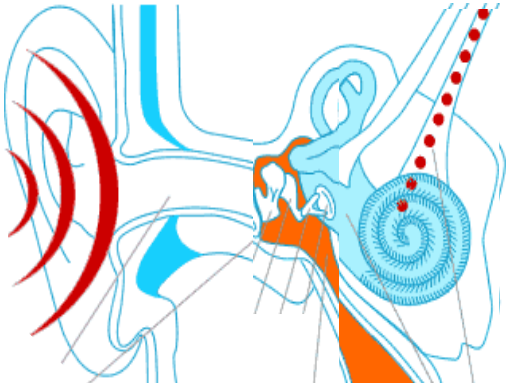
Evanescent Waves at the Interface between Ear Canal and Otoacoustic Emission (OAE) Probe

Makram Zebian[1,2]
Johannes Hensel[1]
Thomas Fedtke[1]

[1]Physikalisch-Technische Bundesanstalt
[2]International Graduate School of Metrology
Germany

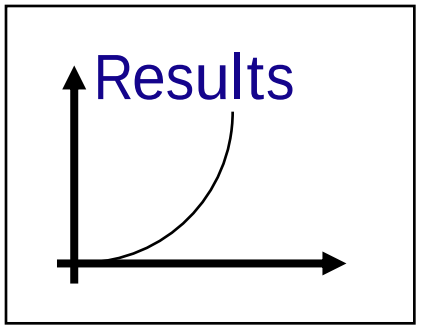
COMSOL, Ludwigsburg 2011

Overview

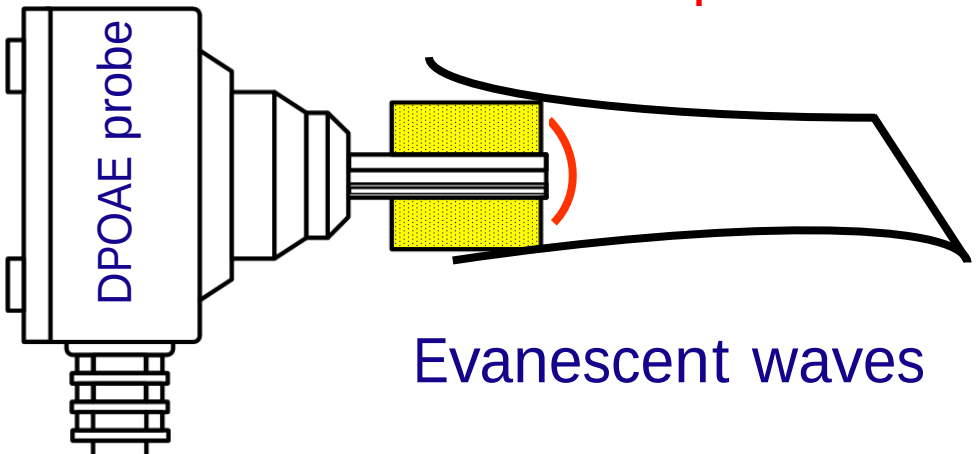


Otoacoustic Emissions

Ways to bypass evanescent waves (FE modelling)

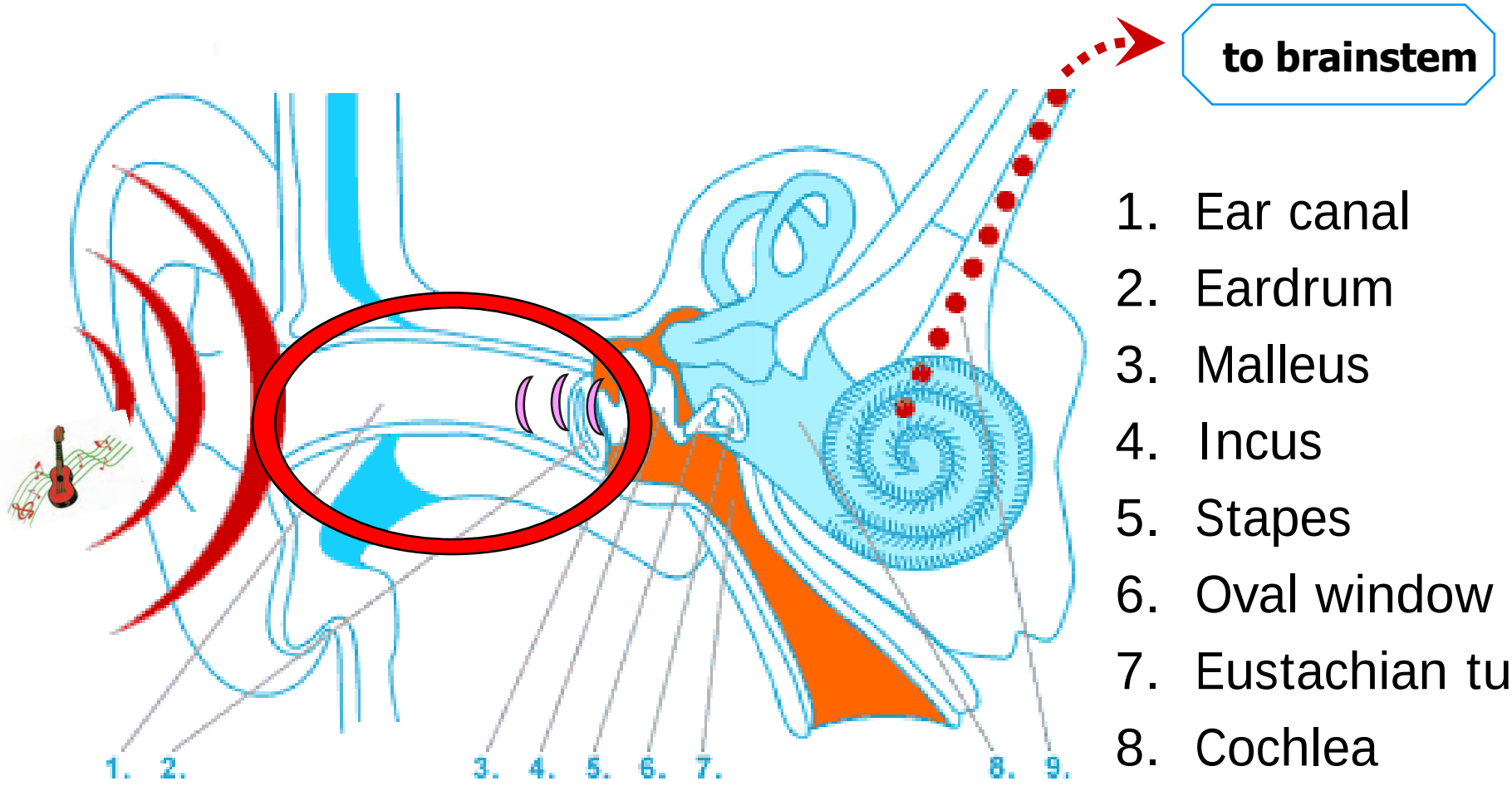


Conclusions



Evanescent waves

Anatomy of the Ear



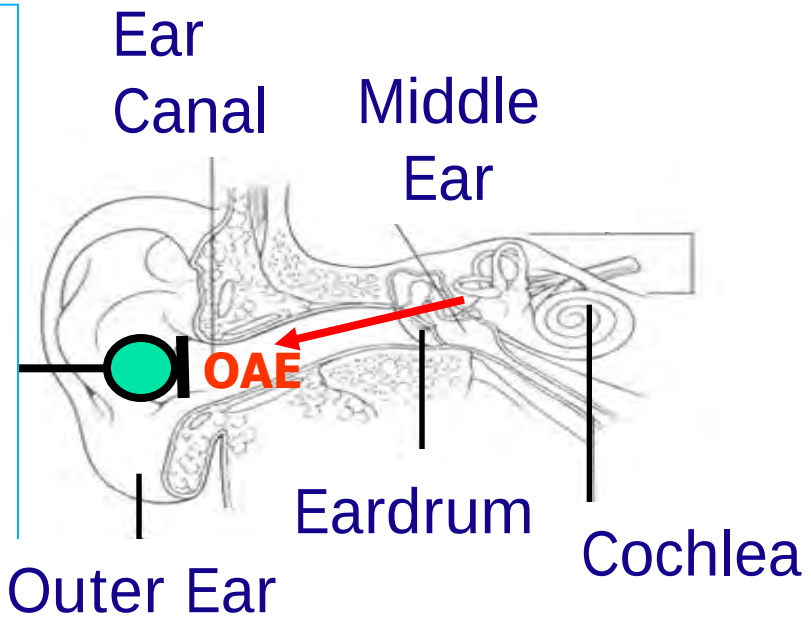
1. Ear canal
2. Eardrum
3. Malleus
4. Incus
5. Stapes
6. Oval window
7. Eustachian tube
8. Cochlea
9. Auditory nerve

Otoacoustic Emissions (OAEs)

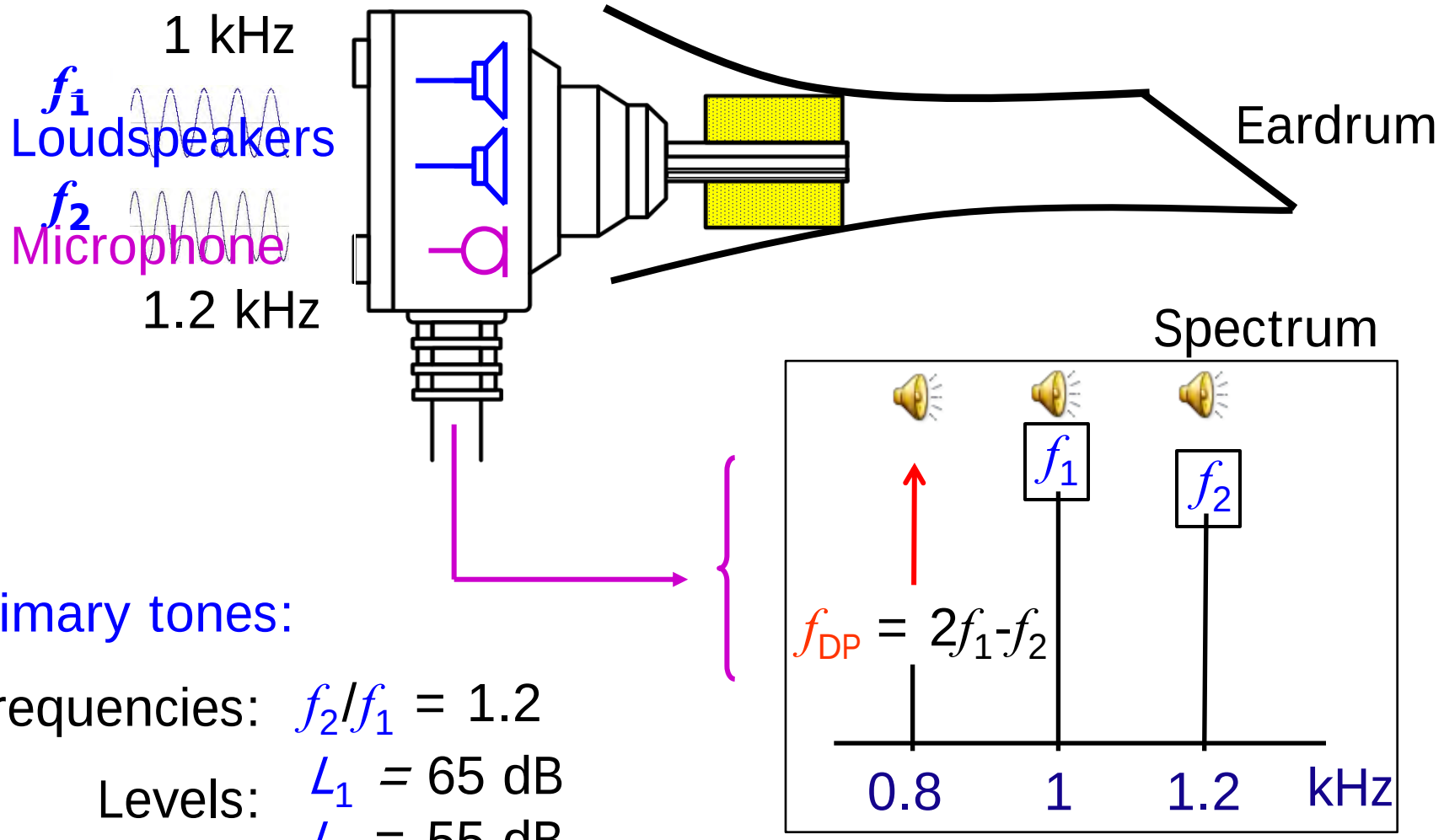
Kemp (1978) → OAE = Oto-Acoustic Emissions

OAE-Screening for newborns

Mack Medizintechnik



Distortion Product Otoacoustic Emission (DPOAE)



Primary tones:

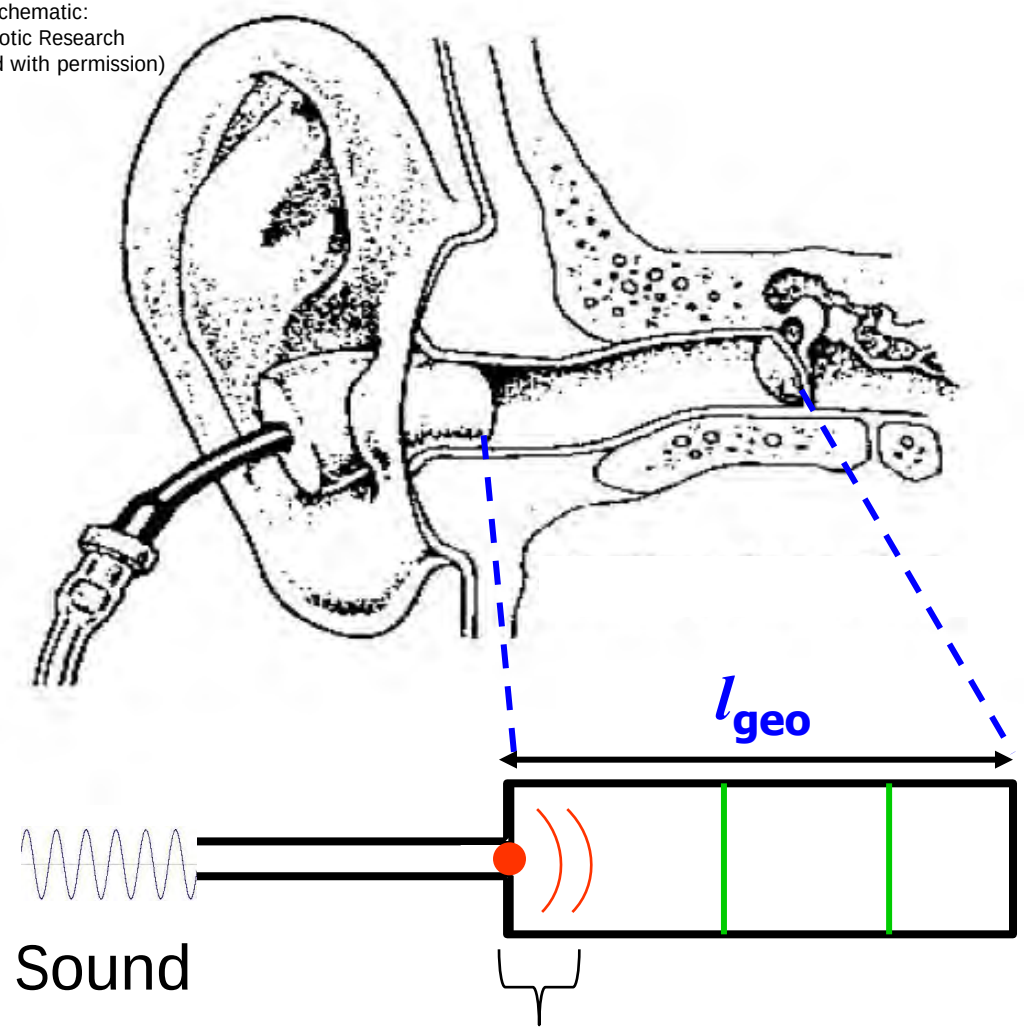
Frequencies: $f_2/f_1 = 1.2$

Levels: $L_1 = 65$ dB

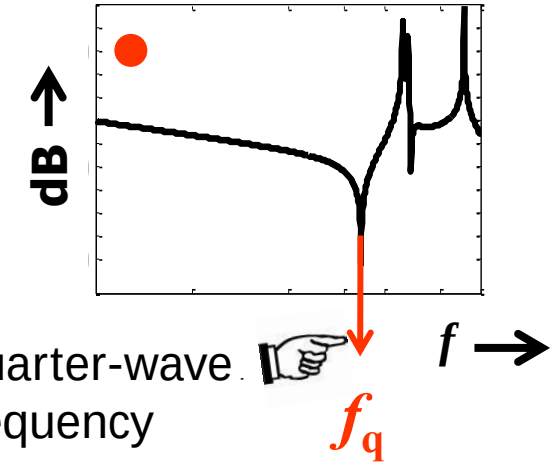
$L_2 = 55$ dB

Where do evanescent waves come from?

Ear schematic:
Etymotic Research
(used with permission)



Frequency response:



Acoustic length:

$$l_{ac} = c / (4 f_q)$$

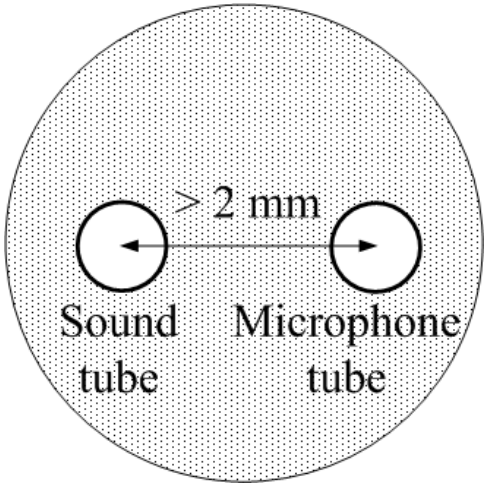
c - speed of sound in air

$$l_{ac} \neq l_{geo}$$

Eartip modifications?

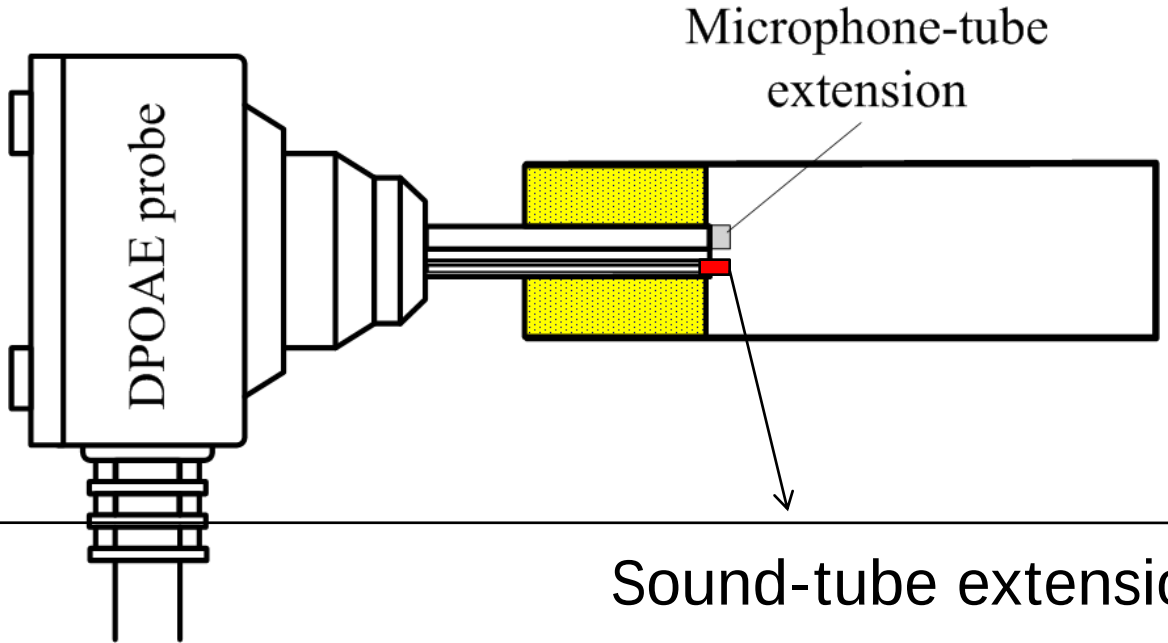
"Ways out"

Brass & Locke (1997)



Ear canal width!

Huang et al. (2000)



Generally applicable?

Sound-tube extension?

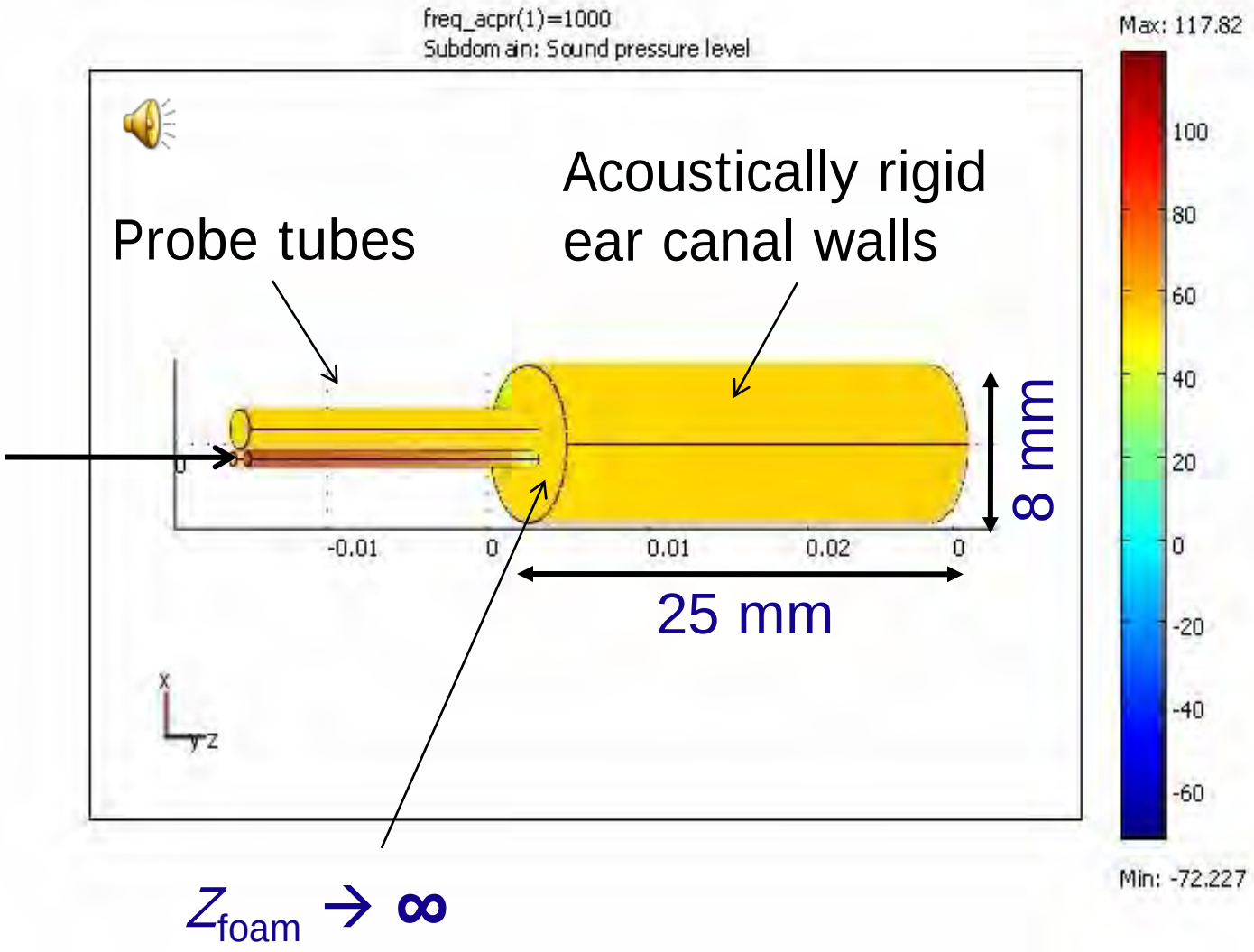
FE Modelling (Video)

PS:

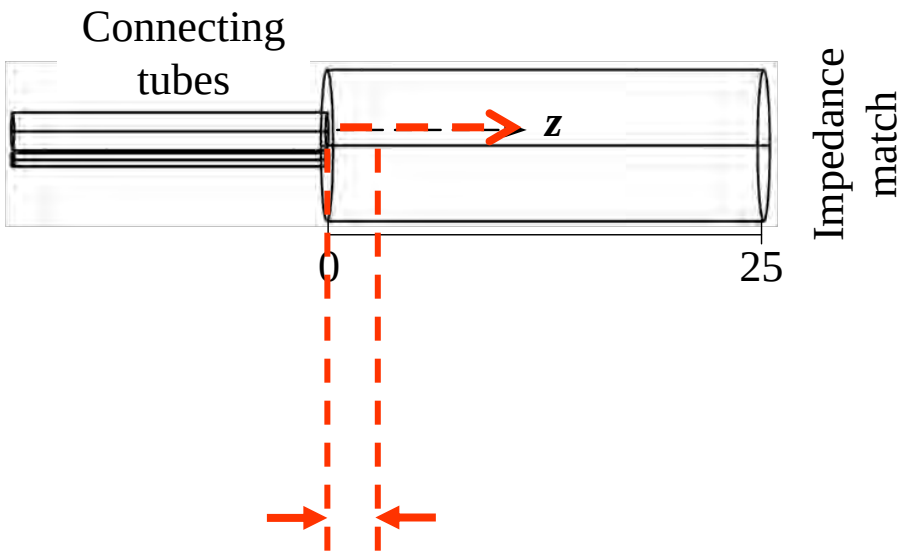
q_0 = 0.8 mm³/s

Volume velocity

piston source



Decay length of the evanescent wave

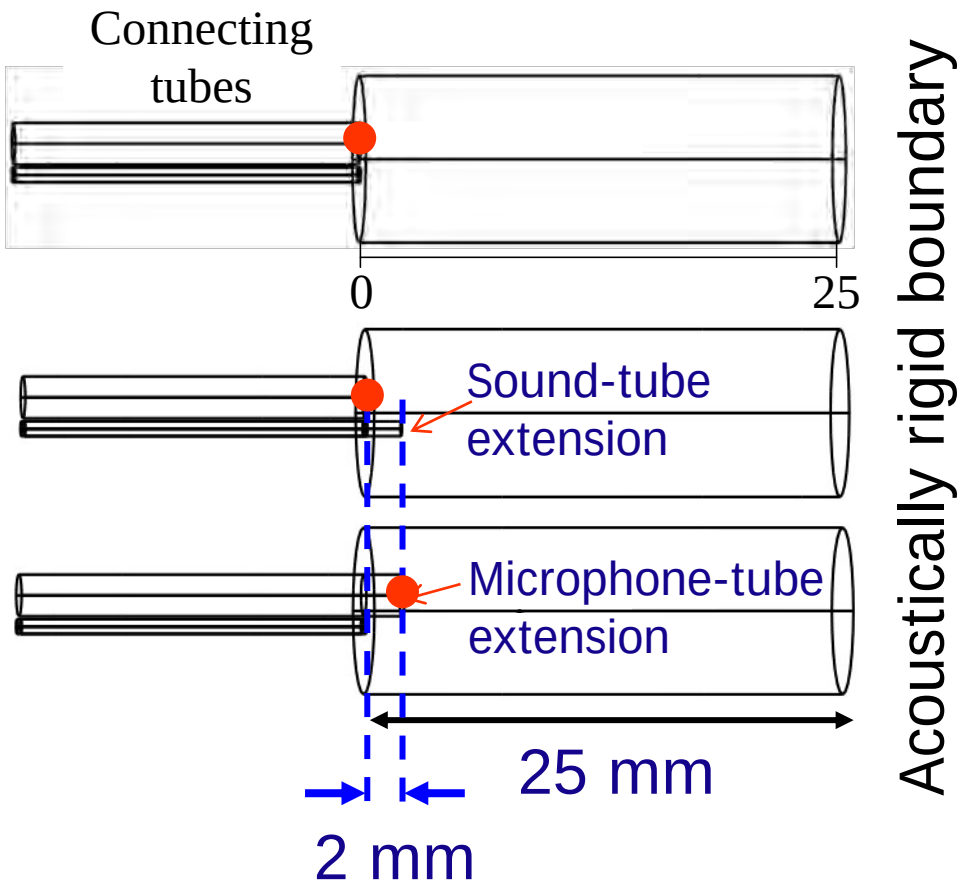


d_{ev} = ?

$d_{ev} \approx 2$ mm

FE Modelling

PS: q_0 = 0.8 mm³/s → Volume velocity piston source



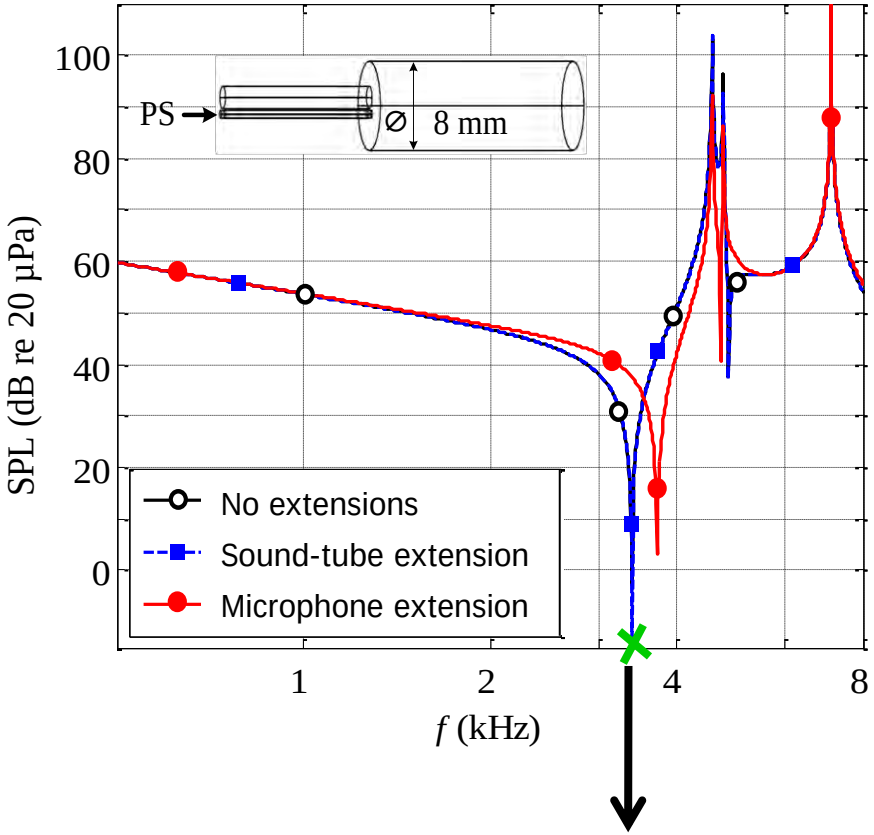
- Sound pressure level at microphone port

- Two ear canal models: EC model A (⌀ 8 mm)
  EC model B (⌀ 12 mm)

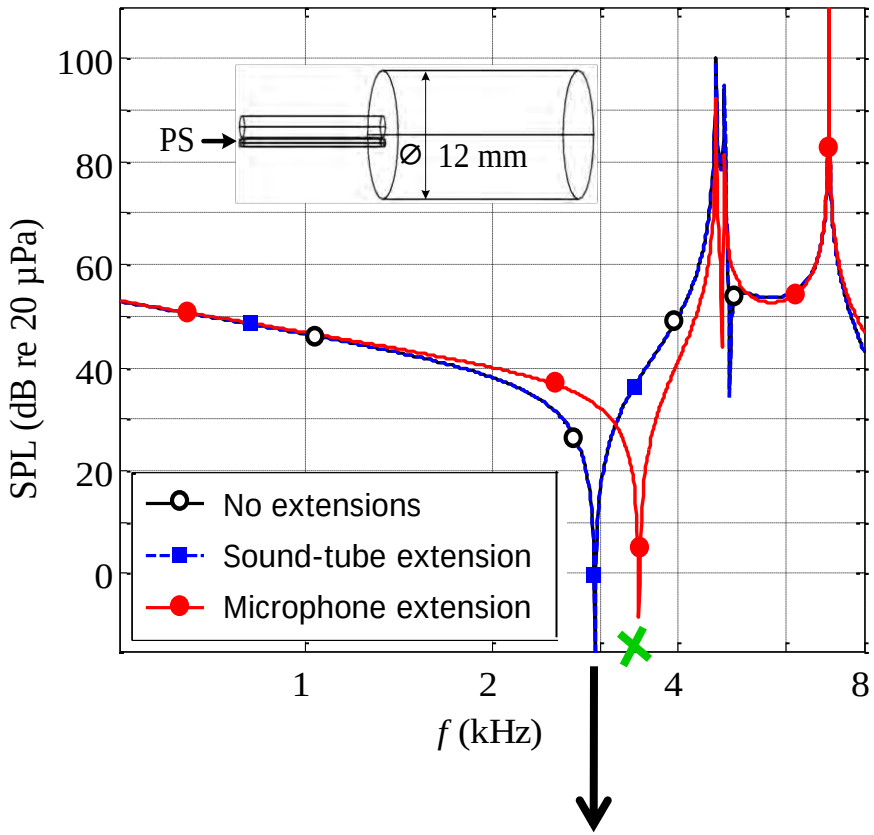
Results: FE Simulations

Expected for 25 mm ear canal → f_q = 3.5 kHz

$$l_{ac} = c / (4 f_q)$$

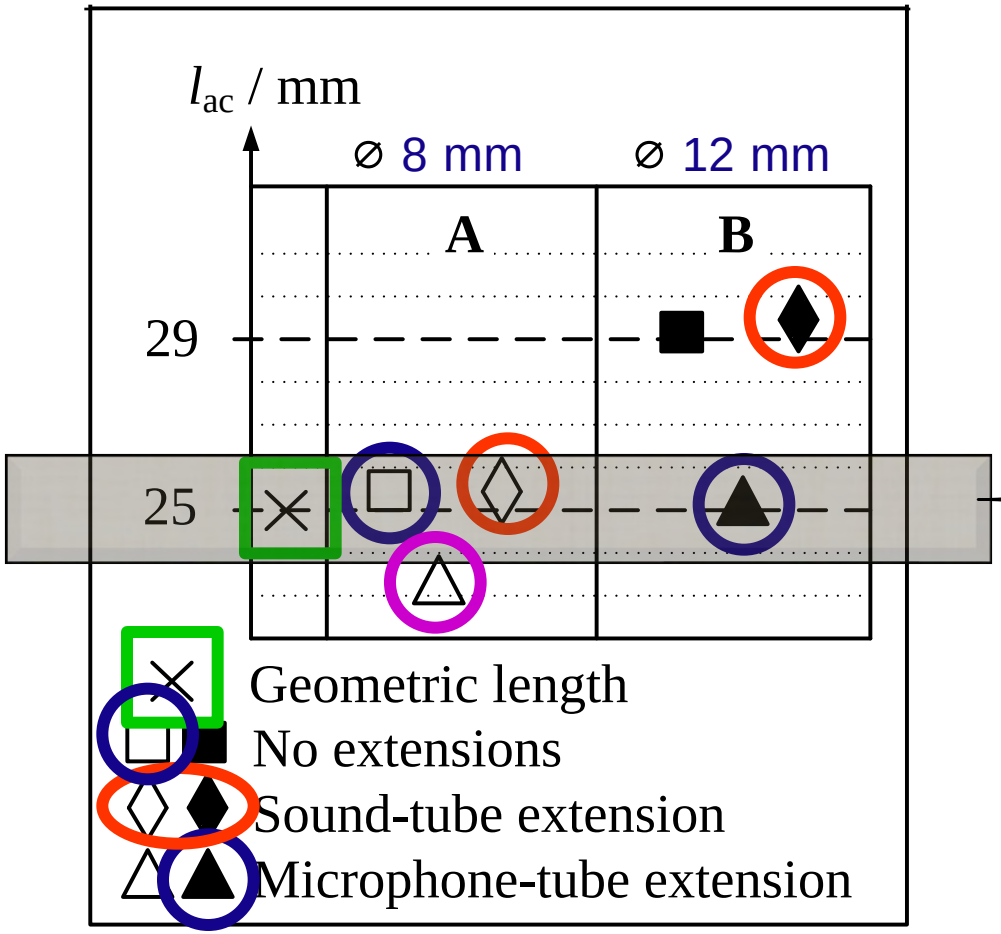


$f_{q,A}$ = 3.35 kHz



$f_{q,B}$ = 2.94 kHz

Acoustic Length Diagram



Results closest to geometric length:

EC model A
→No extensions □

EC model B
→ Microphone extension ▲

Conclusion and Outlook

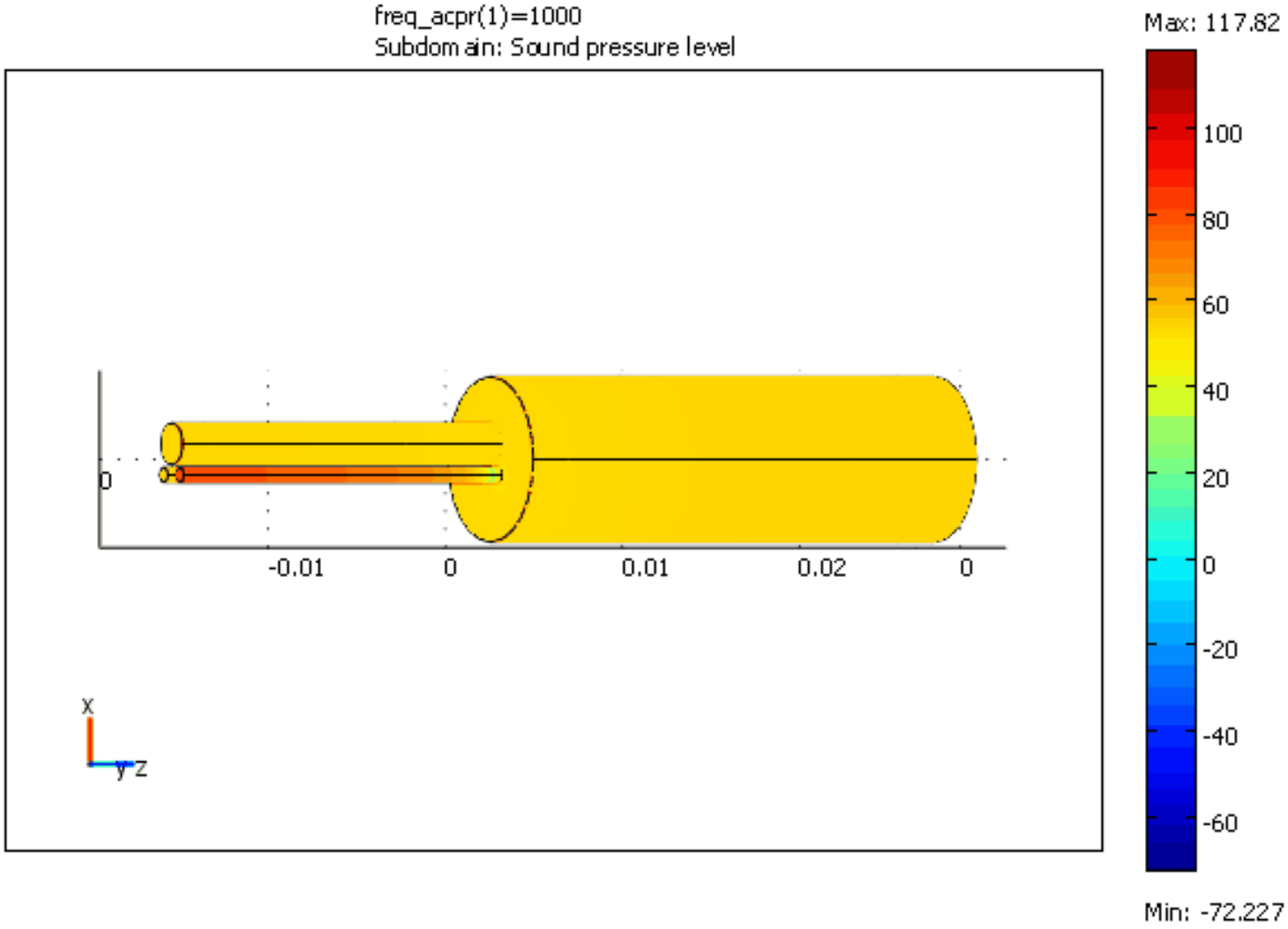
Acoustic length ≠ Geometric length

international graduate school of metrology braunschweig igsm

PTB

Thank you ...

makram.zebian@ptb.de


freq_acpr(1)=1000
Subdomain: Sound pressure level
Max: 117.82
100
80
60
40
20
0
-20
-40
-60
Min: -72.227
0
-0.01
0
0.01
0.02
0
X
Y
Z