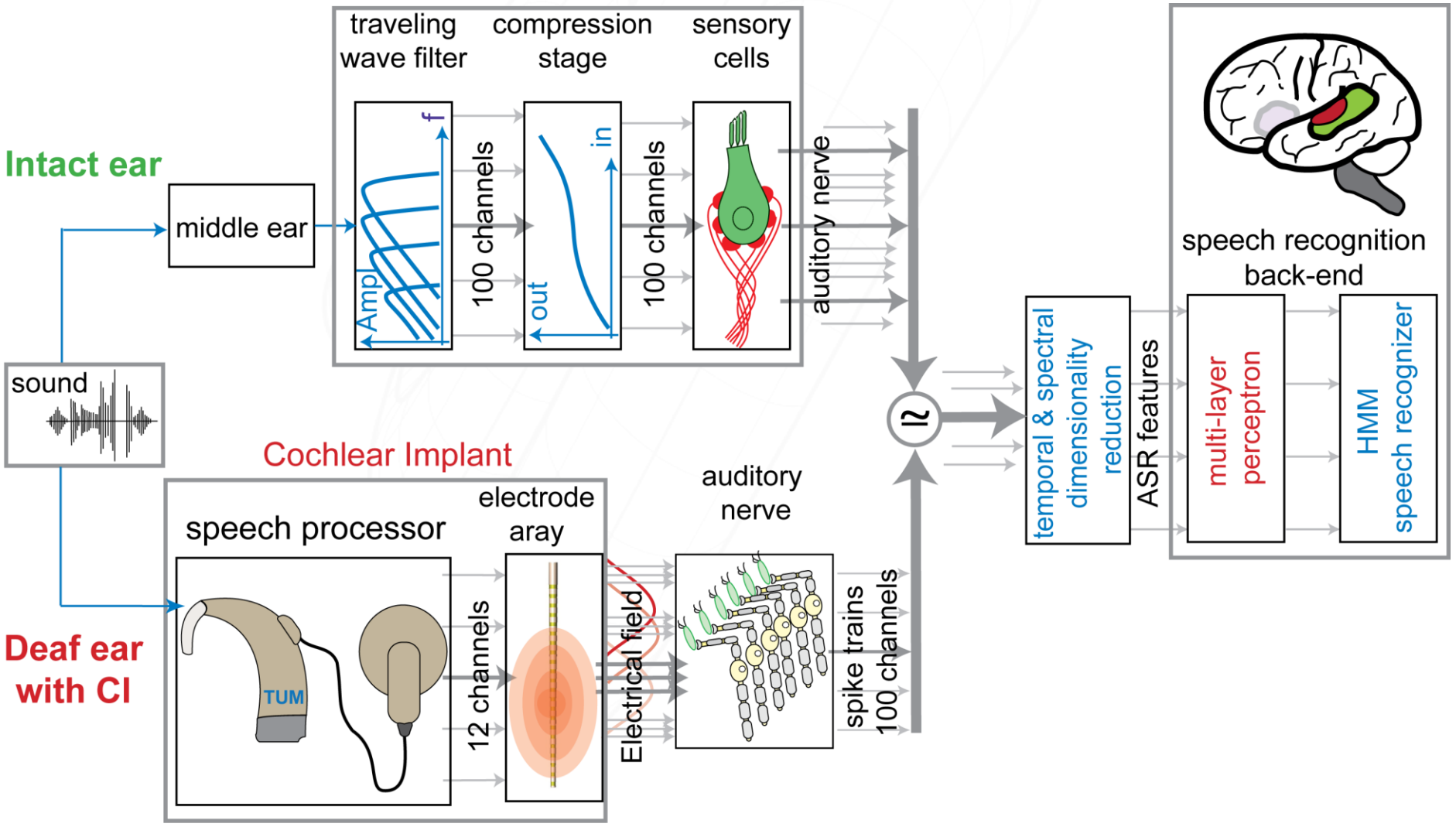
Electrical Excitation of a Neuron




Sound presure [pa]
/ay/
ANF acoustic
ANF CI - CIS
ANF CI - FSP
ANF CI - FS4
E12
E1
Place on Cochlear (mm)
Characteristic Frequency (kHz)
Time (ms)
Averaged firing rate (Spike/sec)

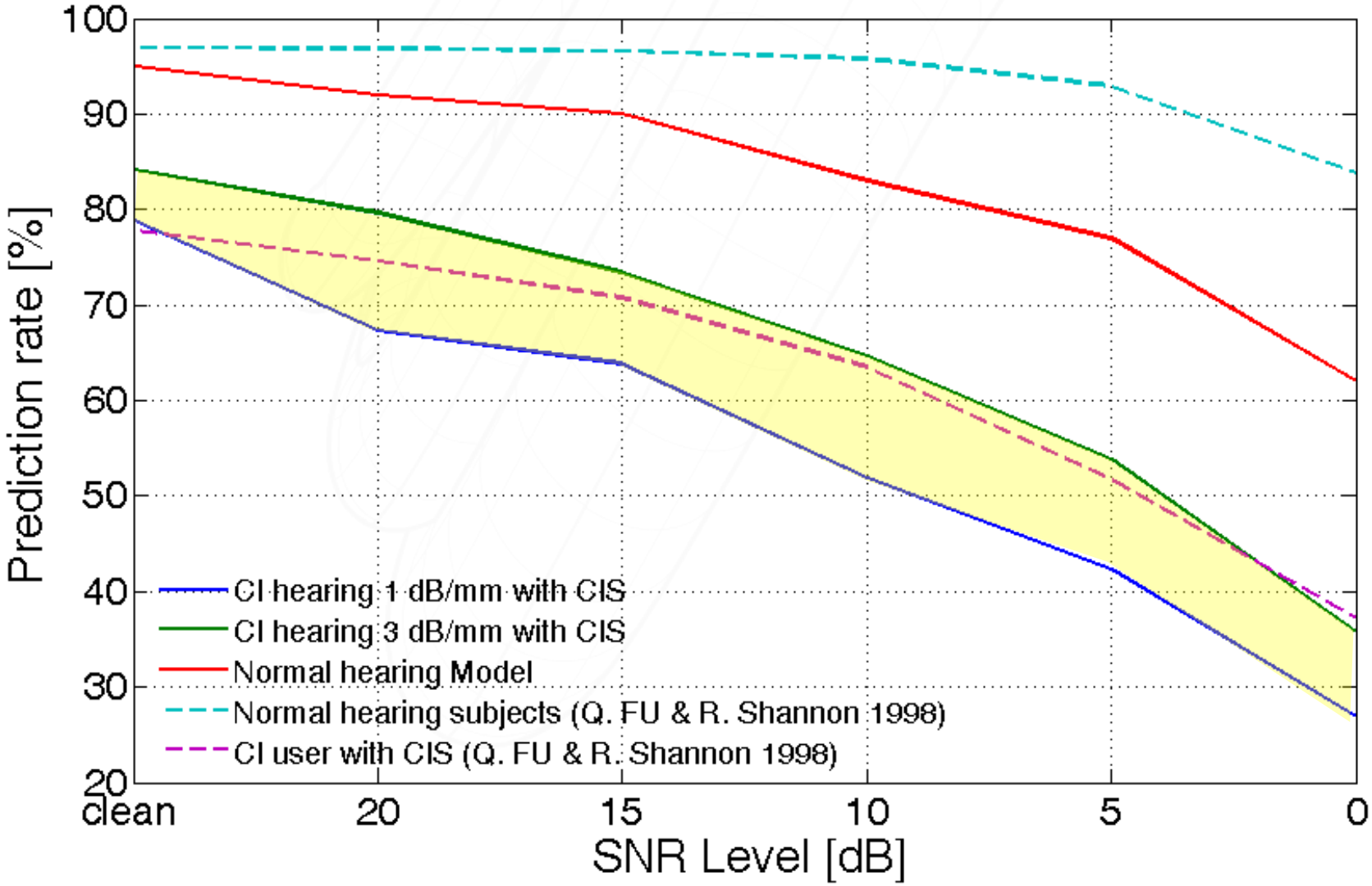

ANF acoustic
ANF CI - CIS
ANF CI - FSP
ANF CI - FS4
Place on Cochlear (mm)
Time (ms)

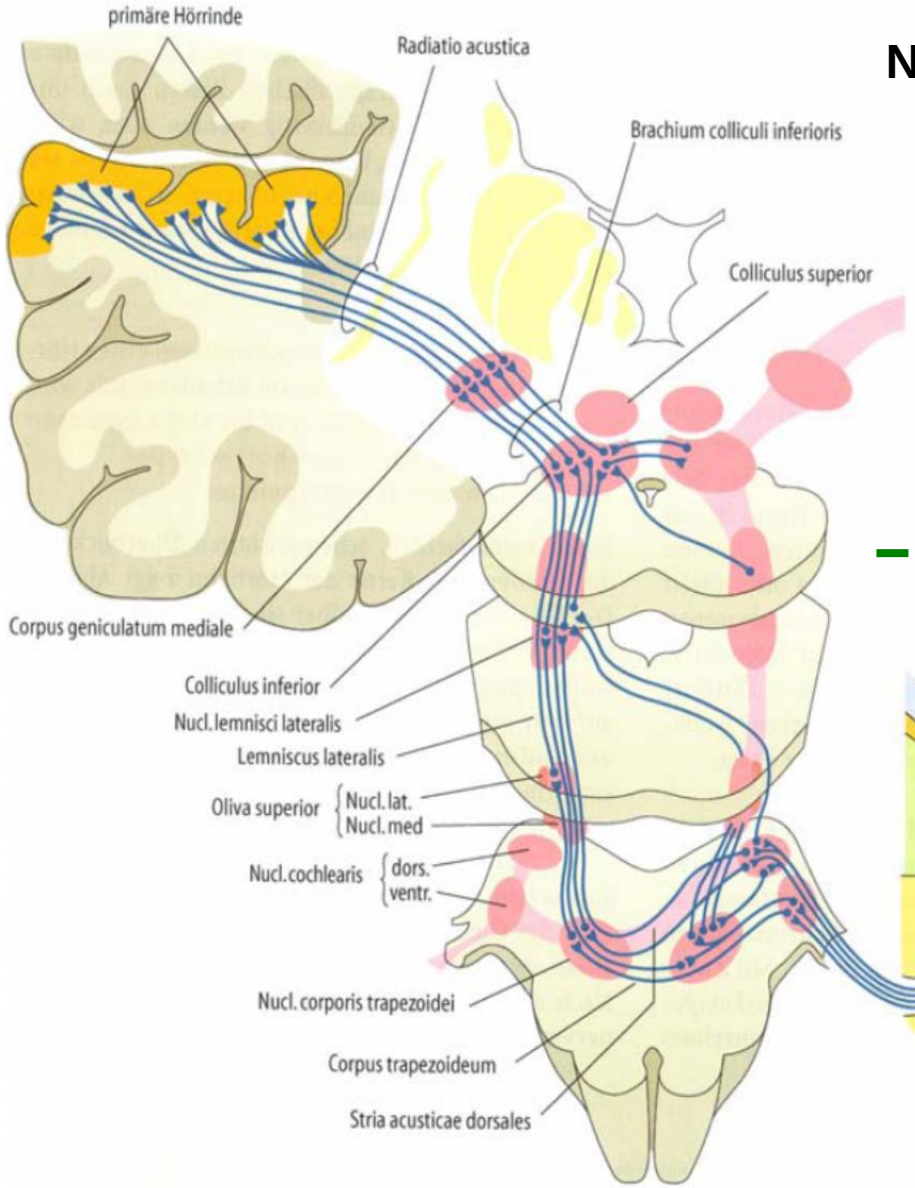
Holmberg, 2007



Nicoletti, 2010

Evaluation of speech coding





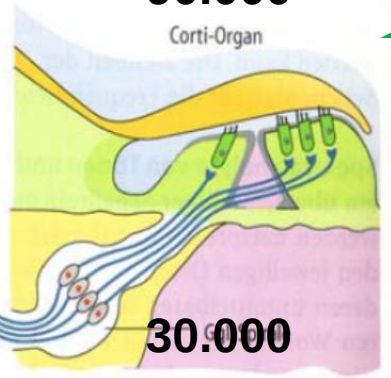
Number of Neurons

100.000.000

500.000

400.000

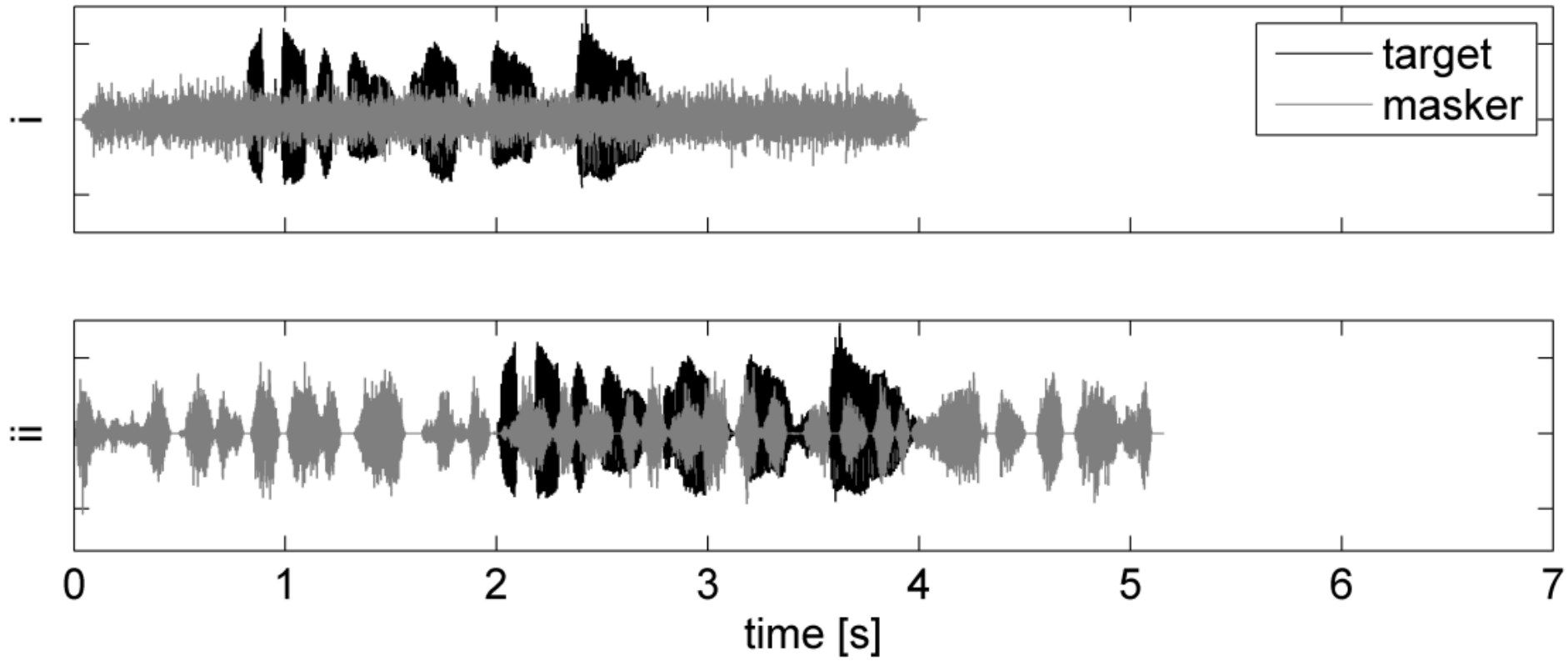
90.000



30.000

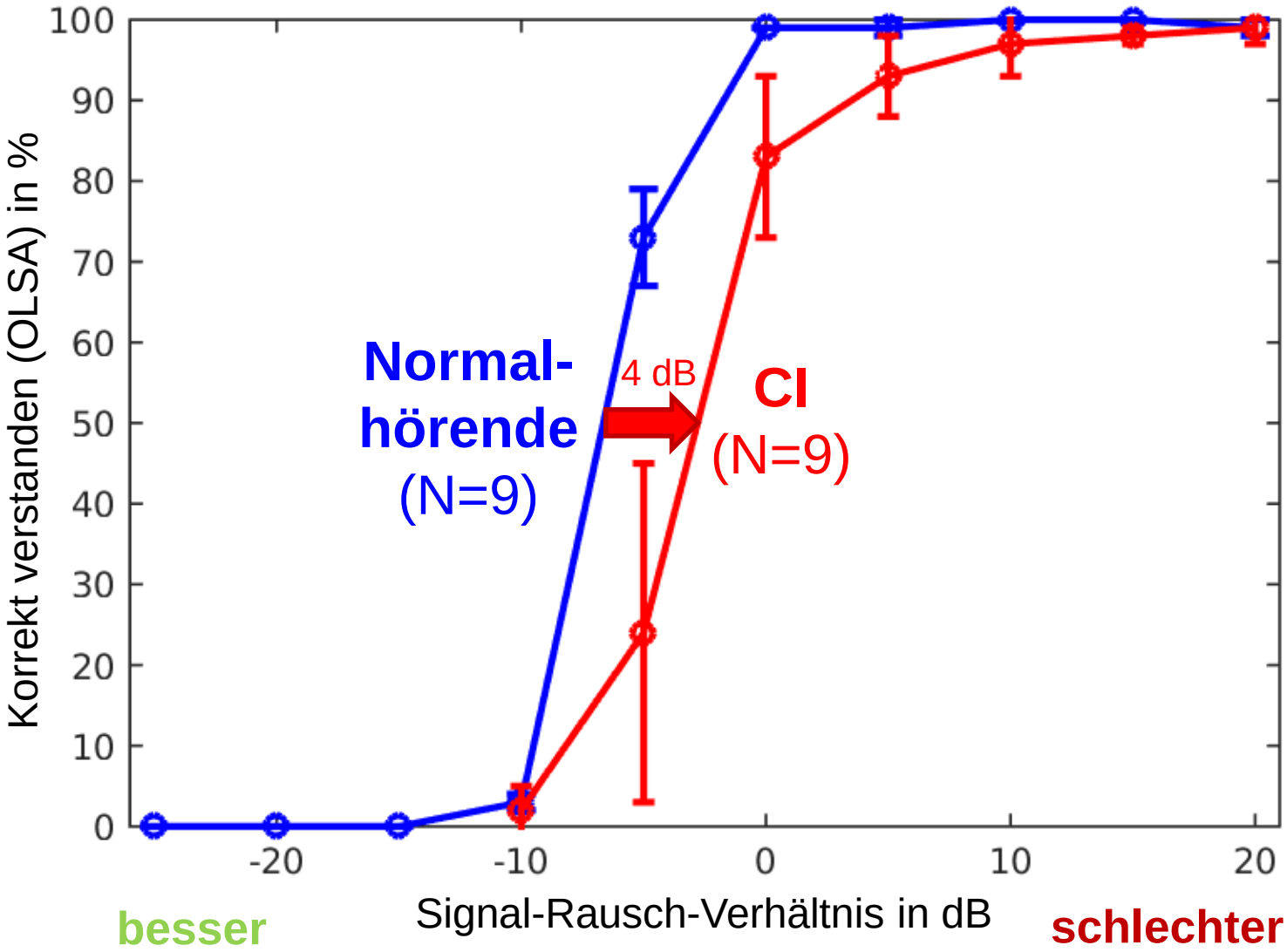
PhD Comics

Sprache in Störgeräuschen



Zirn, Keller, Polterauer & Hemmert: Int. J. Audiol. (2016)

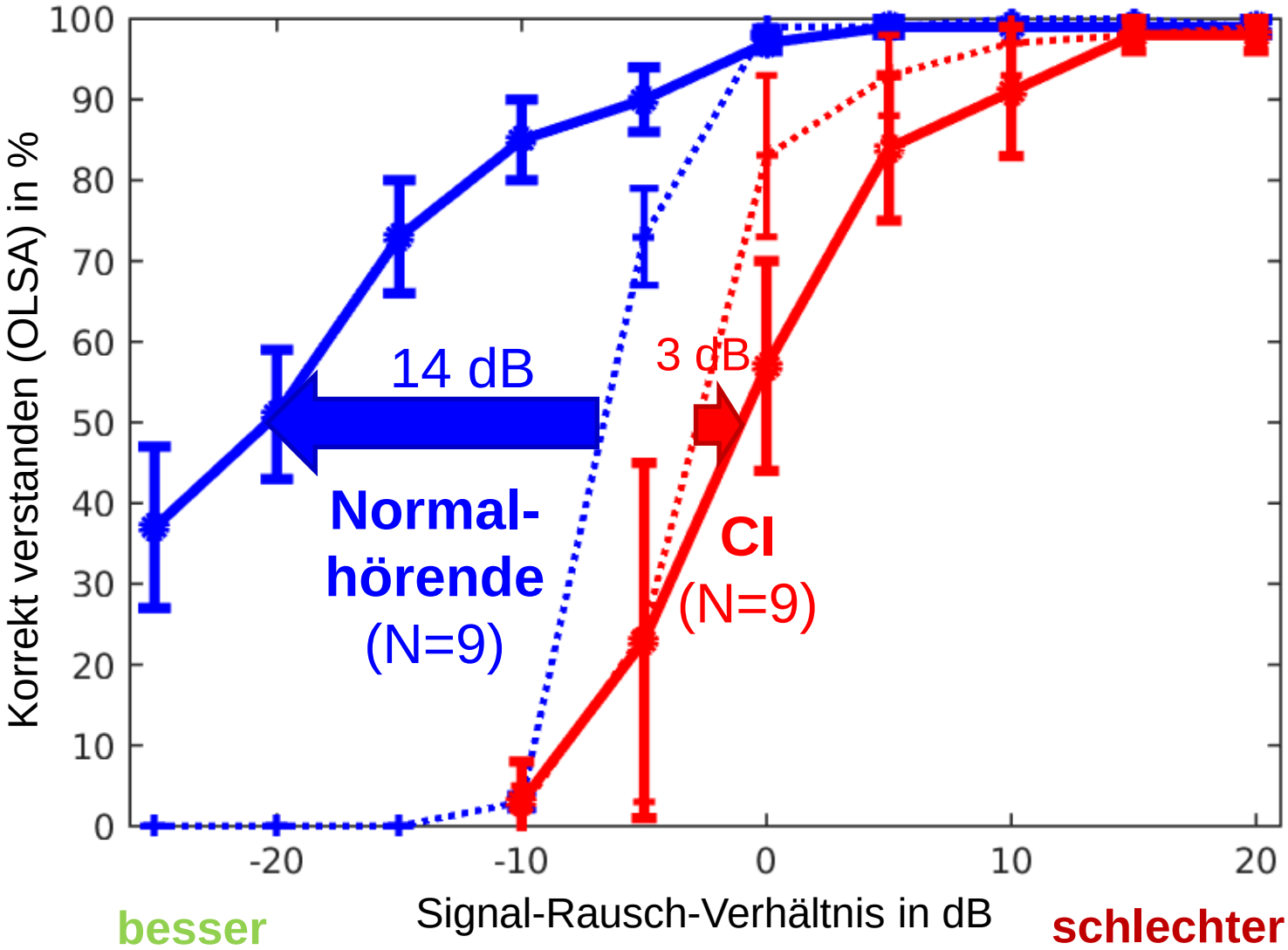
Stationäre Störgeräusche



Dr. Stefan Zirn

Stefanie Keller

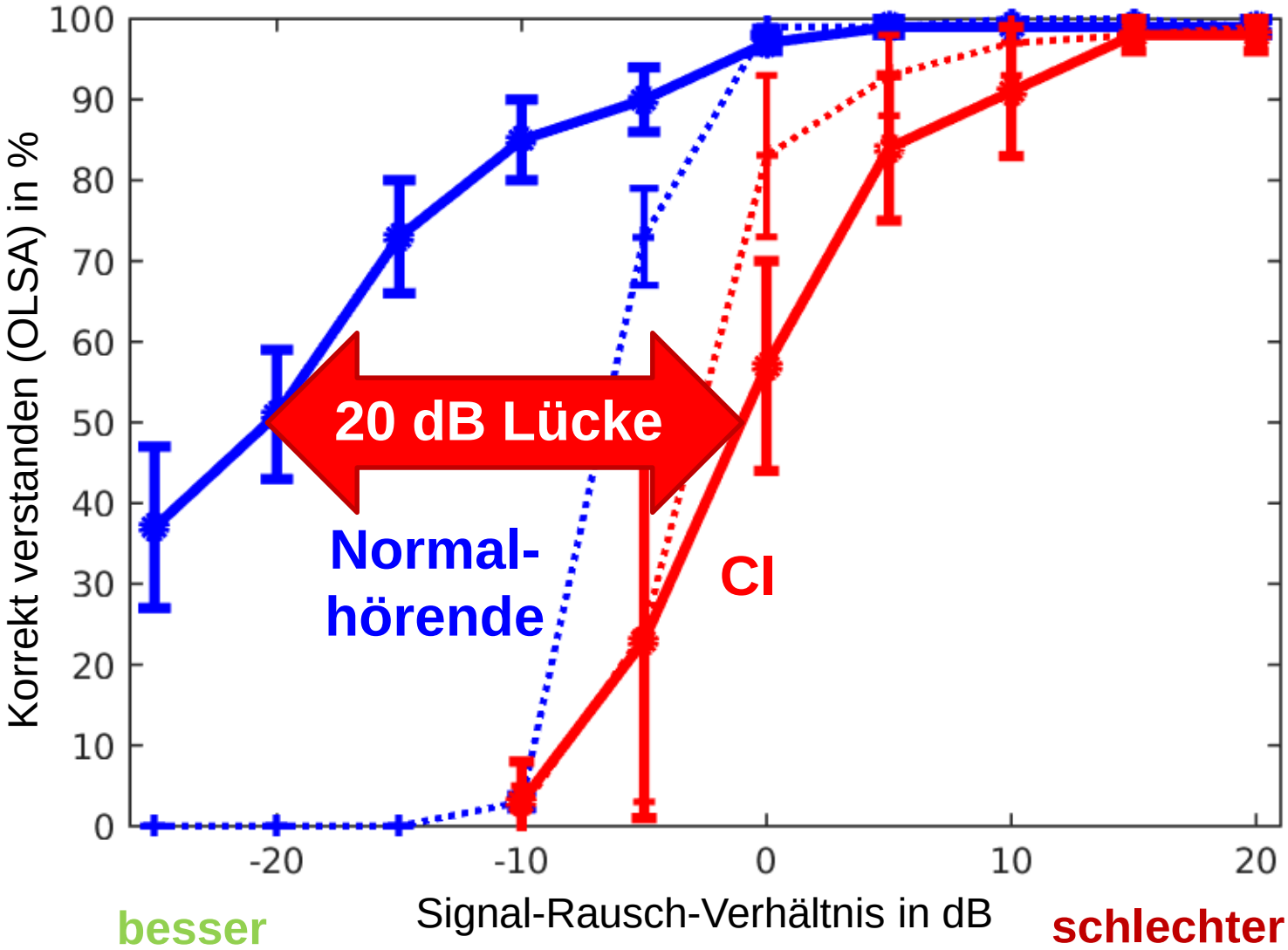
Moduliertes (Fastl) Rauschen



Dr. Stefan Zirn

Stefanie Keller

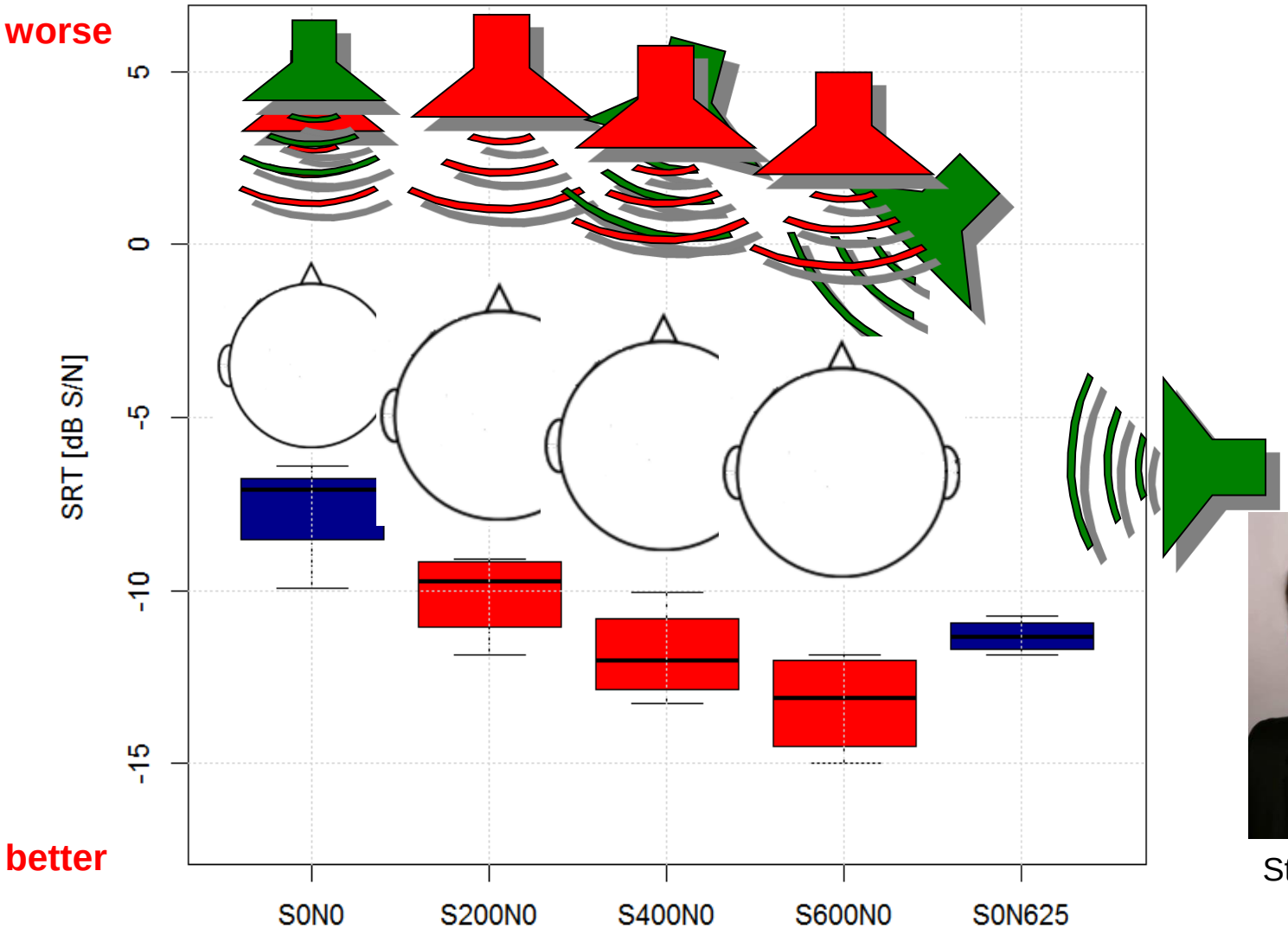
Moduliertes (Fastl) Rauschen



Dr. Stefan Zirn

Stefanie Keller

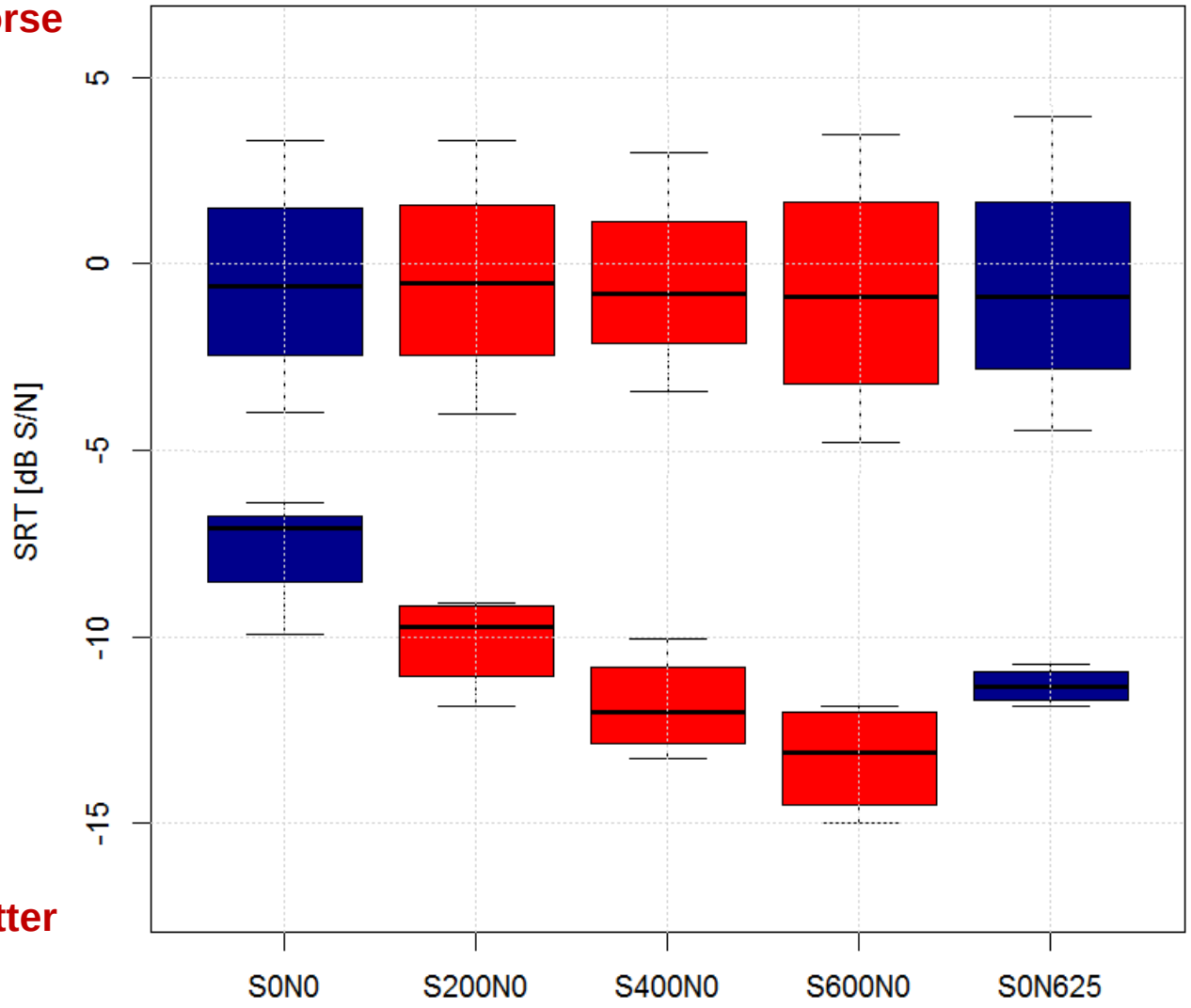
ITD cues enhance speech understanding…



Stefanie Keller

… but (yet) in CI users

worse



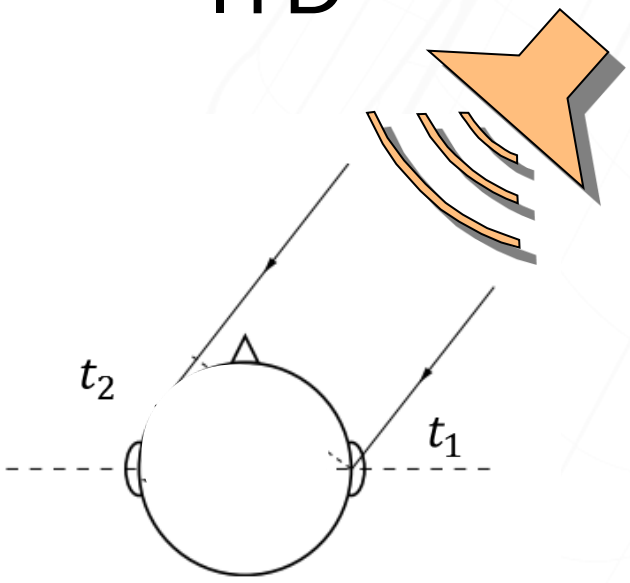
better

CI

NH

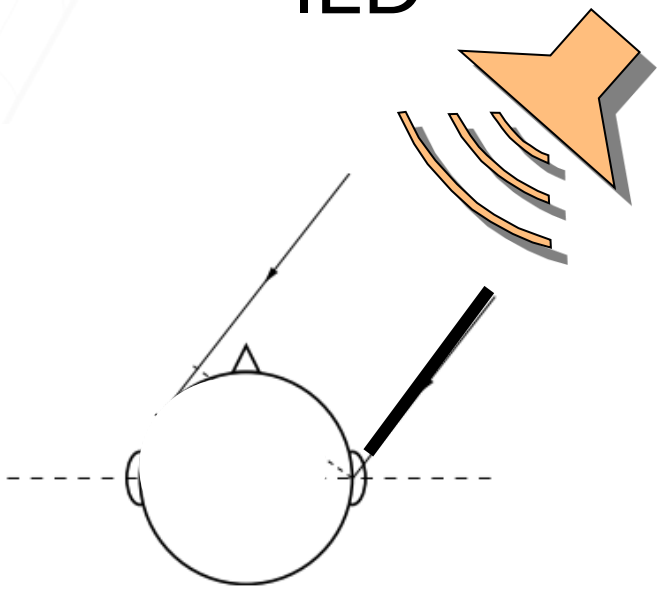
Source Localization in the Median Plane

ITD



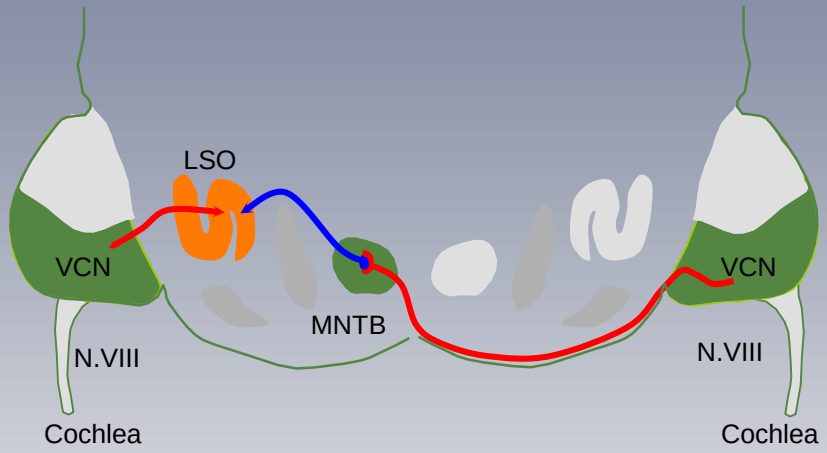
Interaural time differences (ITD)
More important at low frequencies
Higher precision as ILD cues

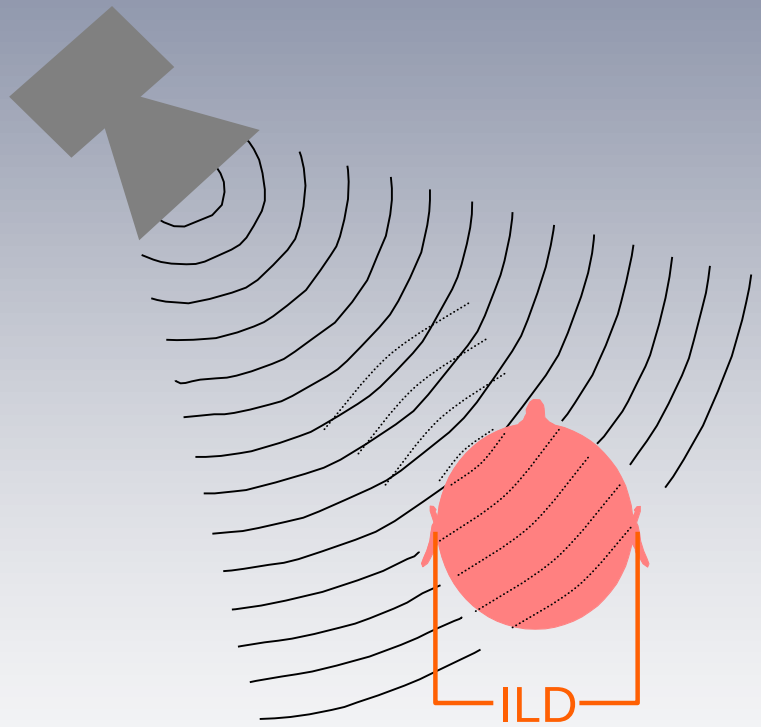
ILD

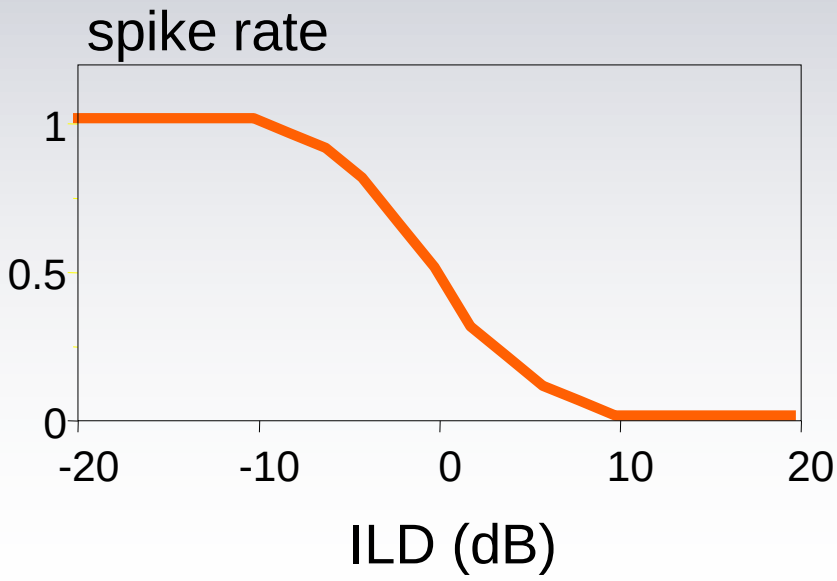


Interaural level differences (ILD)
More important at high frequencies

ILD coding in the LSO

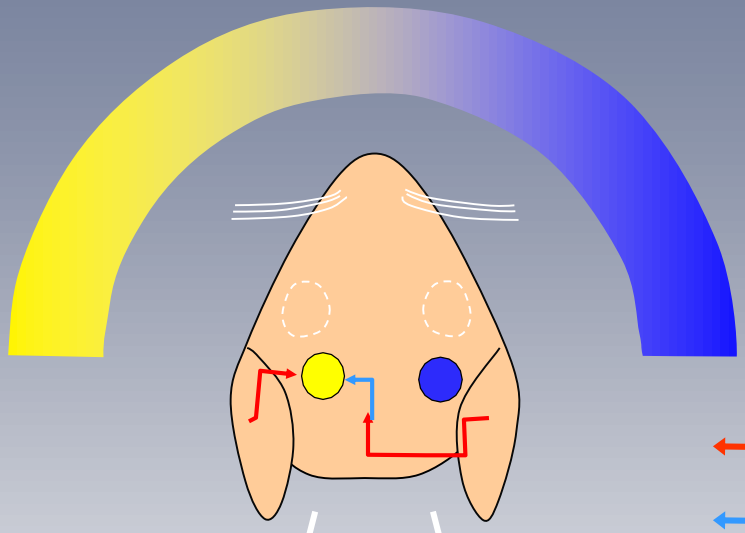






Slides: Prof. Grothe, LMU

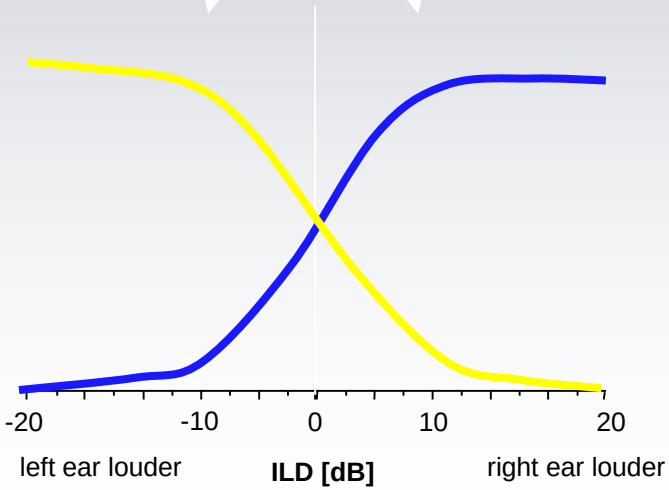
Representation of ILDs



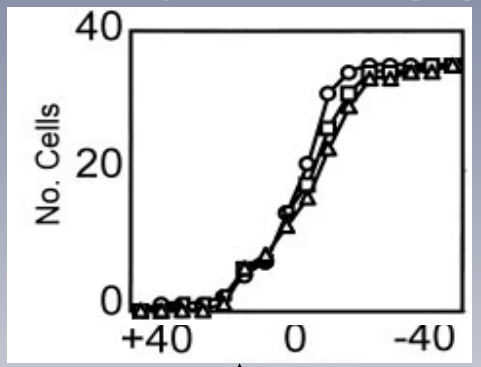
excitation

inhibition

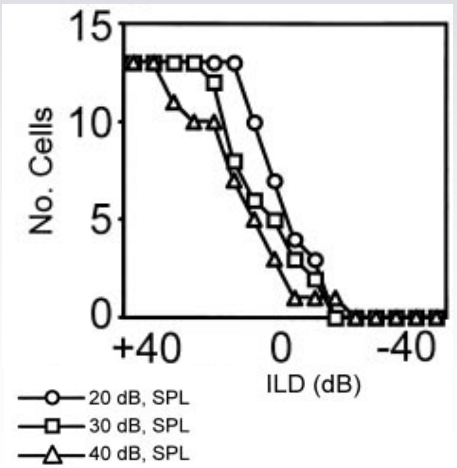
two populations



Auditory midbrain (IC)



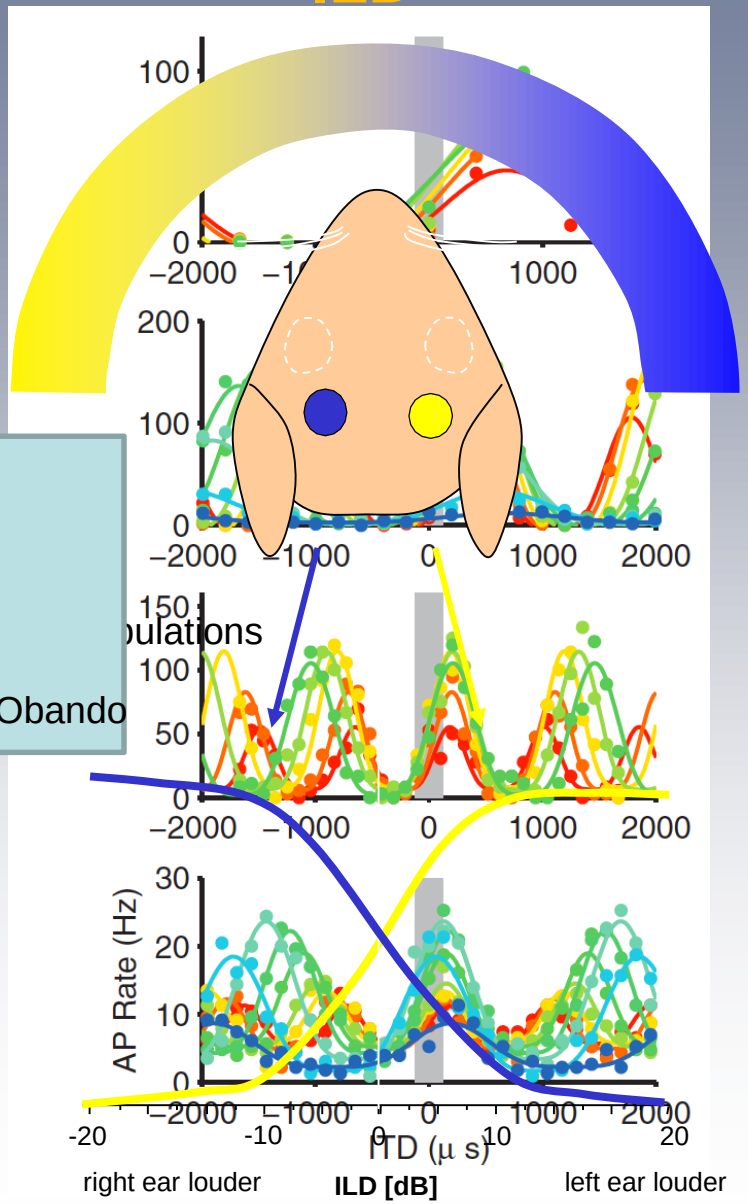
Lateral superior olive (LSO)



Park et al. (2004) *J Neurophysiol*

Binaural Processing Strategy

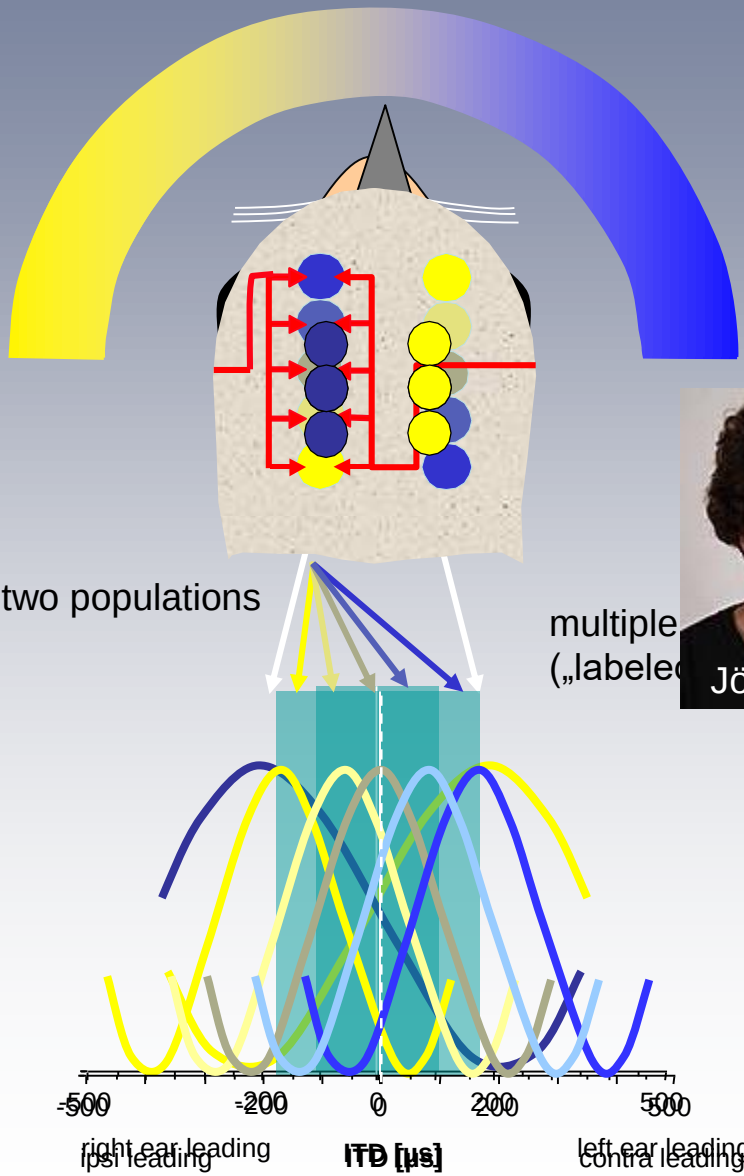
ILD



two populations

right ear louder — **ILD [dB]** — left ear louder

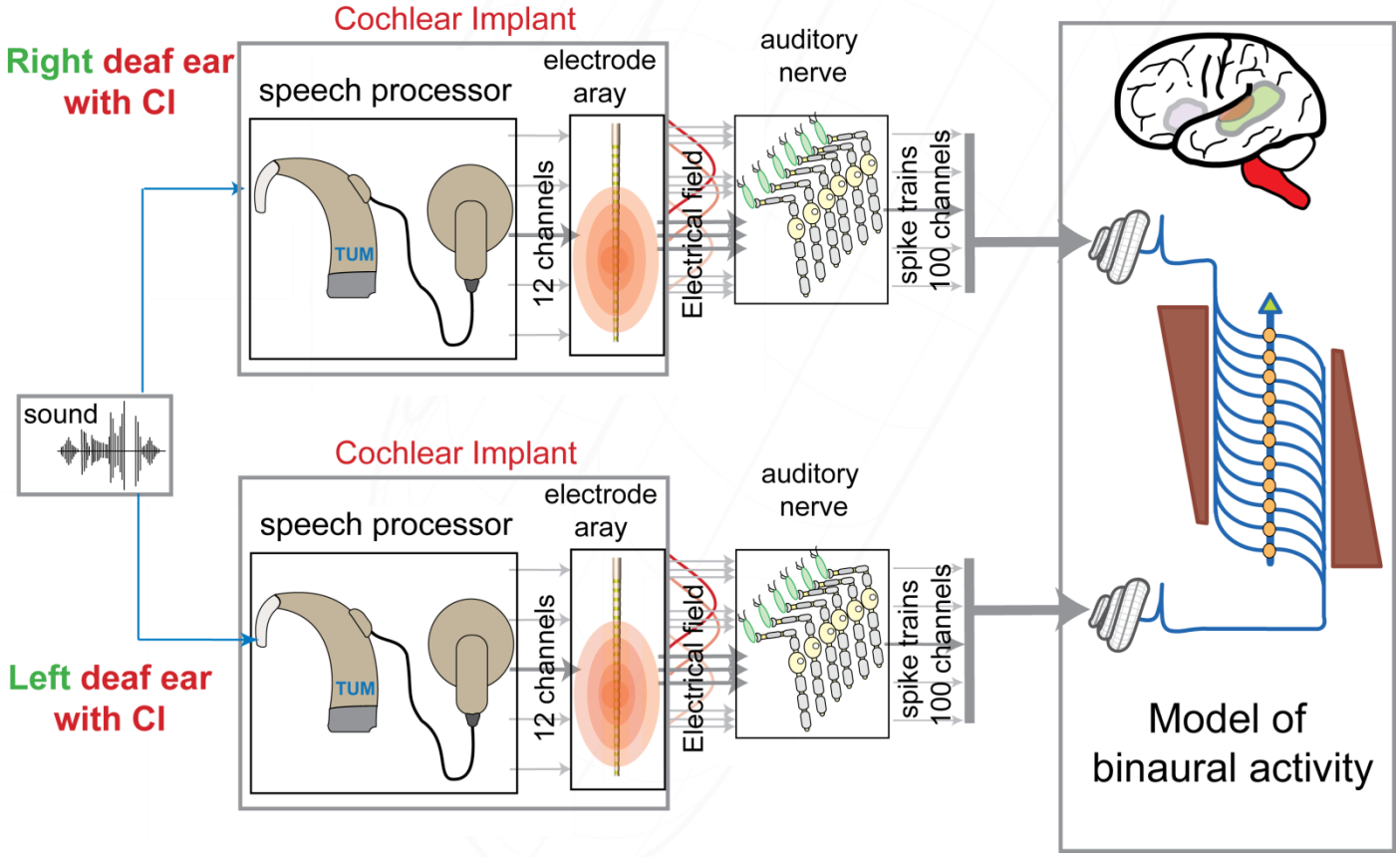
ITD



Miguel Obando

Grothe et al. (2010) *Physiol Rev*

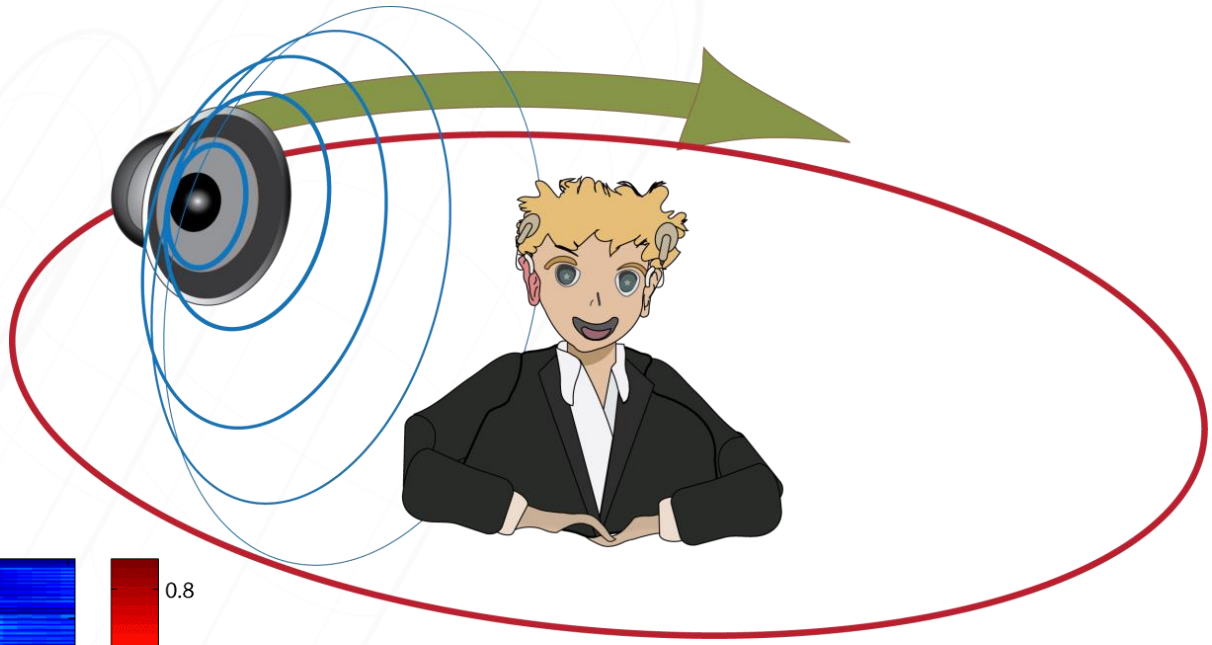
Binaural model

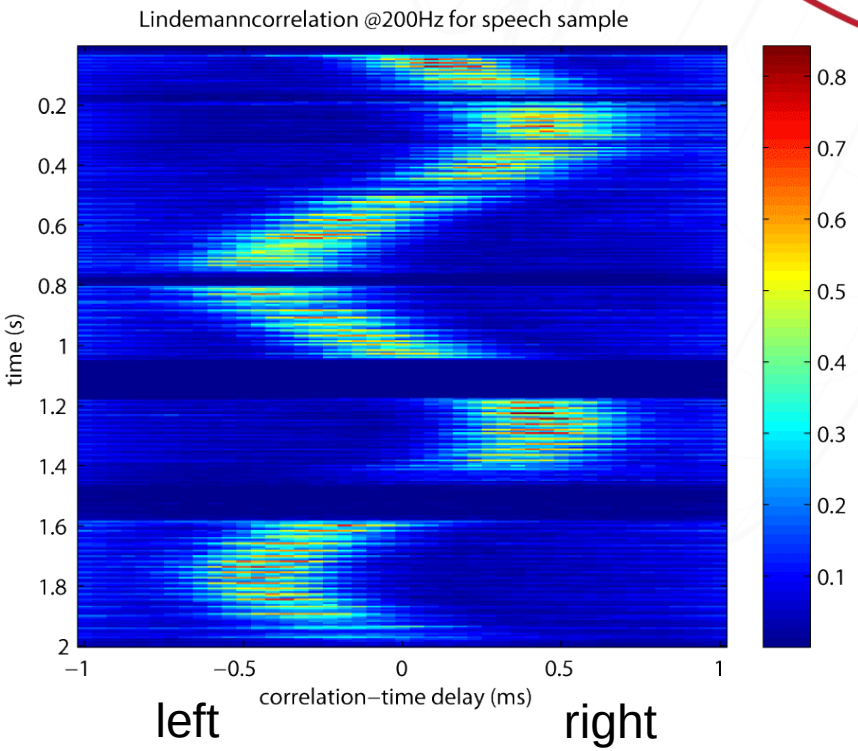


Christian Wirtz

Binaural model

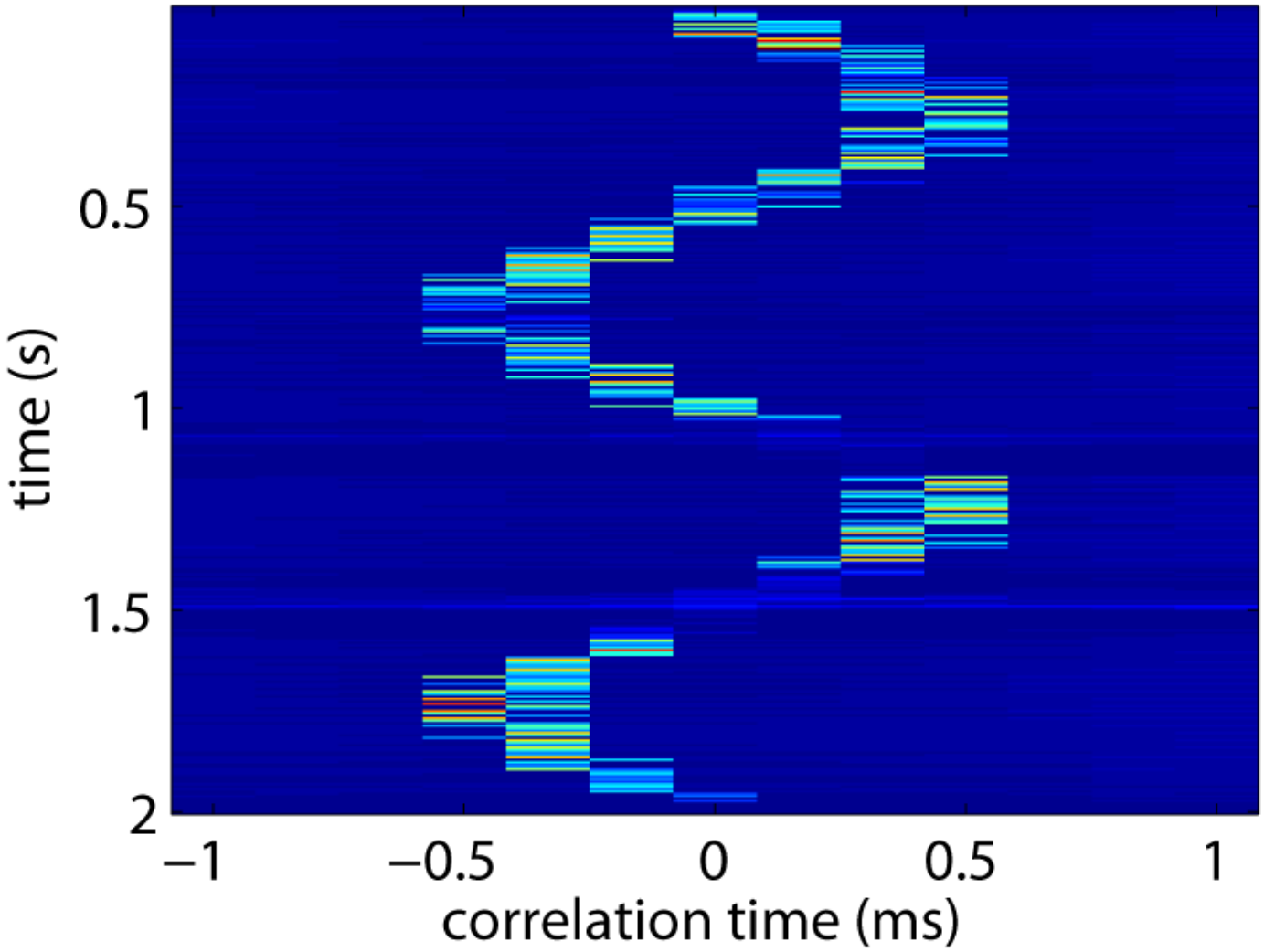
Normal Hearing





FineHearing (FS4)

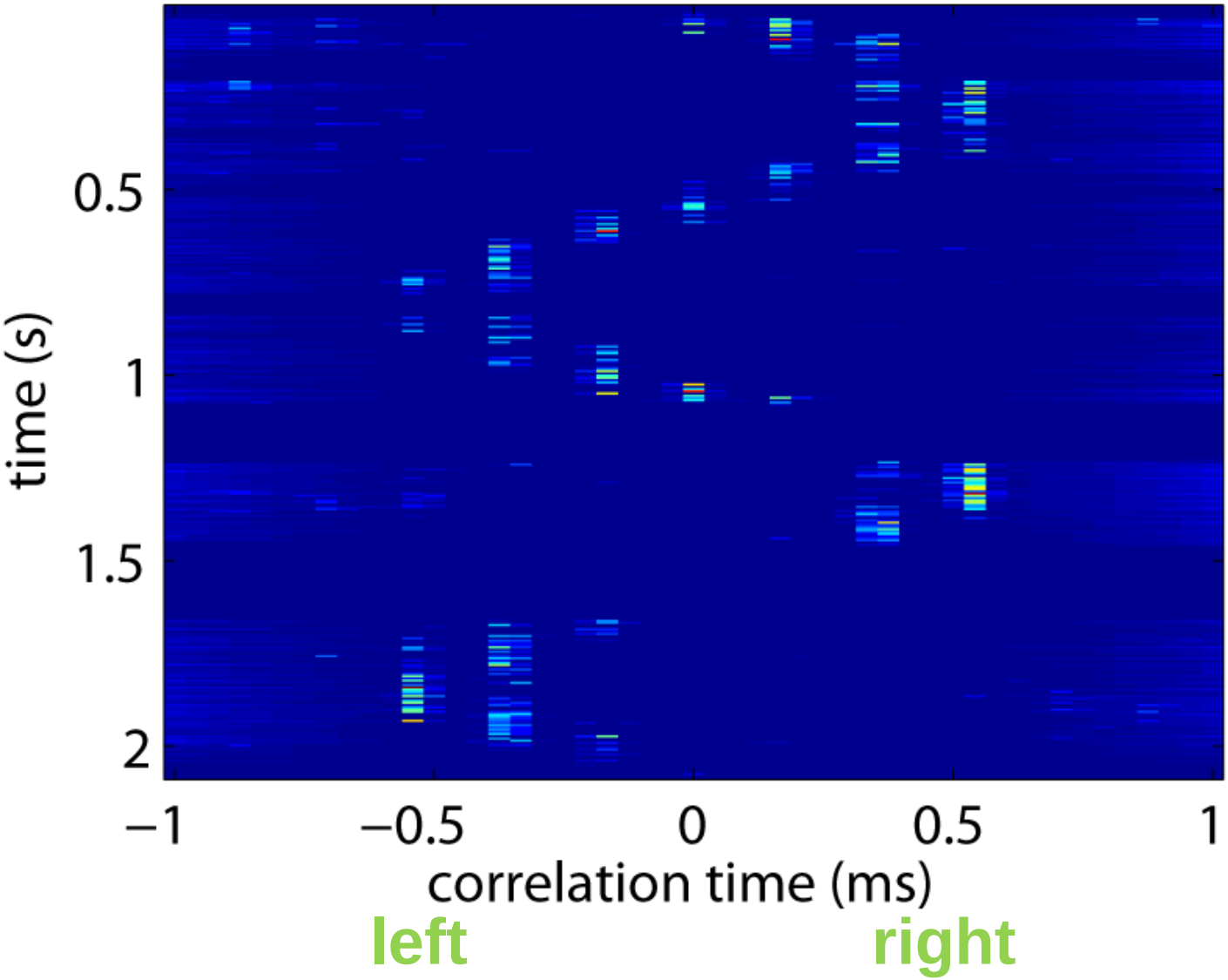
Electrode 2: Lindemann correlation with speech



left right

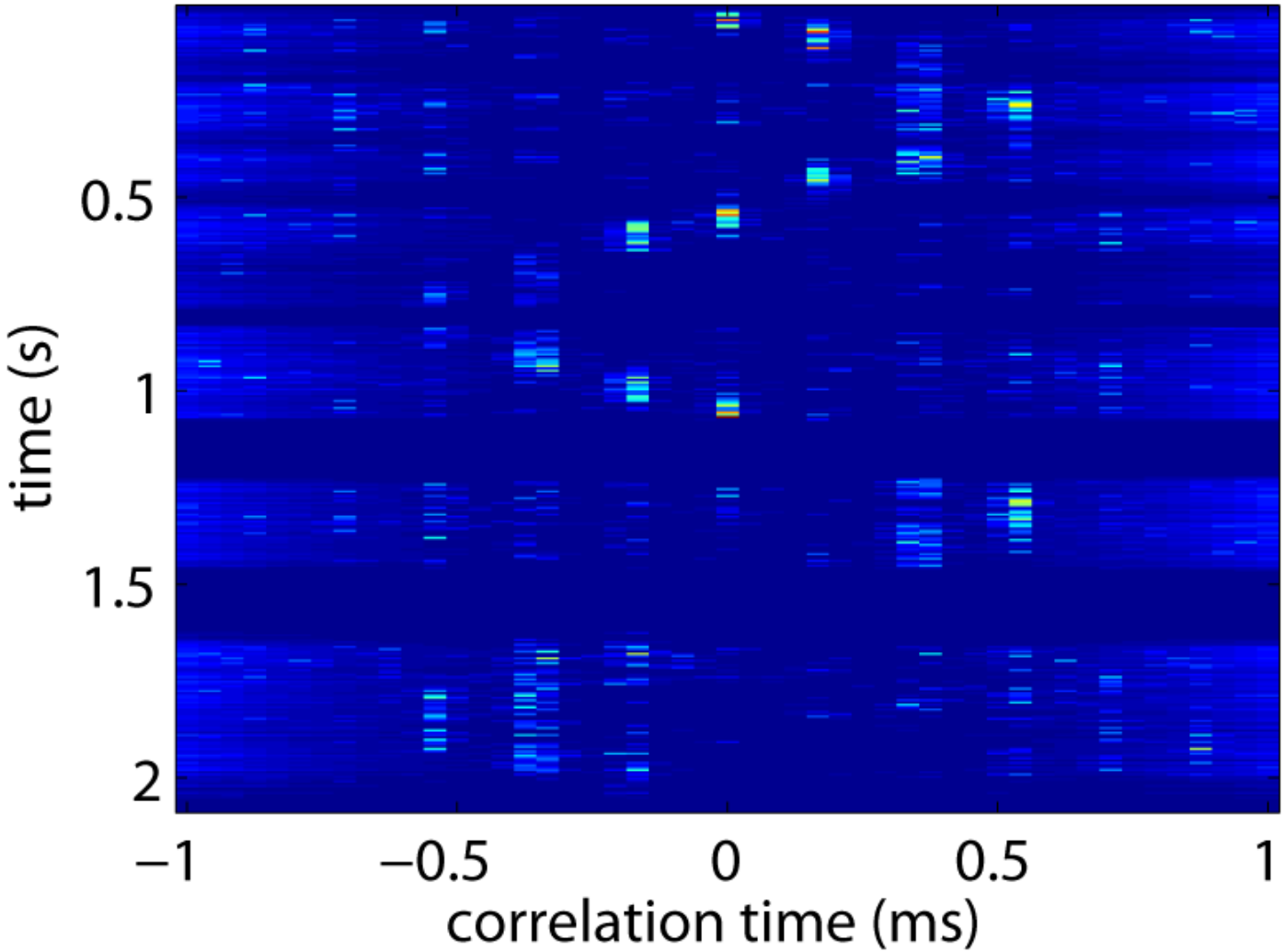
FineHearing (FS4)

Correlation of neuronal spike-trains at electrode 2

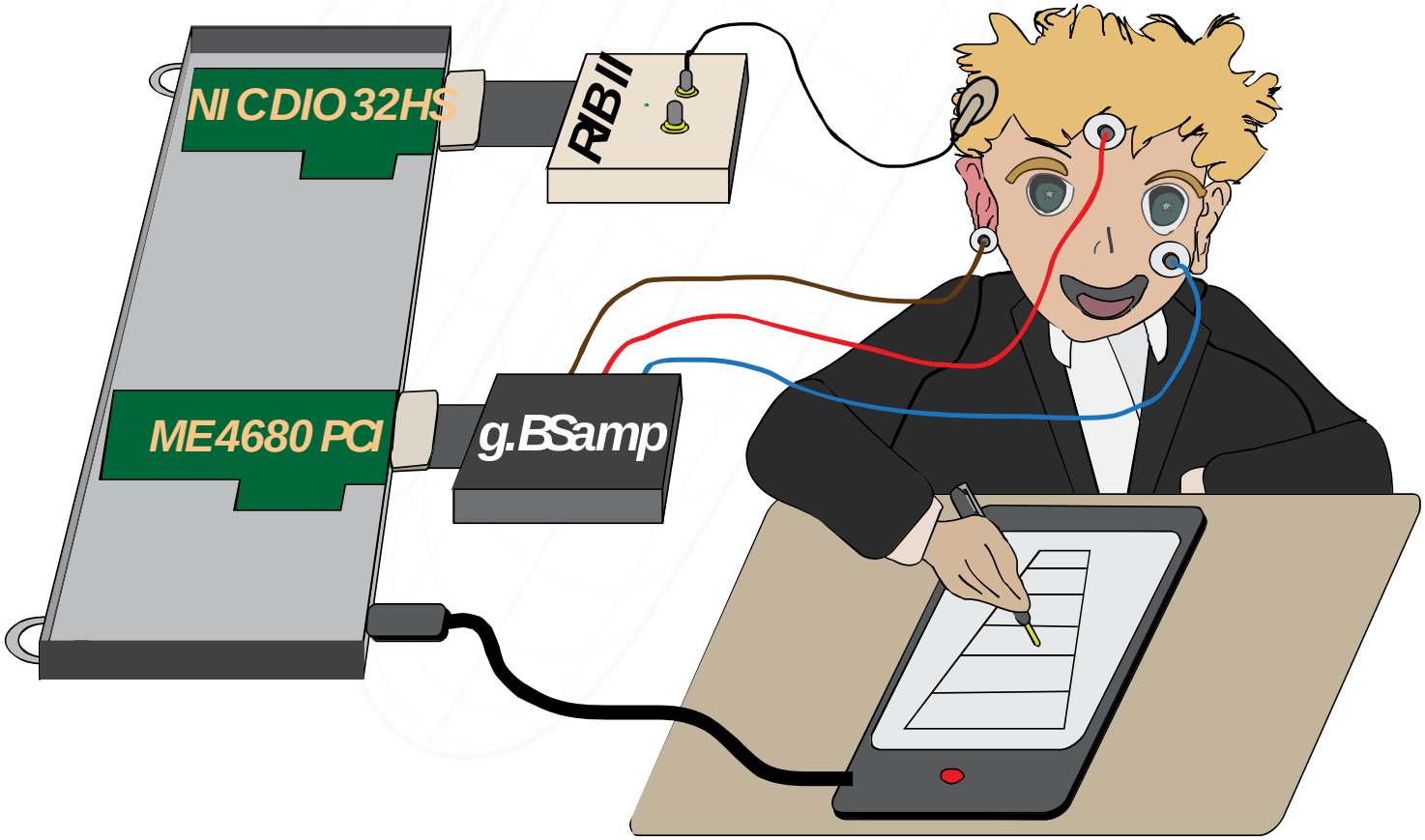


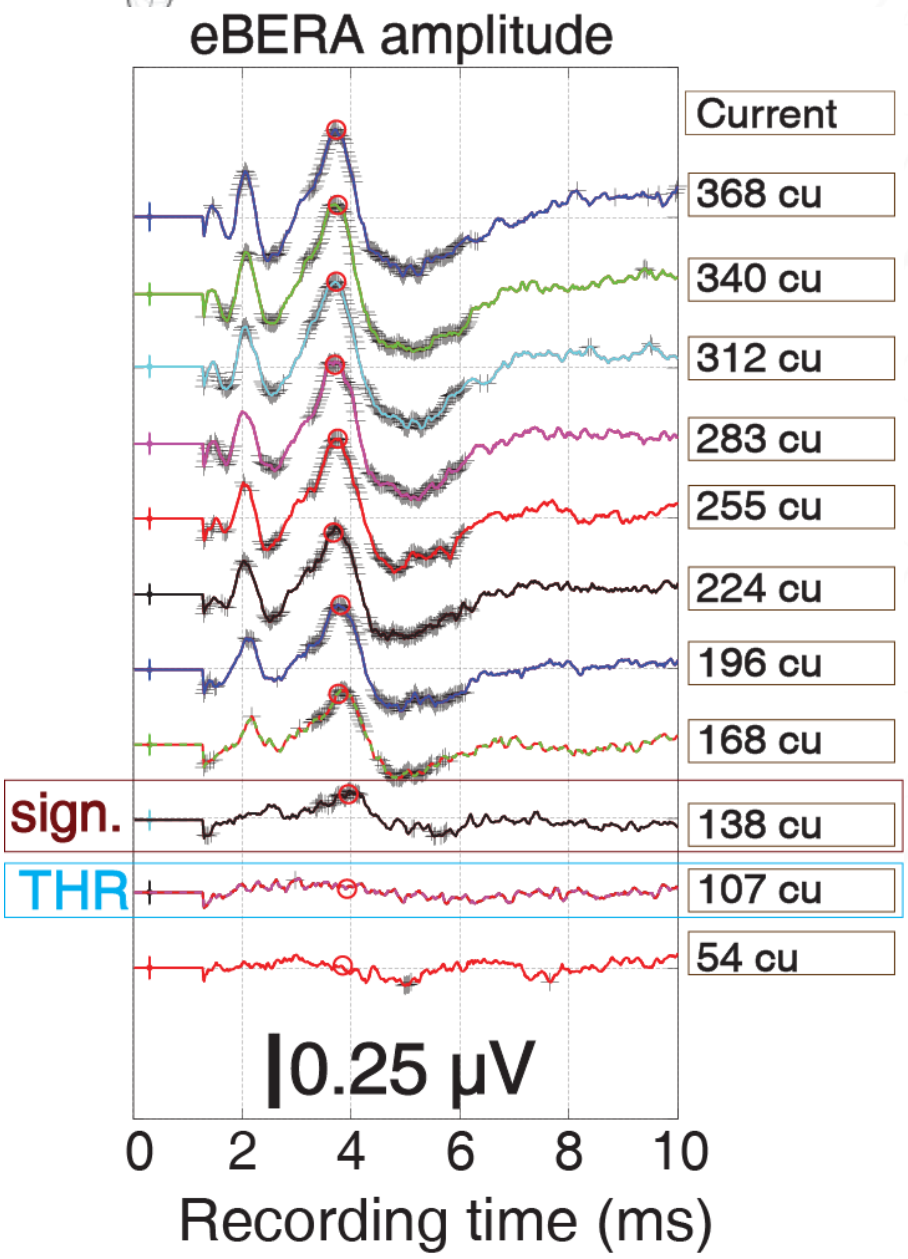
FineHearing (FS4)

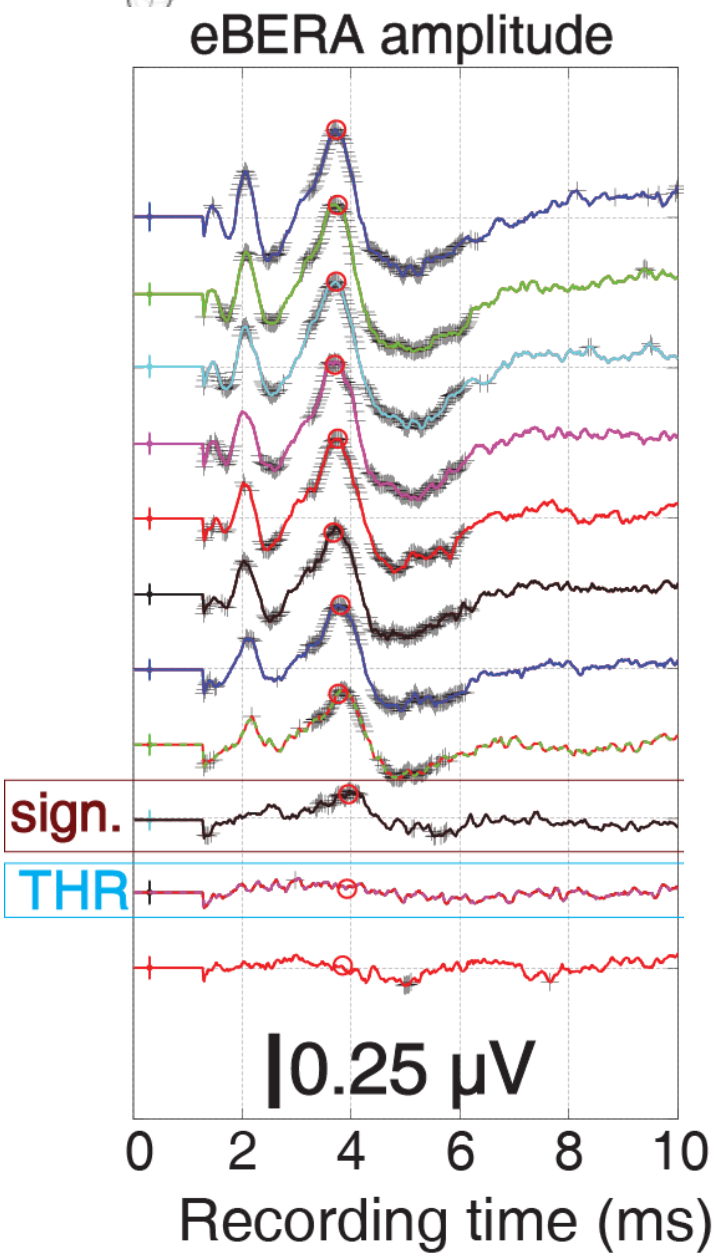
Correlation of neuronal spike-trains between electrode 3 and 4

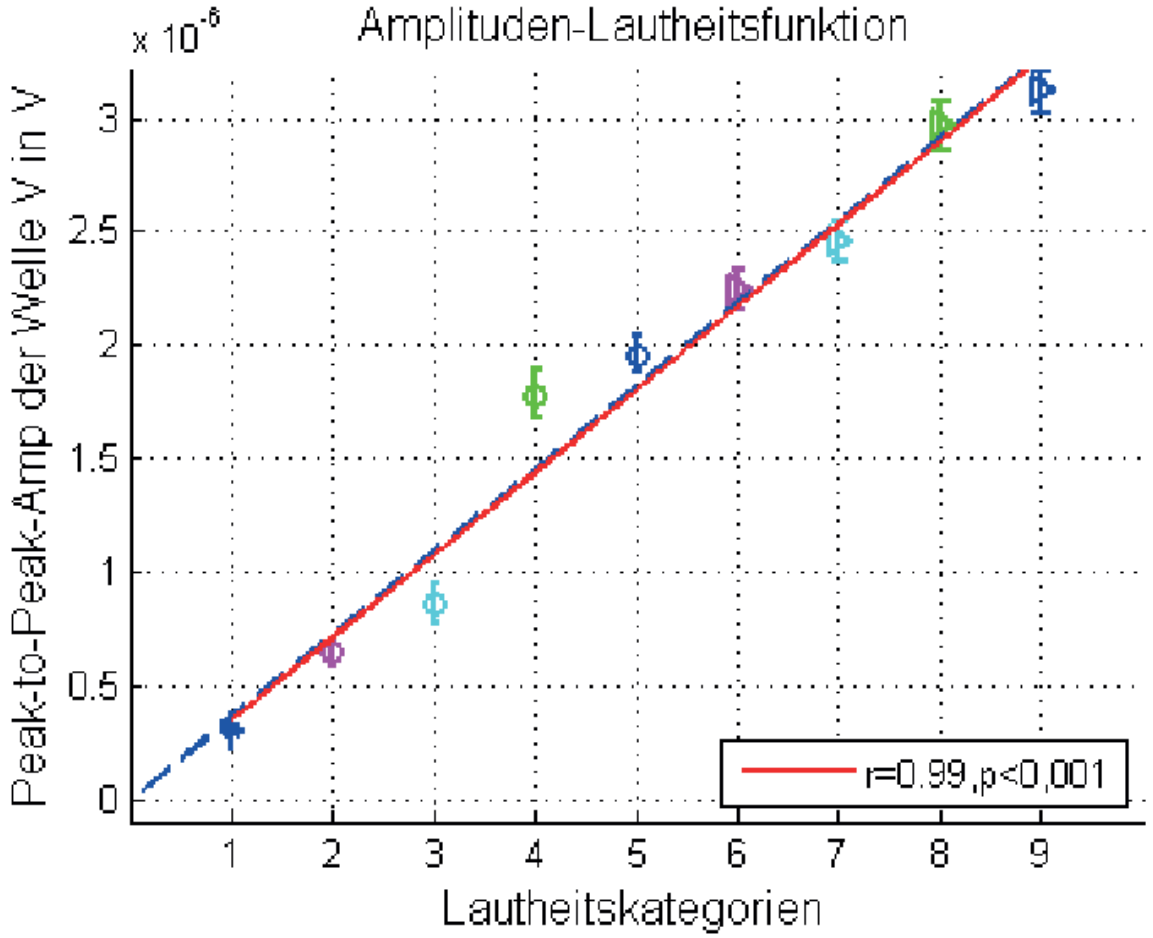


Objective Measurements: eBERA




eBERA amplitude
Current
368 cu
340 cu
312 cu
283 cu
255 cu
224 cu
196 cu
168 cu
sign.
138 cu
THR
107 cu
54 cu
0.25 µV
0
2
4
6
8
10
Recording time (ms)


eBERA amplitude
sign.
THR
0.25 µV
0
2
4
6
8
10
Recording time (ms)


Amplituden-Lautheitsfunktion
x 10^-6
Peak-to-Peak-Amp der Welle V in V
0
0.5
1
1.5
2
2.5
3
1
2
3
4
5
6
7
8
9
Lautheitskategorien
r=0.99,p<0,001

Validation Framework for CIs

LMU KLINIKUM DER UNIVERSITÄT MÜNCHEN

Graduate School of Systemic Neurosciences
LMU Munich

Bernstein Center for Computational Neuroscience Munich

DFG PP 1608

Ultrafast and temporally precise information processing:
Normal and dysfunctional hearing

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