

SCHALLSCHUTZ IM ORCHESTER (I) SUBJEKTIVE STUDIE (II) OBJEKTIVE STUDIE (III)

PROF. DR.-ING. MALTE KOB, M.SC. CRISTINA ZAMORANO-MARTINEZ ET AL.



LÄRM VS MUSIK



≠
?



Without shields



With shields



GLIEDERUNG

I Schallschutz im Orchester (Vormittag)

- 1. Einleitung: Lärmbelastung**
- 2. Europäische Vorgabe: Grenzwerte und Maßnahmen**
- 3. Abstrahlung von Musikinstrumenten**
- 4. Schallschutzschirme: Hypothesen und Umsetzung**

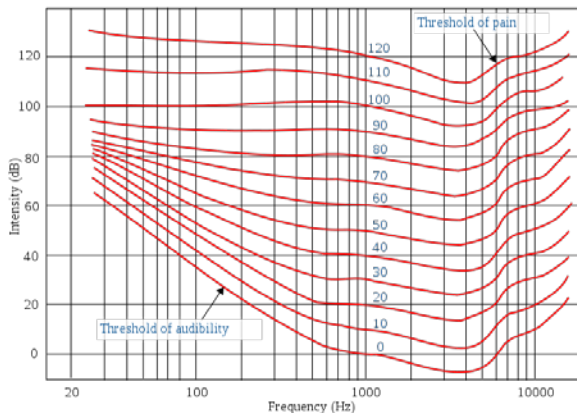
III Objektive Studie (Nachmittag)

- 5. Orchestras, configurations and material**
- 6. Objective methods**
- 7. Results**
- 8. Conclusions**
- 9. Potential improvements**

1. LÄRMBELASTUNG (I)

Hörgrenzen:

- **Wahrnehmungsschwelle (0dB,1kHz)**
- **Schmerzschwelle (120dB,1kHz)**

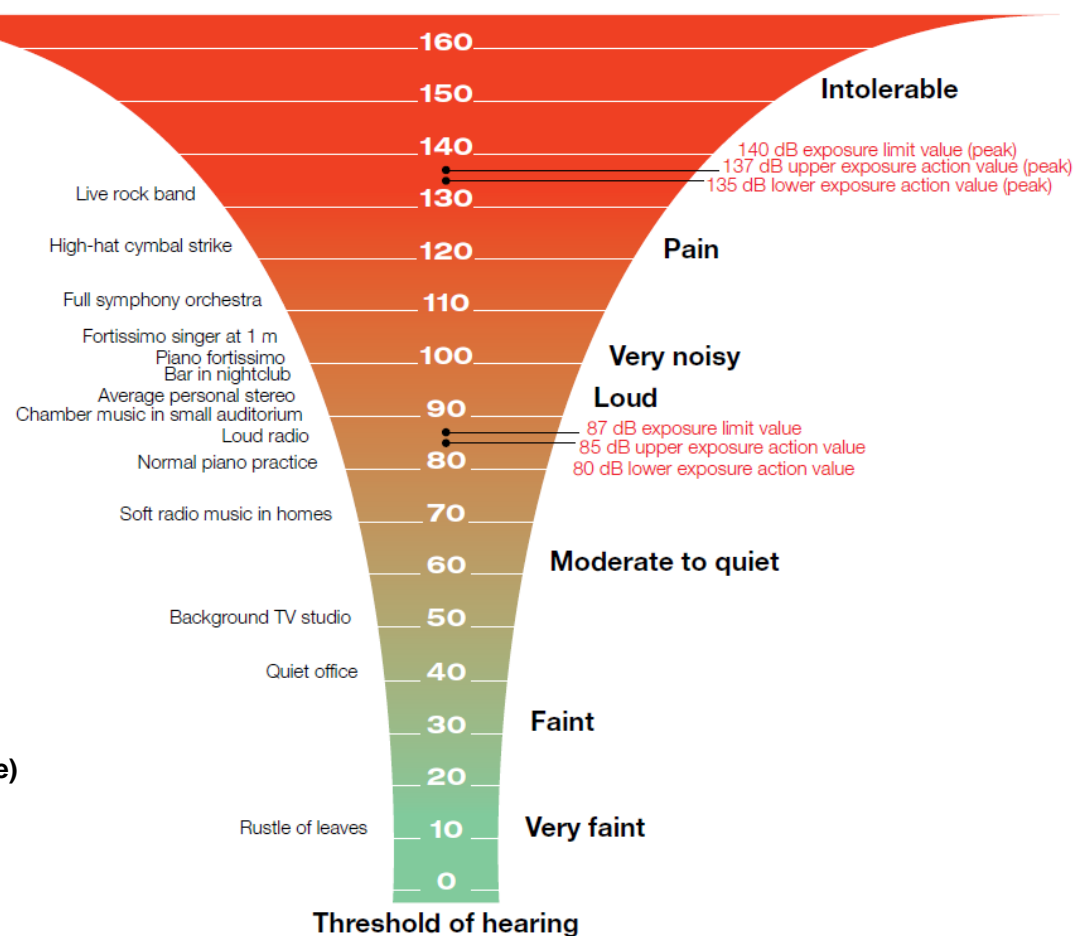


Quelle: Fletcher & Munson equal loudness contours

Hörprobleme, die von Lärmbelastung hervorgerufen werden:

- **Stress, Schlafstörungen, Verletzung z.B. der Basilarmembran, Krankheiten...**
- **Hypoacusis (Anstieg der Wahrnehmungsschwelle)**
- **Hyperacusis (Absenkung der Schmerzschwelle)**
- **(partielle) Taubheit**
- **Tinnitus**

Typische Schallbelastung bei Musikbeschallung



1. LÄRMBELASTUNG (II)

✓ **Lärmbelastung = Lärmdosis**

Die Lärmbelastung von Orchestermusikern berücksichtigt zwei Faktoren:

- **Pegel / Sound Pressure Level exposition (LAeq,LCpeak)**
- **Dauer / Time exposition (per day or week)**

Beispiel:

Wie lange braucht es, um eine bestimmte Lärmdosis zu erreichen?

Average noise level (dBA)	Time exposure (hours)
90	8
93	4
96	2
99	1
102	0.5

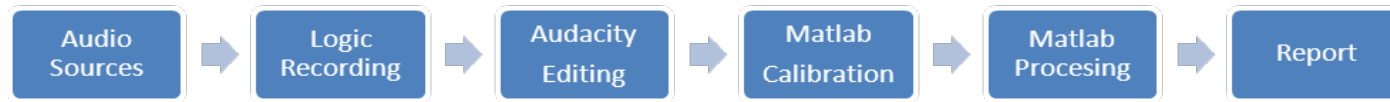
- **Wie kann die Lärmdosis halbiert werden?**
Halbierung des SPL oder der Dauer

Pegel / Noise exposure level verschiedener Instrumente in 3m Abstand

Schallquelle	Leq dB(A)	Lpeak dB(C)
Violin/viola (near left ear)	105	116
Violin/viola	90	104
Cello	104	112
Acoustic bass	94	98
Clarinet	82	112
Oboe	102	116
Saxophone	110	113
Flute	105	109
Flute (near right ear)	114	118
Piccolo	112	120
Piccolo (near right ear)	118	126
French horn	104	107
Trombone	106	109
Trumpet	108	113
Harp	90	111
Timpani and bass drum	94	106
Percussion (hi-hat near left ear)	94	125
Percussion	105	123-134
Singer	85	94
Soprano	110	118
Choir	86	-
Normal piano practice	90	105
Loud piano	105	110
Keyboards (electric)	110	118
Chamber music (classical) (several musicians)	92	99
Symphonic music (several musicians)	102	120-137
Conductor	82	-

Schallpegel-berechnung

L, Level, SPL, Leq, LCeq, LCpeak, ...



- ✓ Recording settings: microphones & shields placement
- ✓ Audio edition: choice of samples of music
- ✓ Matlab calibration
- ✓ Matlab processing: SPL envelope calculation:
 1. Calibrate the sample of music
 2. Apply a fast time signal window; Time Constant (T_c) = z.B. 125ms = L (length)
 3. Calculate the RMS and level for every interval
$$RMS = \sqrt{\frac{1}{L} \sum_n^{(n+L)-1} x[n]^2} \quad (n \leq x[n] \leq (n+L))$$
$$RMS[dB] = 20 \cdot \log_{10}(RMS)$$
 4. SPL(t): Einhüllende des Schalldruckpegels
 5. Optional: Anwendung eines Filters (A, C)

2. EU-RICHTLINIEN: GRENZWERTE UND MAßNAHMEN

1. Lower exposure action values (LEAV):

- **Daily or weekly exposure of $L_{eq,d}=80$ dB(A)**
- **Peak sound pressure of $L_{peak}=135$ dB(C)**
- **ACTION:**
 - Undertake risk assessment. Health surveillance program implemented
 - Supply suitable hearing protection to reduce noise risk
 - Provide training

2. Upper exposure action values (UEAV):

- **Daily or weekly exposure of $L_{eq,d}=85$ dB(A)**
- **Peak sound pressure of $L_{peak}=137$ dB(C)**
- **ACTION:**
 - Implement the actions required by lower exposure action values
 - Implement a program of control measures
 - Suitable hearing protection must be used

3. Exposure limit values (ELV):

- **Daily or weekly exposure of $L_{eq,d}=87$ dB(A)**
- **Peak sound pressure of $L_{peak}=140$ dB(C)**
- **ACTION:**
 - Must reduce to below limit values

Source: European Directive (2003/10/EC)

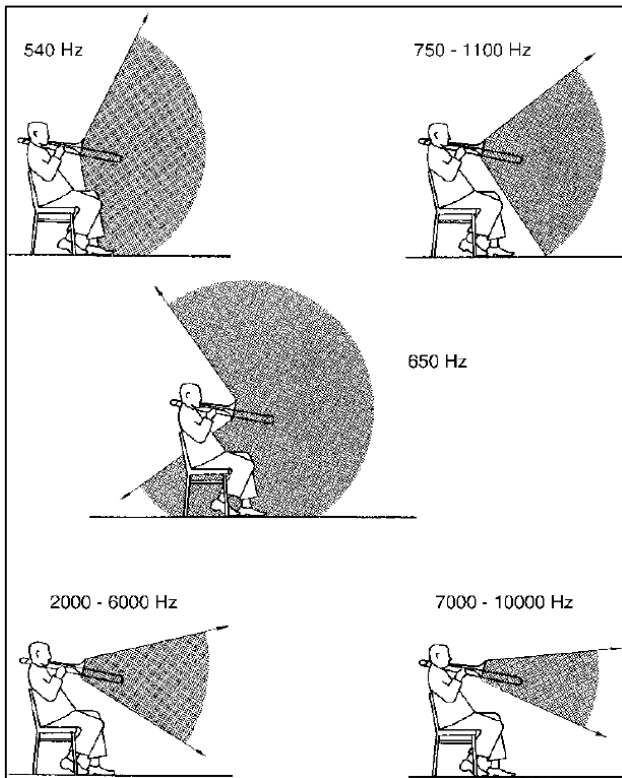
3. ABSTRAHLUNG VON MUSIKINSTRUMENTEN (I)

Ursprung typischer Schallbelastung im Orchester

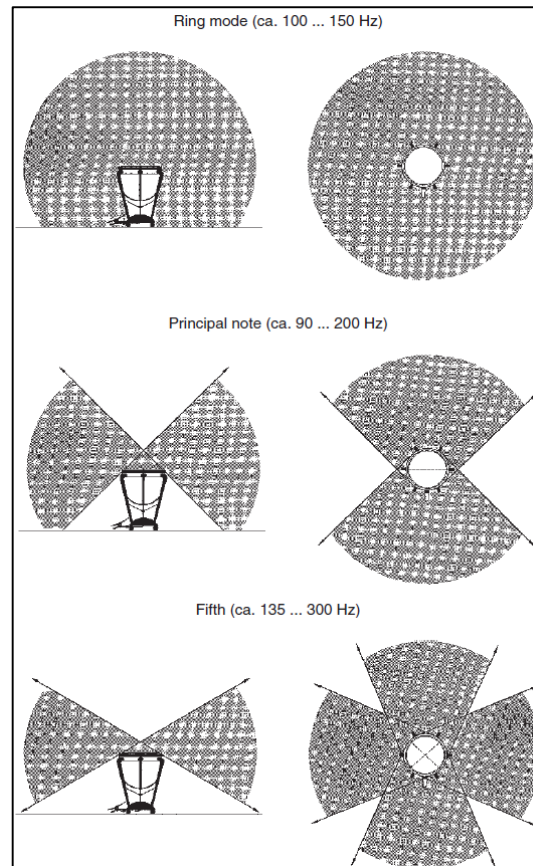
Instrumentengruppe	Situation	Problem für diese Gruppe
Woodwinds	Proximity to brasses or percussion radiation	Exposed to loud peak levels. Intense high or low frequencies sound
Flutes and piccolos	Instrument with high peak level at high frequencies	Exposed to loud peak levels. Intense high frequencies sound
Brasses	Proximity to other brasses or percussion radiation	Exposed to loud peak level. Intense high or low frequencies sound
Violins and violas	Instrument with lower level	Lose the reference of lower level instruments
Basses, cellos, harps	Proximity to brasses radiation	Exposed to loud levels. Intense high frequencies sound
Drums and percussion	Instrument with high peak levels	Exposed to loud peak levels. Intense high frequencies (cymbals or snare), and low frequencies sound (timpani)
Conductors	Better hearing conditions	Lose the lower level and higher frequency references

3. ABSTRAHLUNG VON MUSIKINSTRUMENTEN (II) (BEISPIELE)

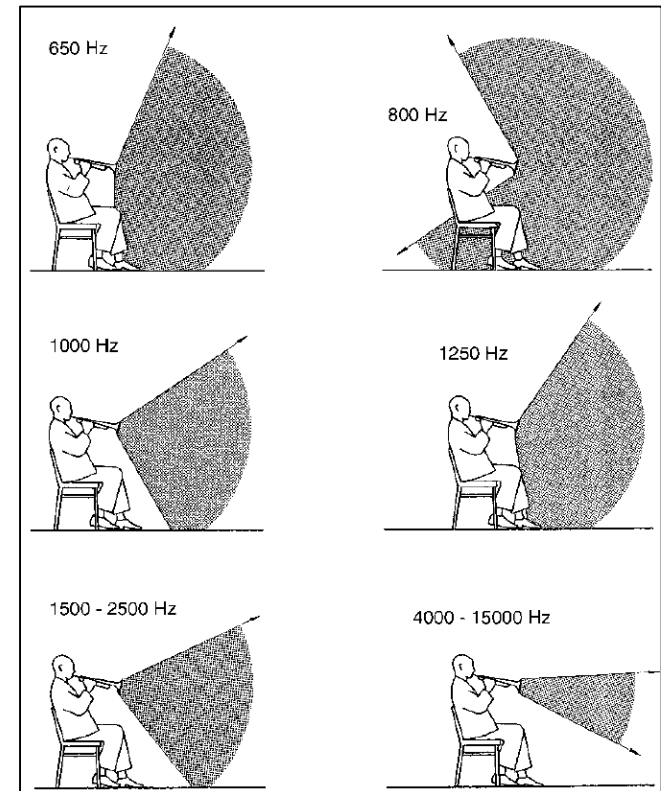
Posaunen: 540 Hz - 10 kHz



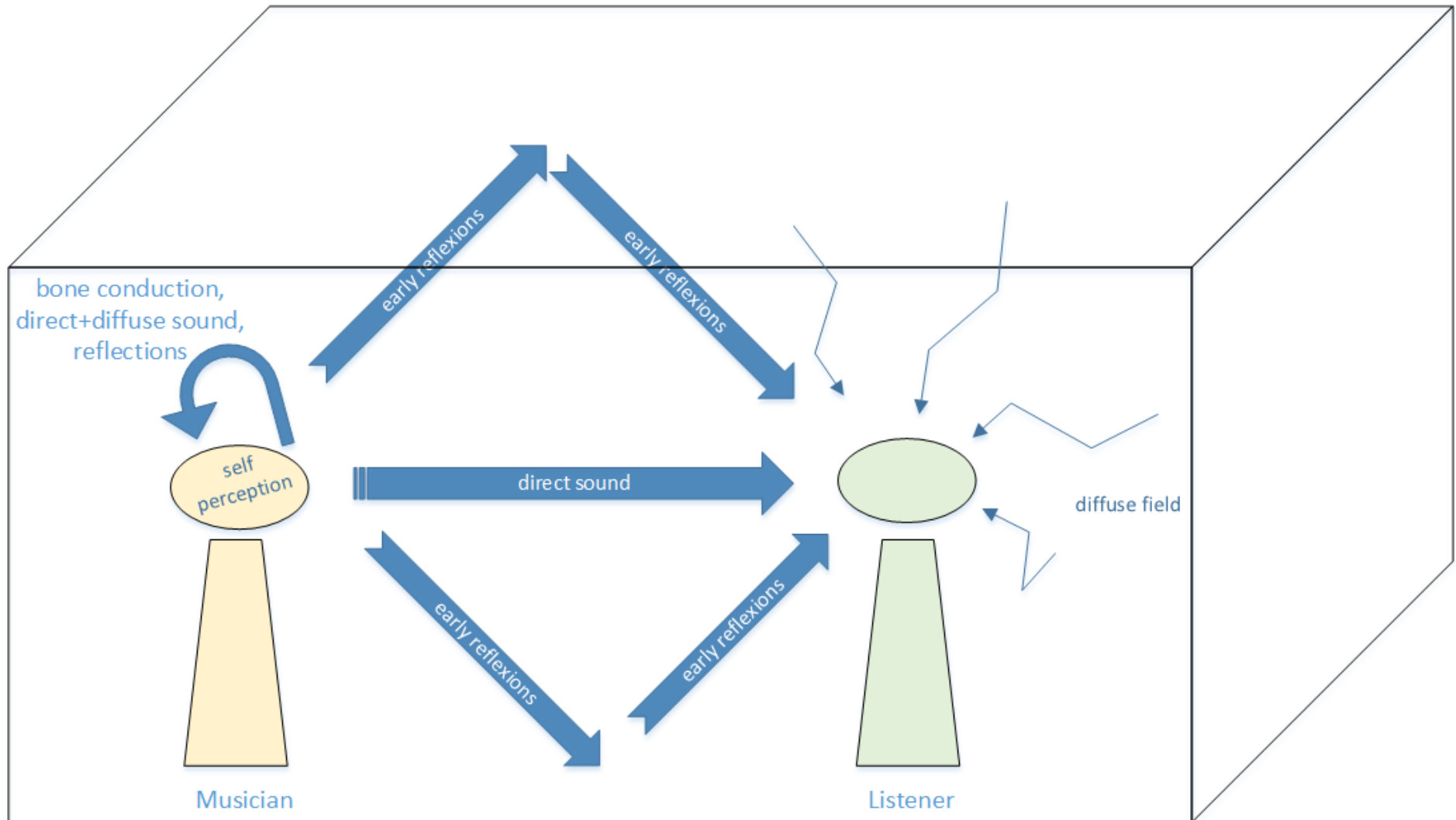
Timpani: 100-300 Hz



Trompeten: 650 Hz - 15 kHz



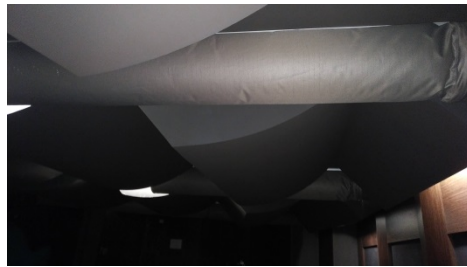
INTERAKTION RAUM – MUSIKERIN - HÖRER



RAUMAKUSTISCHE HERAUSFORDERUNG: ORCHESTERGRABEN

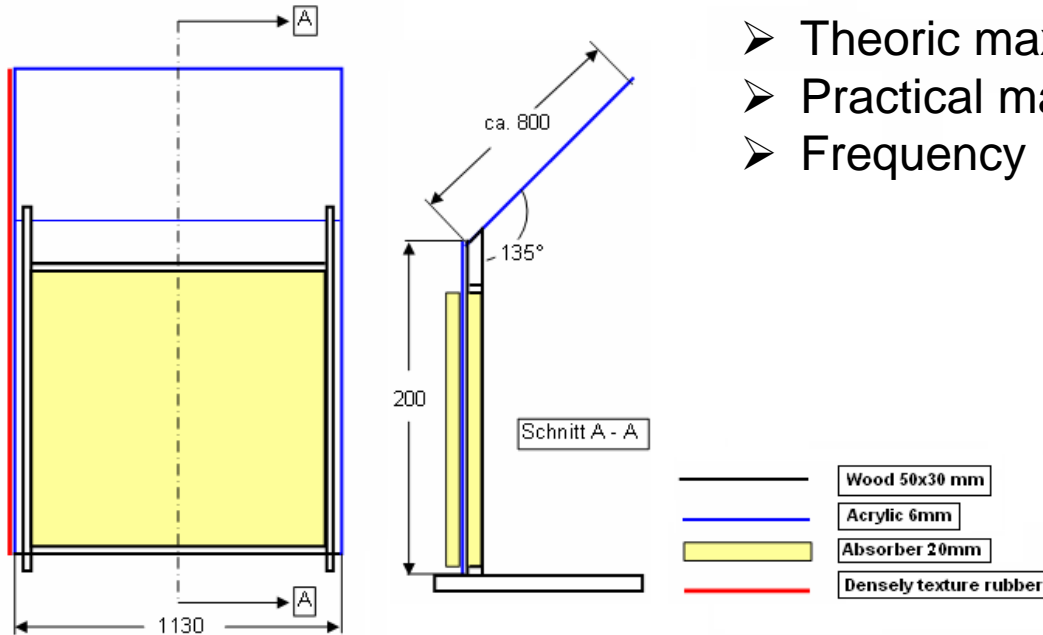
Einfluss und Optimierung der Deckenstruktur

Optimierung der Seiten- und Rückwandabsorber



4. SCHALLSCHUTZSCHIRME (I)

Acoustic screen model with absorbent material



- Theoric maximum attenuation: 20 dB (10 kHz)
- Practical maximum attenuation: 12 dB
- Frequency range: 400 Hz-10 kHz

Source: PTB report

Alternatives:

- Individual protection
- Better rooms: more absorbent or with pits
- Different instruments distribution
- Softer rehearsals



4. SCHALLSCHIRME (II): HYPOTHESEN UND AUSWERTEMETHODEN

Hypothesen:

- Impact of direct sound from loud instruments could be reduced
- Perception of softer instruments could be reduced, especially for loud instruments
- Balance could change at conductor and in audience position
- Screens could introduce disadvantageous acoustic and optic reflections
- Visual communication could be reduced
- Verbal communication could be reduced
- Freedom of movement could be reduced
- Lack of space for a proper use of the screens

Analyse der Wirkung von Schallschutzschirmen mit zwei Methoden:

I) Subjektive Studie: Befragung von Musikern (Maria Schuppert)

II) Objektive Studie: Auswertung von Schalldruckpegeln (Malte Kob)

5. ORCHESTRAS, CONFIGURATIONS AND MATERIAL

Recorded orchestras:

- Hochschulorchester of the HfM Detmold. Rehearsal and New Year Concert
- Junge Sinfoniker OWL. Rehearsal and concert
- Dortmunder Philharmoniker. Rehearsal
- Hochschulorchester of the HfM Detmold.
Percussion, woodwinds & brass group of instruments rehearsal

Configurations:

- Few shields
- Shield barrier
- Reflecting/absorbent
- With/without
- In front/behind

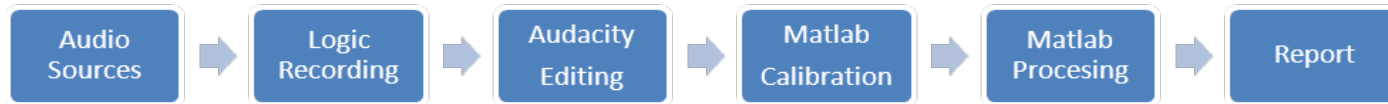
Material:

- Microphones: Omnidirectional, flat frequency response, high sensibility..
- Sonometers
- Dosemeters
- Dummyhead
- Pistonphone



6. OBJECTIVE METHODS (I):

CALIBRATION



- ✓ Recording settings: microphones & shields emplacement
- ✓ Audio edition: choice of samples of music
- ✓ Matlab calibration:
 1. Record pistonphone signal (94dB) with same audio settings
 2. Calculate RMS level from digital signal:

$$RMS^2 = \frac{1}{L+1} \sum_{k=0}^L x^2(n)$$
$$Level(dBFS) = 10 \log_{10}(RMS^2)$$

3. Obtain the Lineal Corrector Factor (LCF):

$$CF = 94 - Level(dBFS)$$

$$LCF = 10^{(CF/20)}$$

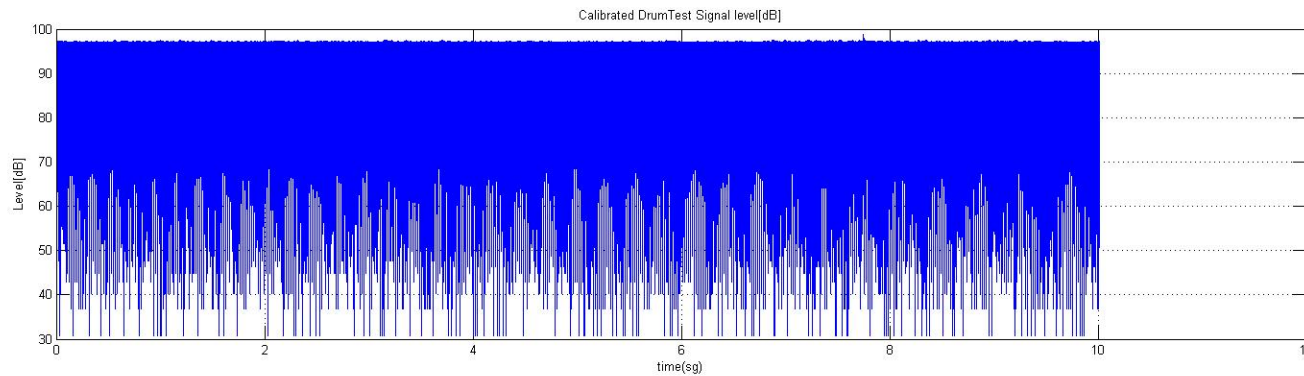
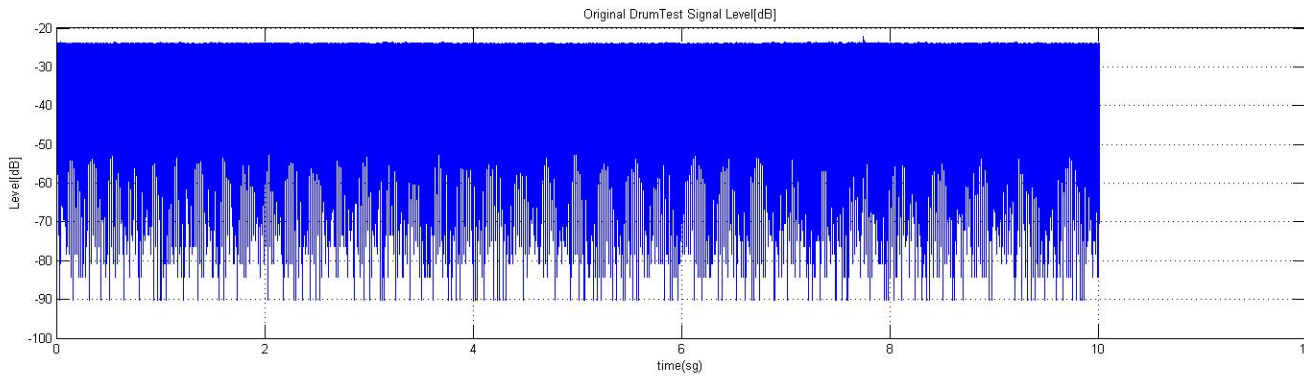
4. Multiply every signal by the LCF

- ✓ Matlab processing. Envelope calculation

6. OBJECTIVE METHODS (II):

CALIBRATION

✓ Matlab calibration: EXAMPLE



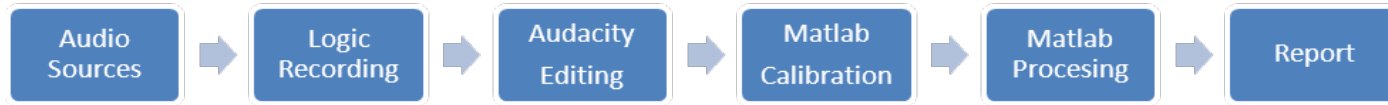
```
Command Window
Choose the microphone you want to calibrate
1.At Drums
2.At Horn
3.At Trombone
4.At Trumpet
5.At Cello
6.At Conductor
7.At Audience
8.Exit

Option: 1

calibrated =

    94.0000
```


6. OBJECTIVE METHODS (III): ENVELOPE CALCULATION



- ✓ Recording settings: microphones & shields emplacement
- ✓ Audio edition: choice of samples of music
- ✓ Matlab calibration
- ✓ Matlab processing. Envelope calculation:
 1. Calibrate the sample of music
 2. Apply a fast time response filter; Time Constant (T_c) = 125ms = L(Length)
 3. Calculate the RMS level for every interval

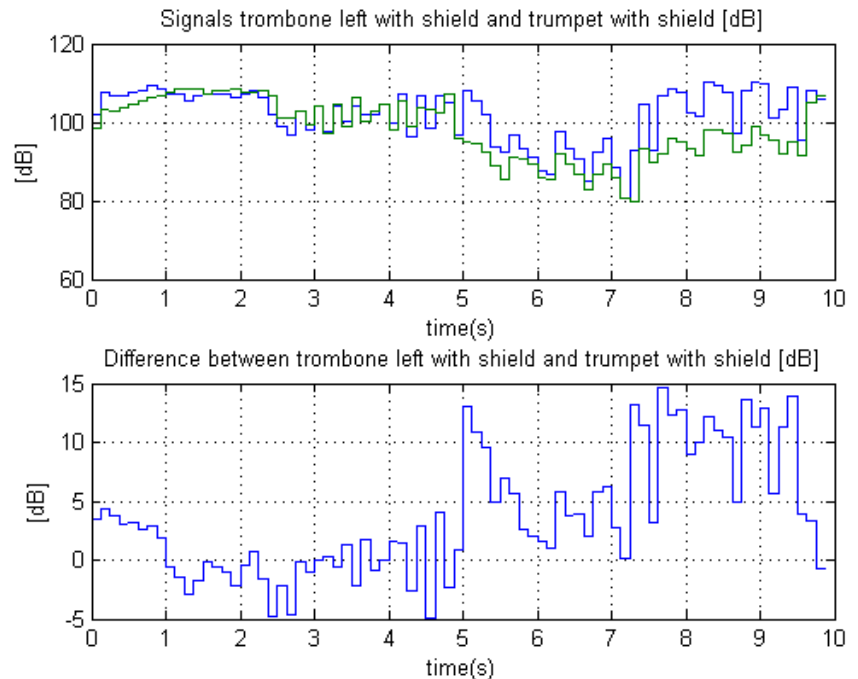
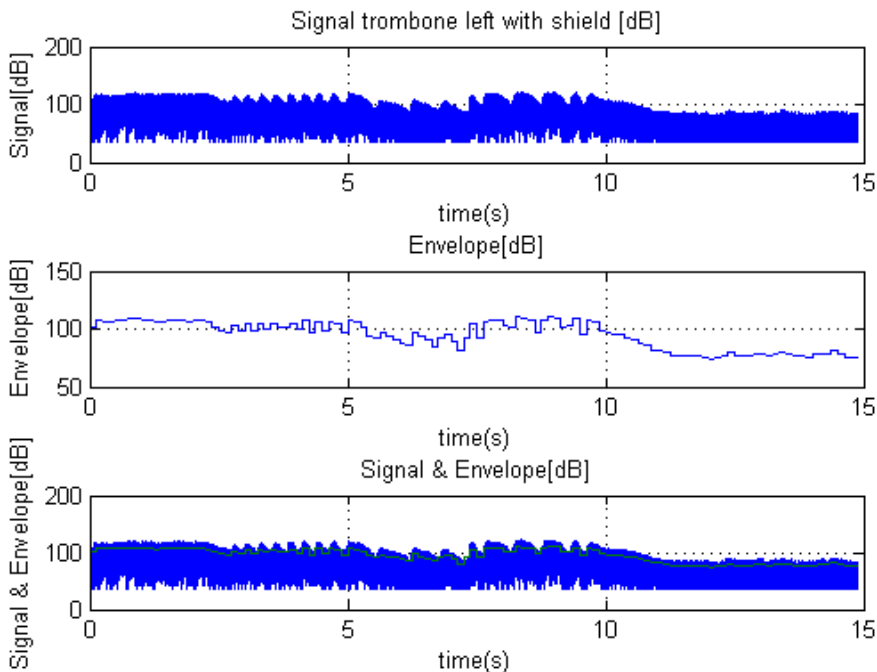
$$RMS = \sqrt{\frac{1}{L} \sum_n^{(n+L)-1} x[n]^2} \quad (n \leq x[n] \leq (n+L))$$

$$RMS[dB] = 20 \cdot \log_{10}(RMS)$$

4. SPL(t): Envelope representation

6. OBJECTIVE METHODS (IV): ENVELOPE CALCULATION

✓ Envelope representation: EXAMPLE



Attenuation evaluation depends on :

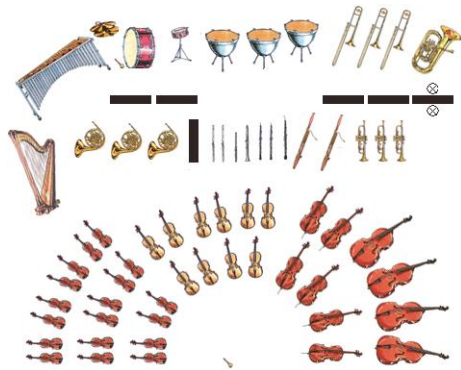
- Phase
- Dynamics
- Score

Maximum attenuation: 15dB

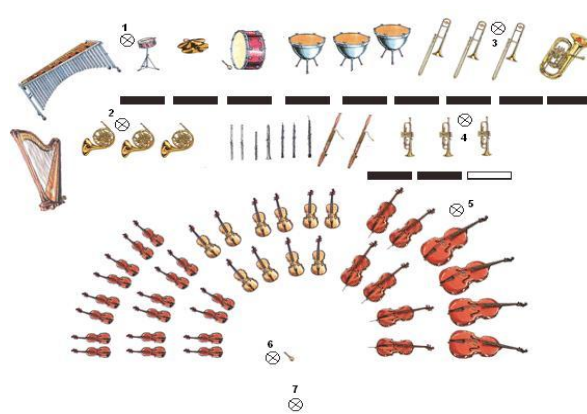
Blue Line: represents signal with reflecting material
Green Line: represents signal with absorbent material

7. RESULTS: HFM ORCHESTRA. NEW YEAR CONCERT

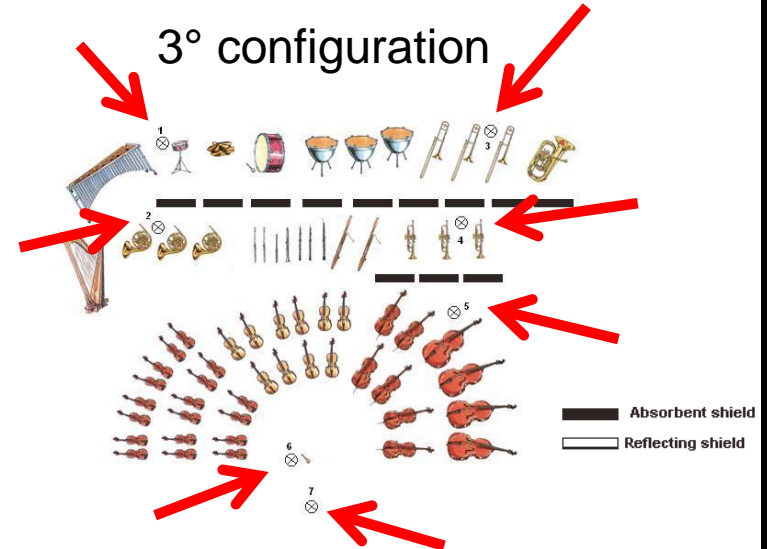
1° configuration



2° configuration



3° configuration



No Statistic results



Statistic results from 3
samples of music
*Same samples to compare



Statistic results from 5
samples of music
*Different samples to compare

7. RESULTS: HFM ORCHESTRA. NEW YEAR CONCERT COMPARISON WITH/WITHOUT SCREENS



1. At drums
without shield



2. At horns
without shield



3. At trombones
without shield



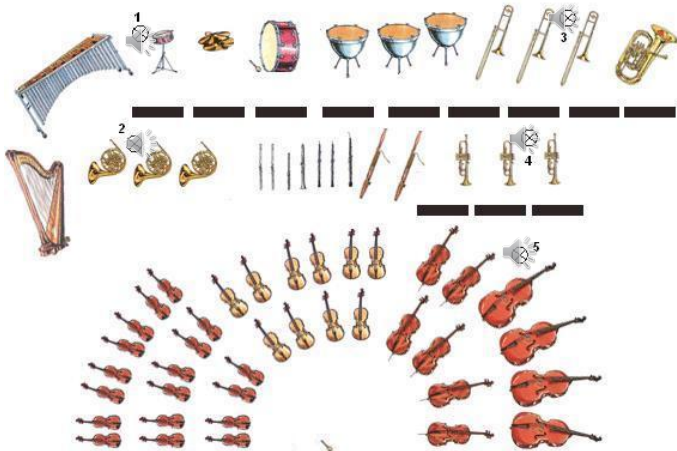
4. At trumpet
without shield



5. At cello
without shield

Statistics results from 5 pieces of music comparing levels in front and behind the screens

✓ 3° Configuration

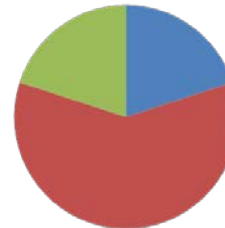


- ✓ Samples with shields **are different** from without shields
- ✓ Statistic from 5 samples of music

Between Drum and Horn
position with screen



Between Trombone and
trumpet position with screen



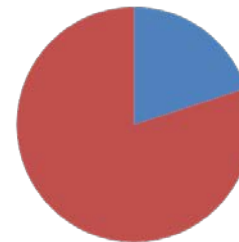
Between Trumpet and Cello
position with screen



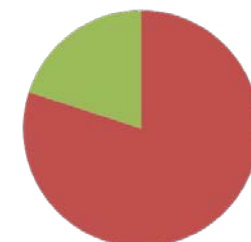
Between Drum and Horn
position without screen



Between Trombone and
trumpet position
without screen



Between Trumpet and Cello
position
without screen



- Same level in front and behind the screen
- More level behind than in front of the screen
- More level in front than behind the screen

7. RESULTS: HFM ORCHESTRA. NEW YEAR CONCERT COMPARISON REFLECTING/ABSORBENT SCREENS



1. At drum with
absorbent shield



2. At horn with
absorbent shield



3. At trombone
with absorbent
shield



4. At trumpet with
absorbent shield



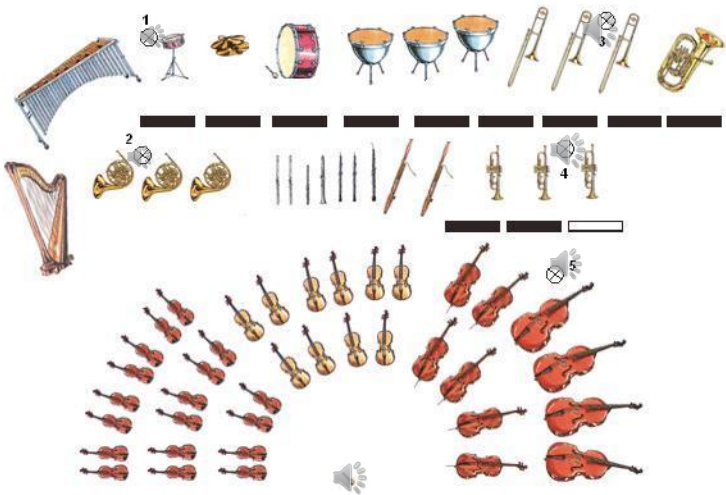
5. At cello with
absorbent shield



6. At conductor
with absorbent
shield

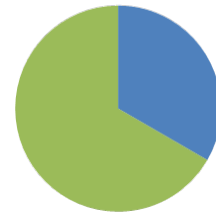
Statistics results from 3 pieces of music comparing levels in front and behind the screens

✓ 2° Configuration: in front/ behind

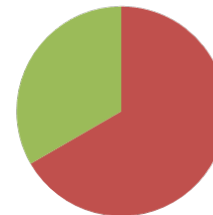


- ✓ Samples with reflecting shields are **the same** as with absorbent shields
- ✓ Statistic from 3 samples of music

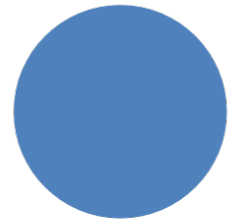
Between Drum and Horn
with reflecting shield



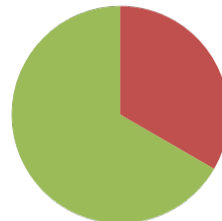
Between Trombone and Trumpet
with reflecting shield



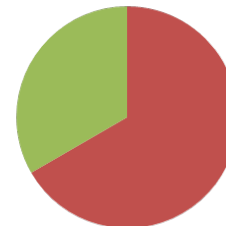
Between Trumpet and Cello
with reflecting shield



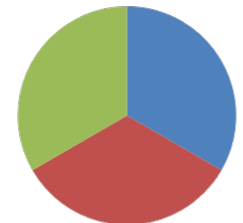
Between Drum and Horn
with absorbent shield



Between Trombone and trumpet
with absorbent shield




Between Trumpet and Cello
with absorbent shield




- Same level in front and behind the screen
- More level behind than in front the screen
- More level in front than behind the screen


7. RESULTS: HFM ORCHESTRA. NEW YEAR CONCERT COMPARISON REFLECTING/ABSORBENT SCREENS

 1. At drum with absorbent shield

 2. At horn with absorbent shield

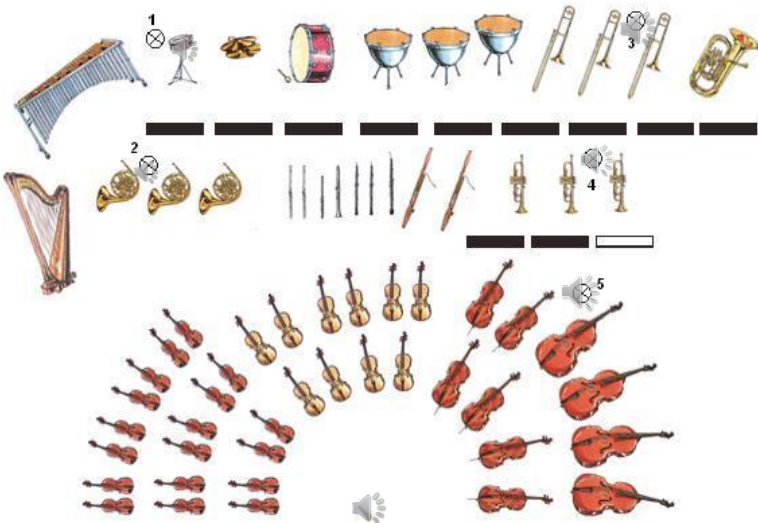
 3. At trombone with absorbent shield

 4. At trumpet with absorbent shield

 5. At cello with absorbent shield

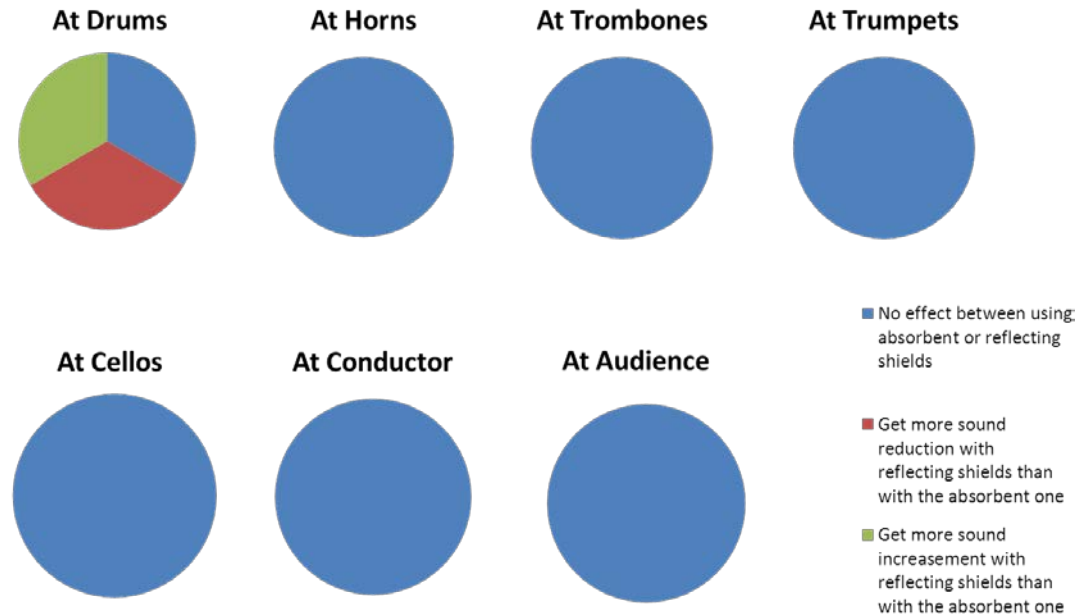
 6. At conductor with absorbent shield

✓ 2° Configuration: at every position

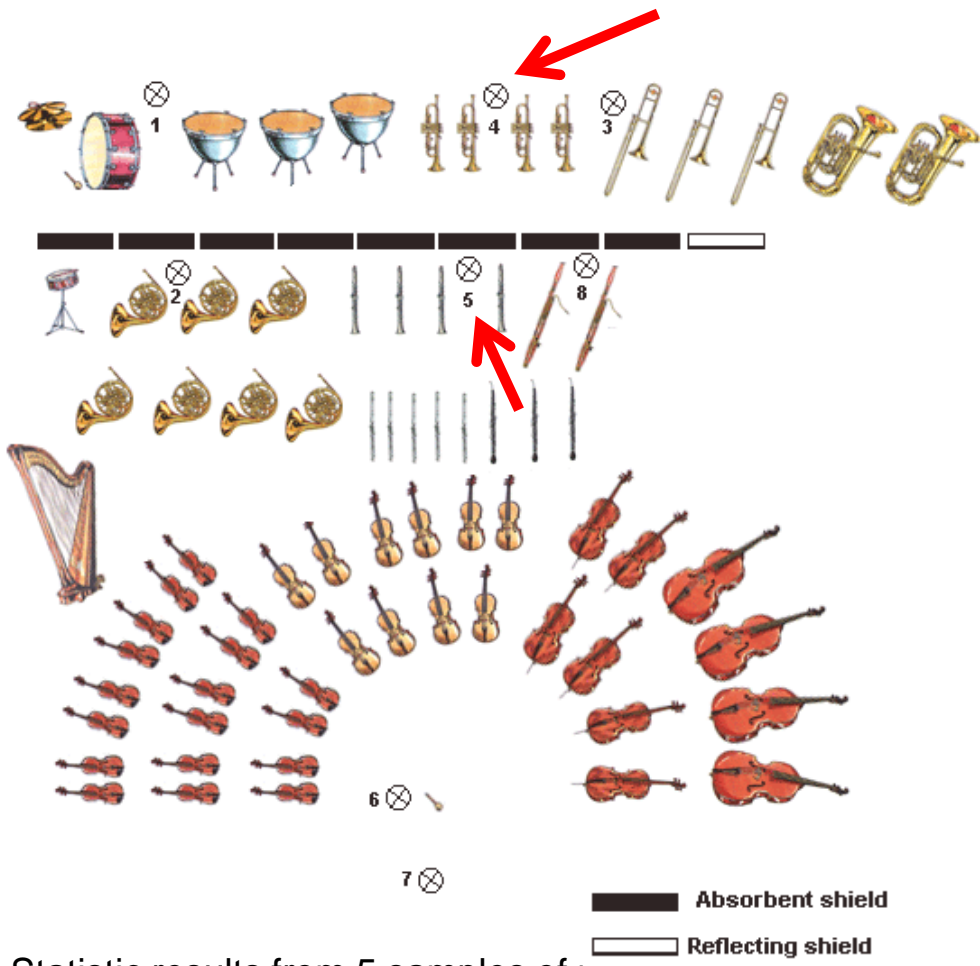


- ✓ Samples with reflecting shields are **the same** as with absorbent shields
- ✓ Statistic from 3 samples of music

Statistics results from 3 pieces of music comparing levels between the situation with reflecting and absorbent screens



7. RESULTS: HFM YOUNG ORCHESTRA

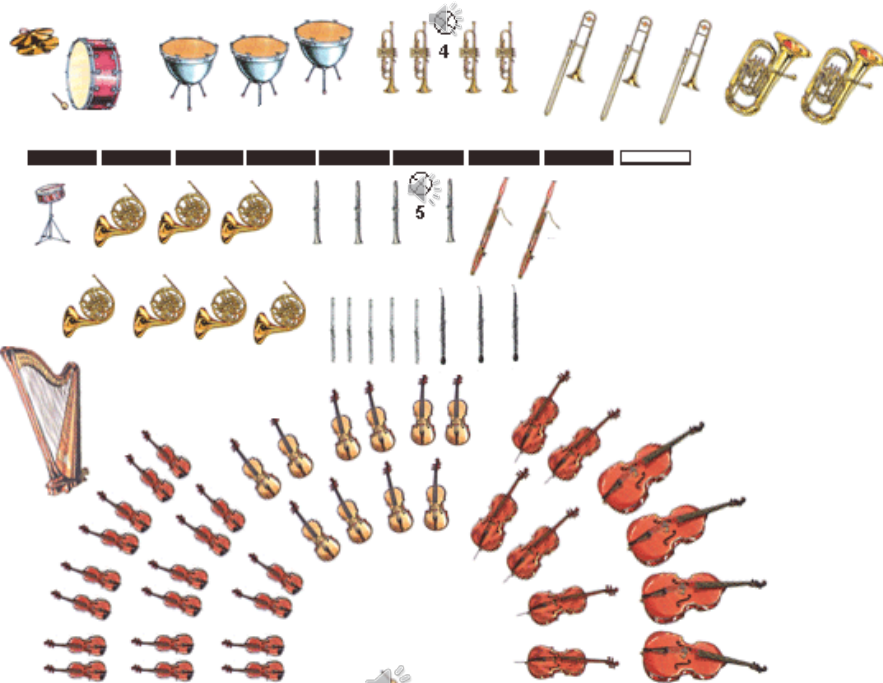


Statistic results from 5 samples of music
 *Different samples to compare



7. RESULTS: HFM YOUNG ORCHESTRA COMPARISON WITH/WITHOUT SHIELDS

✓ Measure: in front/behind screens



- ✓ Samples with shields **are different** from without shields
- ✓ Statistic from 5 samples of music



At trumpet
without shield

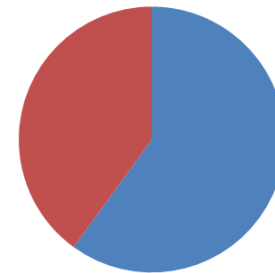


At clarinet
without shield



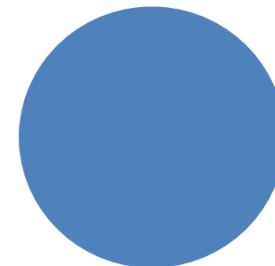
At conductor
without shield

Between trumpet and clarinet with shields



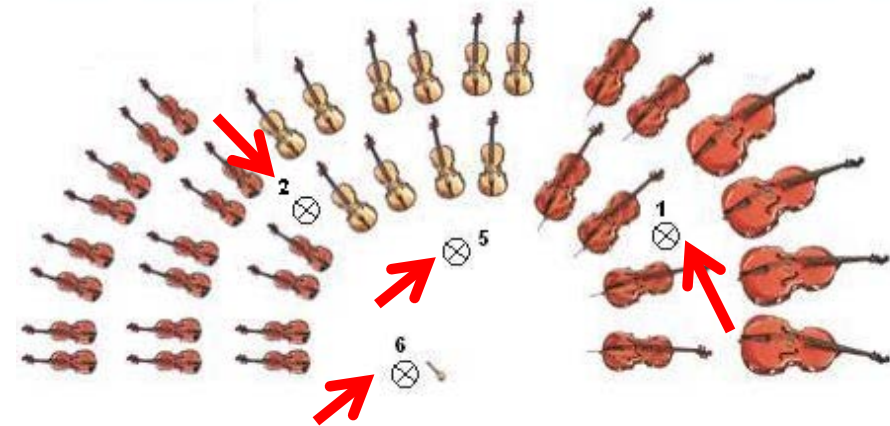
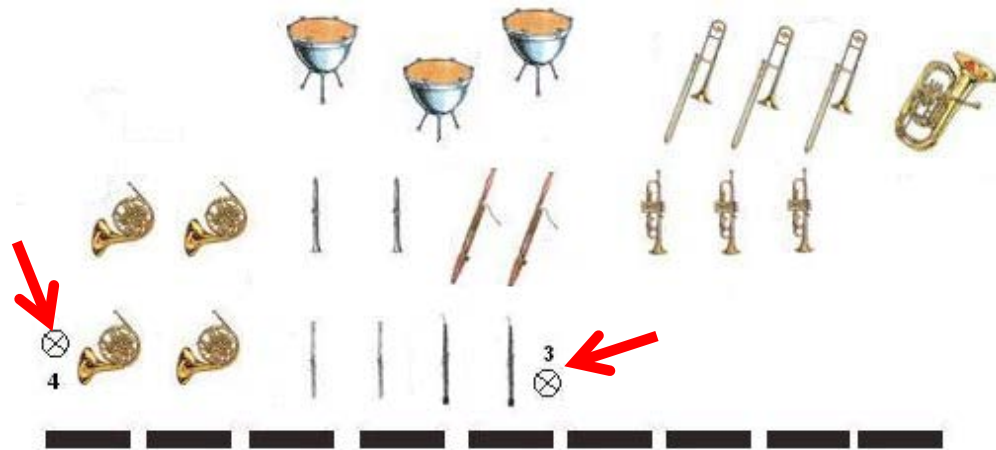
■ Same Level
■ Attenuation Level
■ Increment Level

Between trumpet and clarinet without shields



■ Same Level
■ Attenuation Level
■ Increment Level

7. RESULTS: DORTMUNDER PHILHARMONIKER



Statistic results from 4 samples of music
*Same samples to compare

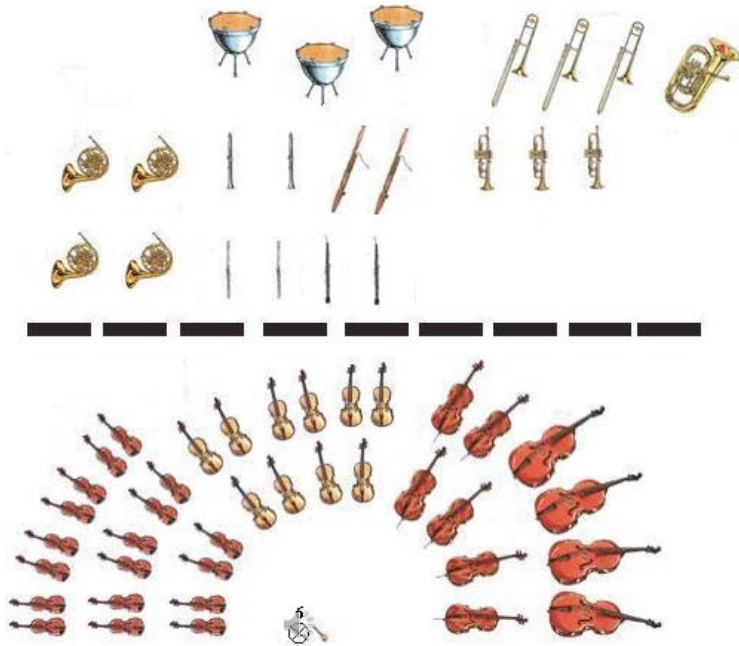


7. RESULTS:DORTMUNDER PHILHARMONIKER COMPARISON WITH/WITHOUT SHIELDS



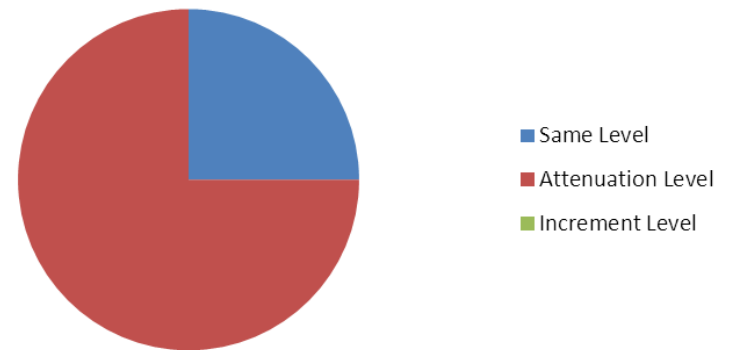
At conductor
without shield

✓ Measure: Only at conductor position



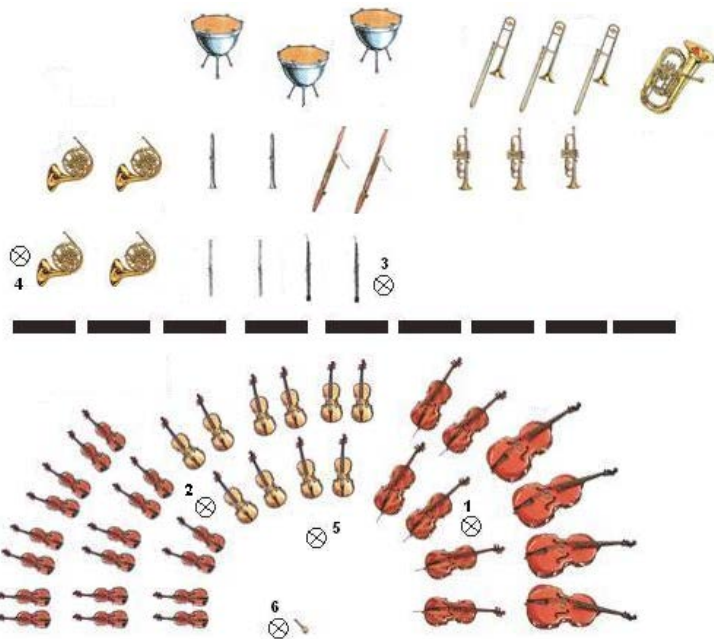
- ✓ Samples with shields **are the same** as without shields
- ✓ Statistic from 4 samples of music

Comparison between levels at
Conductor without and with shields



7. RESULTS:DORTMUNDER PHILHARMONIKER LAEQ AND LCPEAK WITH/WITHOUT SHIELDS

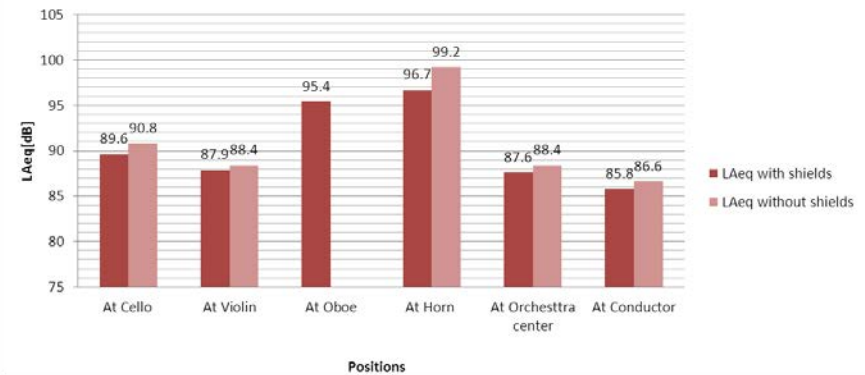
✓ Measure: at every dosemeter position



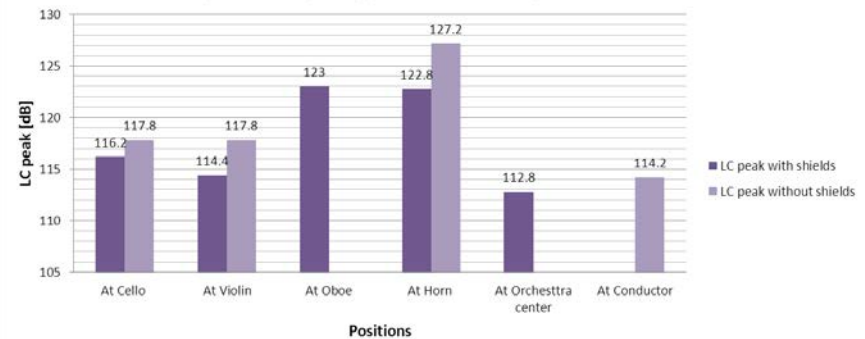
✓ Samples with shields **are the same** as without shields

✓ Statistic from 4 samples of music

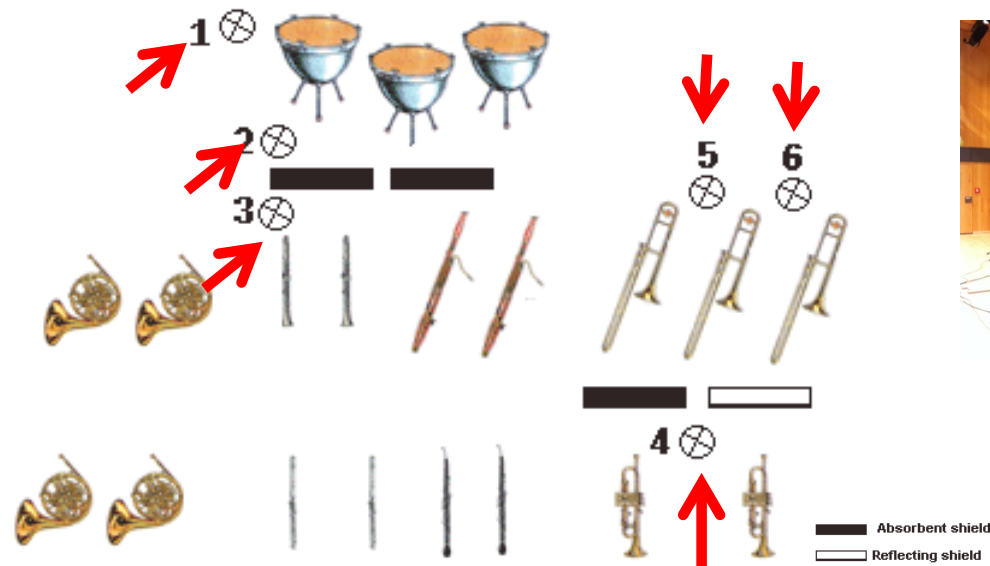
LAEq comparing with the same pieces of music



LC peak comparing with the same pieces of music



7. RESULTS: HFM ORCHESTRA. PERCUSSION, WOODWINDS AND BRASSES



Statistic results from 3 samples of music

*Same samples to compare

7. RESULTS: HFM ORCHESTRA. PERCUSSION, WOODWINDS AND BRASSES

MEASURE WITH SCREENS

✓ Measure: in front/behind screens



✓ Statistic from 3 samples of music

Statistics results from 3 pieces of music comparing levels in front and behind the screens.

Situation with shields

Between Drums and Clarinet in front of the screen



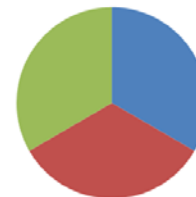
Between Clarinet behind and Clarinet in front of screen



Between Trombone left and Trumpet



Between Trombone right and Trumpet



- Same Level in front and behind the screen
- Less level in front than behind the screen
- More level in front than behind the screen

7. RESULTS: HFM ORCHESTRA. PERCUSSION, WOODWINDS AND BRASSES MEASURE WITHOUT SCREENS

✓ Measure: in front/behind screens



✓ Statistic from 3 samples of music

Statistics results from 3 pieces of music comparing levels in front and behind the screens.

Situation without shields

Between Drums and
Clarinet in front of the
screen



Between Clarinet behind the
screen and Clarinet in front
of screen



Between Trombone left
and Trumpet



Between Trombone right
and Trumpet



■ Same Level in front and
behind the screen
■ Less level in front than
behind the screen
■ More level in front than
behind the screen

7. RESULTS: HFM ORCHESTRA. PERCUSSION, WOODWINDS AND BRASSES

COMPARISON WITH/WITHOUT SHIELDS



1. At drums without shield



2. At clarinet behind the screen without shield



3. At clarinet in front of the screen without shield



4. At trumpet without shield



5. At trombone left without shield



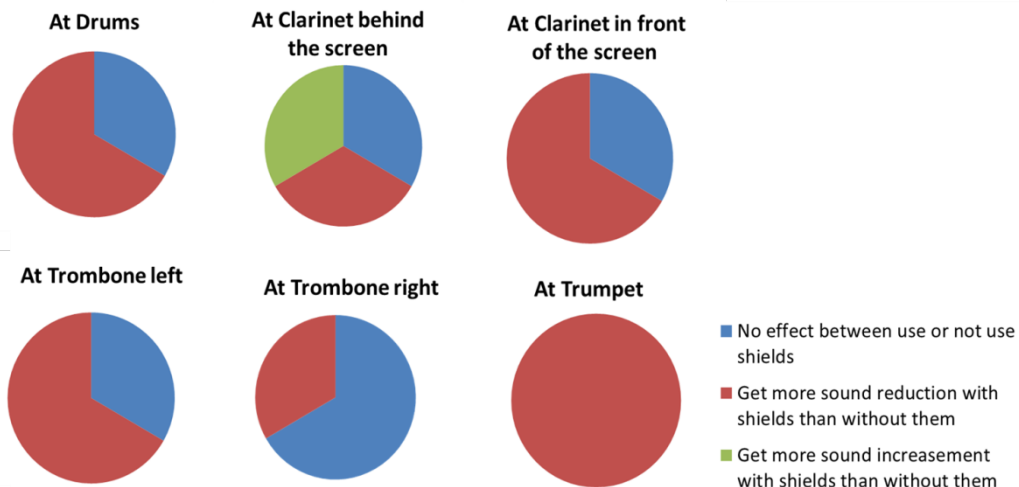
6. At trombone right without shield

✓ Measure: at every position



- ✓ Samples with shields **are the same** as without shields
- ✓ Statistic from 3 samples of music

Statistics results from 3 pieces of music comparing levels between the situations with and without shields



8. CONCLUSIONS

- ✓ Impact of direct sound from loud instruments is reduced
- ✓ Perception of lower instruments is reduced, especially for loud instruments
- ✓ Balance is changed at conductor and in audience position
- ✓ Screens can introduce disadvantageous acoustic reflections
- ✗ Visual communication is not reduced
- ✓ Verbal communication is reduced
- ✗ Freedom of movement is not reduced
- ✓ Lack of space for a proper use of the screens

9. POTENTIAL IMPROVEMENTS

- Improve the absorption capacity: adjust material (frequency dependent)
- Avoid acoustic reflections (eliminate reflecting material completely, or use only a window for visual communication)
- Versatility to adapt to any type of stages (adjustable legs and height)
- Facilities for transport (adding wheels)
- User manual. Proposed distances and orientation of the shields to obtain maximum efficiency
- In particular for brasses : an individual absorbent screens could be used (smaller and adjustable)
- In particular for drums: the size is appropriate but the absorbent material should be changed, and the reflecting material should be removed.

DANKE



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FRAGEN?

DISKUSSION IM ROUNDTABLE



Kontakt:
Prof. Dr.-Ing. Malte Kob
malte.kob@hfm-detmold.de
www.eti.hfm-detmold.de
+49 5231 975 644