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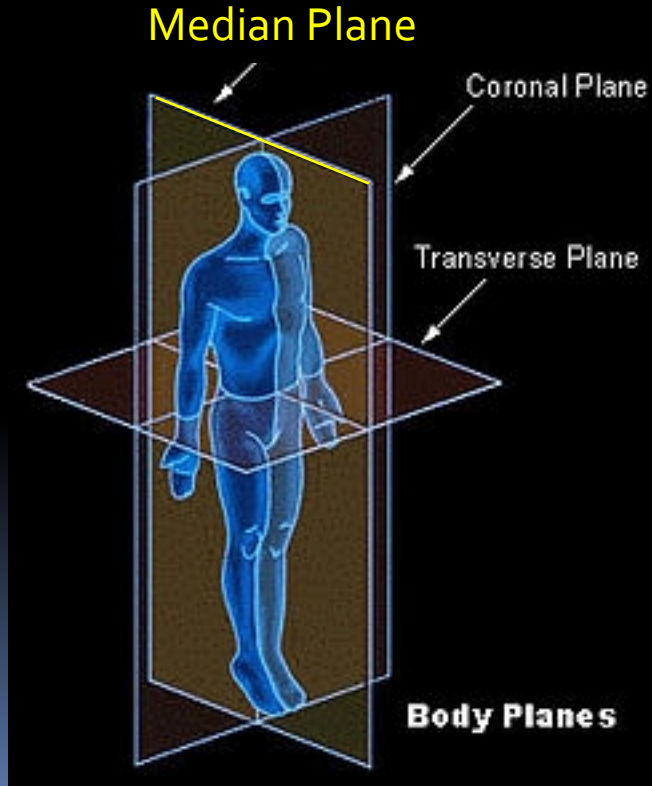
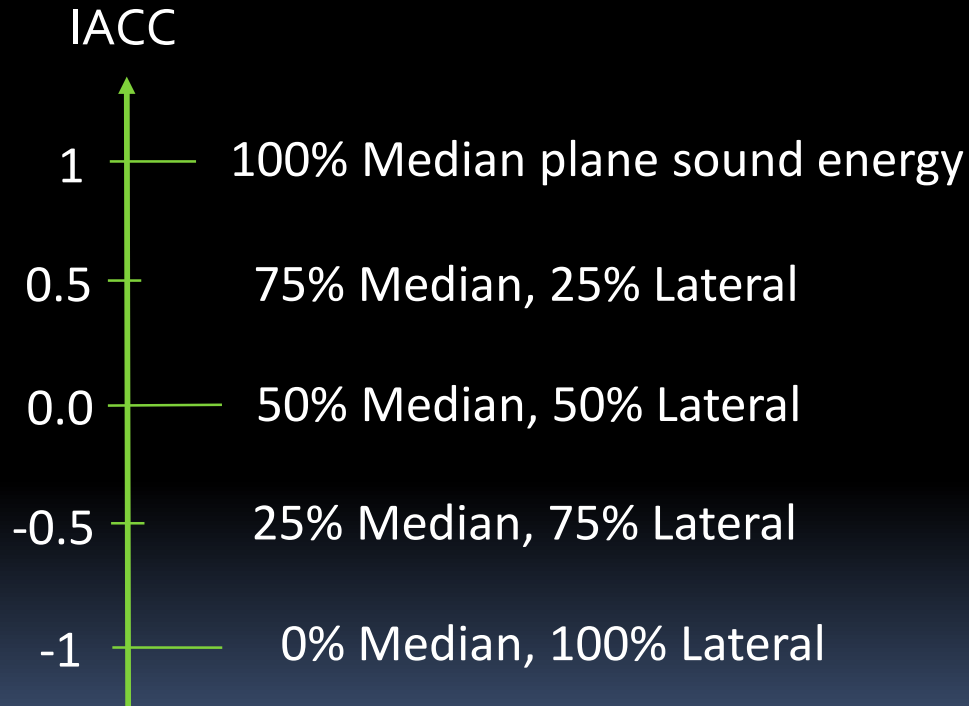
# INTER-AURAL CROSS-CORRELATION MEASURED DURING SYMPHONY ORCHESTRA PERFORMANCE IN BIG CONCERT HALLS

Acoustics '17, ASA EAA, Boston, Thursday 29 June 2017, 10:40

# Introduction

- Spatial impression in concert hall listeners is known to depend on lateral reflections causing differences between the sound at the left ear and the right ear
  - Such differences can be measured, so-called inter-aural cross-correlation IACC in a binaural signal pair, i.e. a signal pair from microphones placed in the ear canal entrances.
- IACC data from binaural impulse responses (BRIR) are commonly reported.
- In contrast, little attention has been paid to running IACC, i.e. IACt, during music performance.
- Binaural Project since 2011: Collect binaural signal data from concerts with symphony orchestras.
- Analysis of IACt from 600+ minutes of binaural recordings during concerts in big concert halls is presented.
  - Several famous halls, including Boston Symphony Hall, are included in the data.
- Among questions: Can we observe from the data that concert halls make a difference to IACt?
  - If YES - Is this variation small or big compared to the variation from one moment to another, bar to bar, movement to movement, from one orchestra to another, and so on?
  - If NO - How can we maintain that listeners perceive hall-to-hall differences in ASW and LEV?
  - If NO - Why do not the reported hall-to-hall differences in IACC from impulse responses (ISO-3382) make an observable difference to running IACt ?

# IACC: Median-Lateral sound energy balance

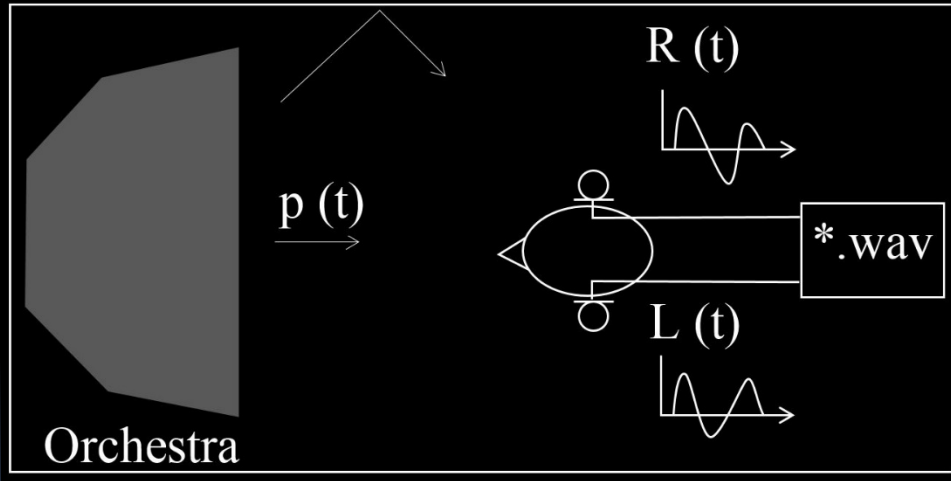


# Measurement equipment?



I don't think so

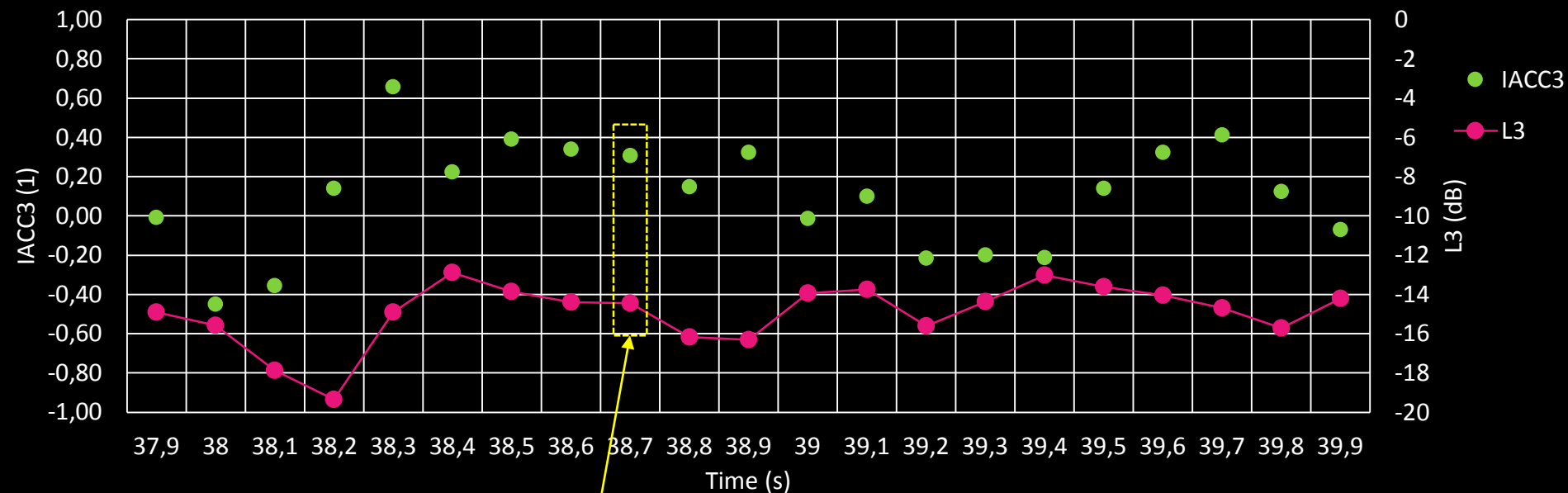
# Measurement setup & equipment



Post-processing:

- Audacity
- winMLS 2004
- Matlab
- Excel

# Sampling IACC and L(dB) from binaural signal



# Example: 1 symphony 2 halls

- ▣ Tchaikovsky 4th
- ▣ Stavanger Concert Hall
- ▣ Chicago Orchestra Hall



1

0,5

0

-0,5

-1

A

B

C

D

E

F

x

G

H

I

x

1

0,5

0

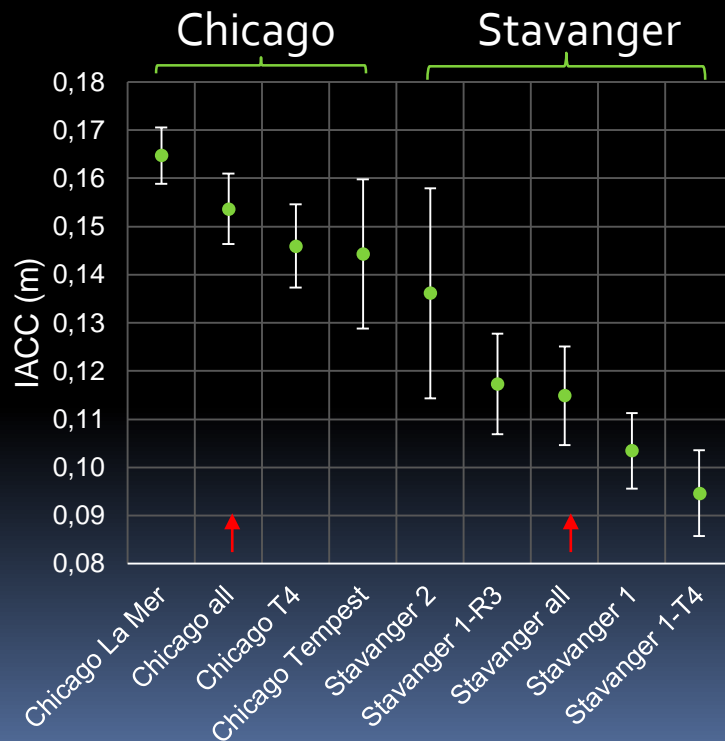
-0,5

-1



# IACct means, content and halls

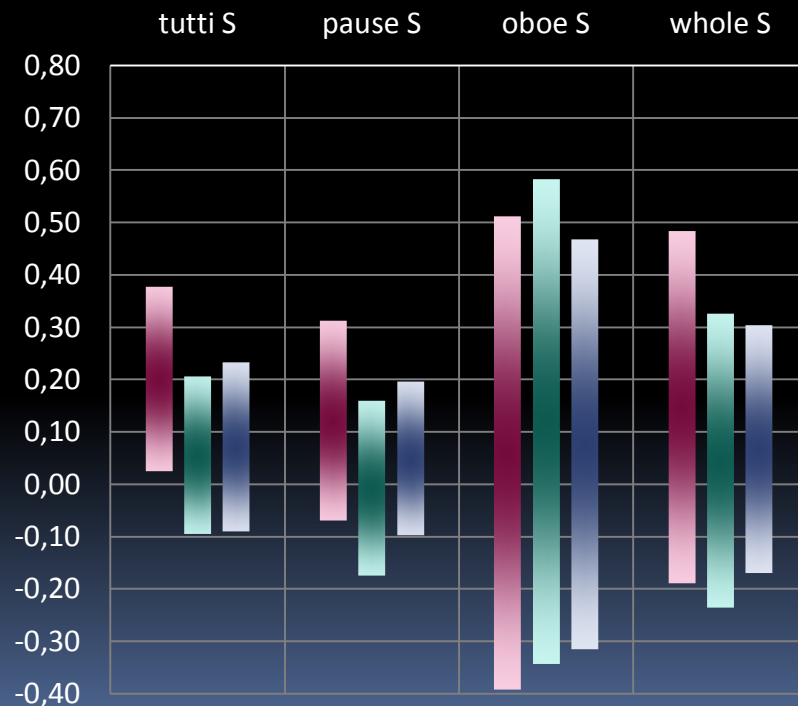
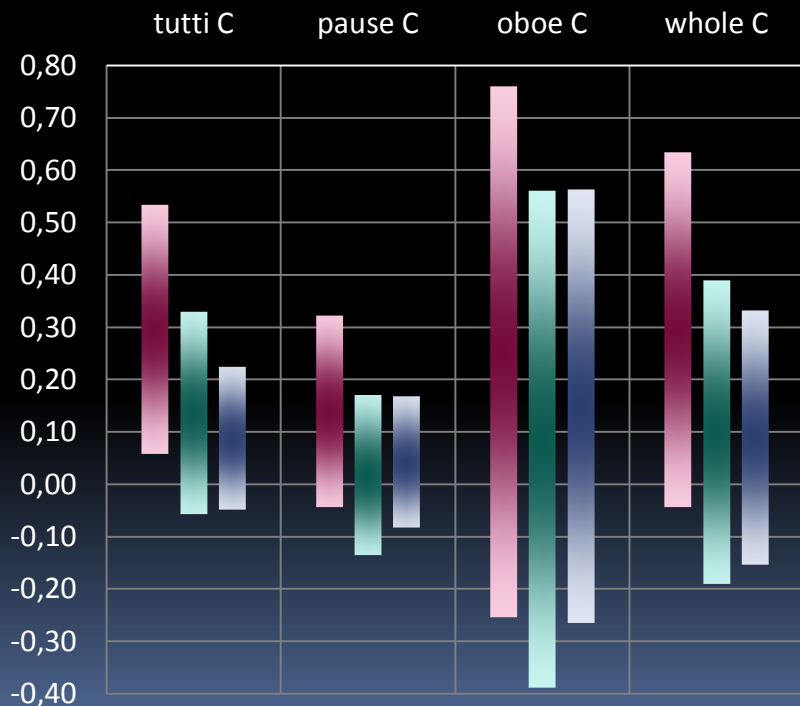
Means and 95% confidence interval



Content can make a difference, but the hall can make an even greater difference

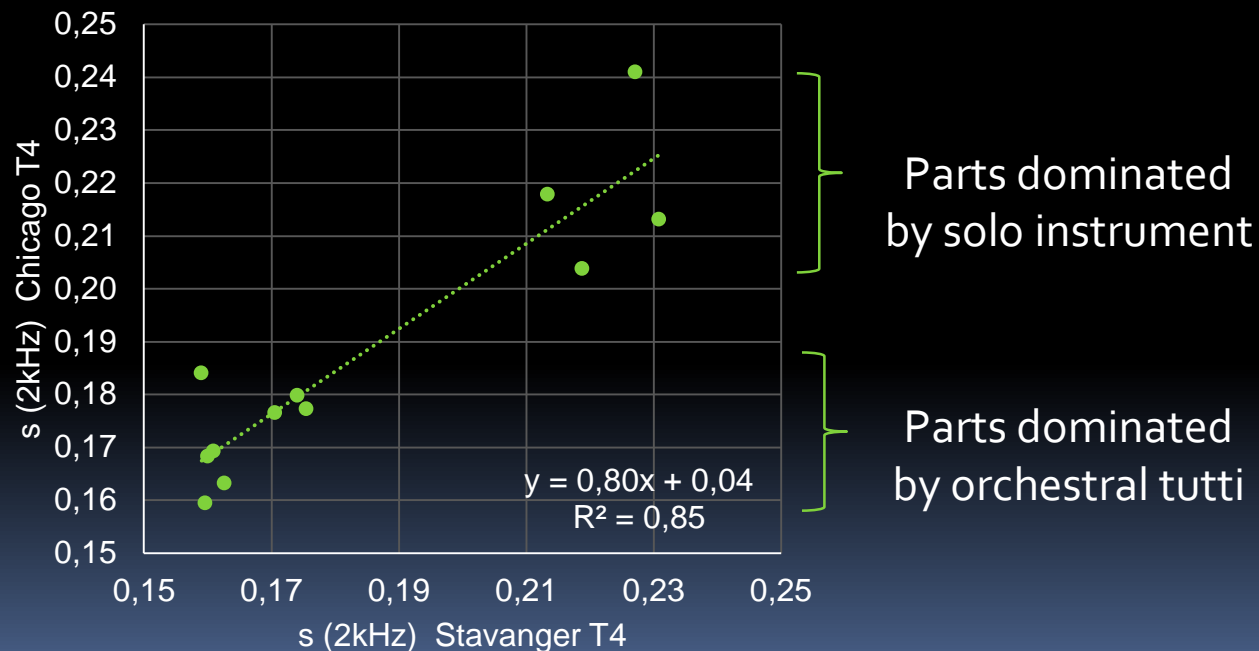
# Distribution, Chicago vs Stavanger

Bar triplets are mean  $\pm$  standard dev. of IACC<sub>500Hz</sub> – IACC<sub>1kHz</sub> – IACC<sub>2kHz</sub>

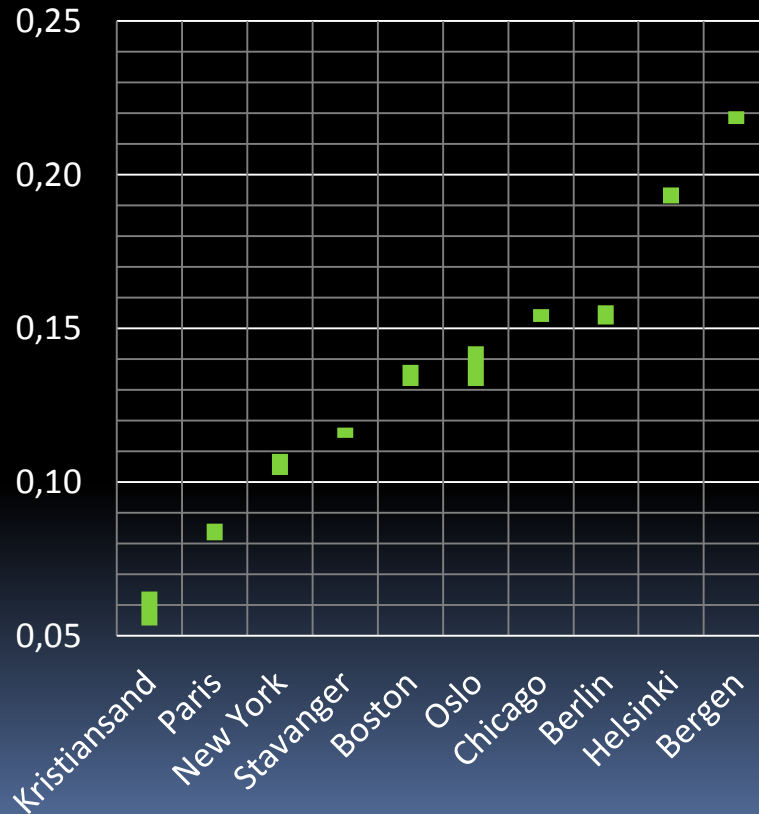


# IACCT spread varies with content

Tchaikovsky 4th, 12 parts  
standard deviation IACCT

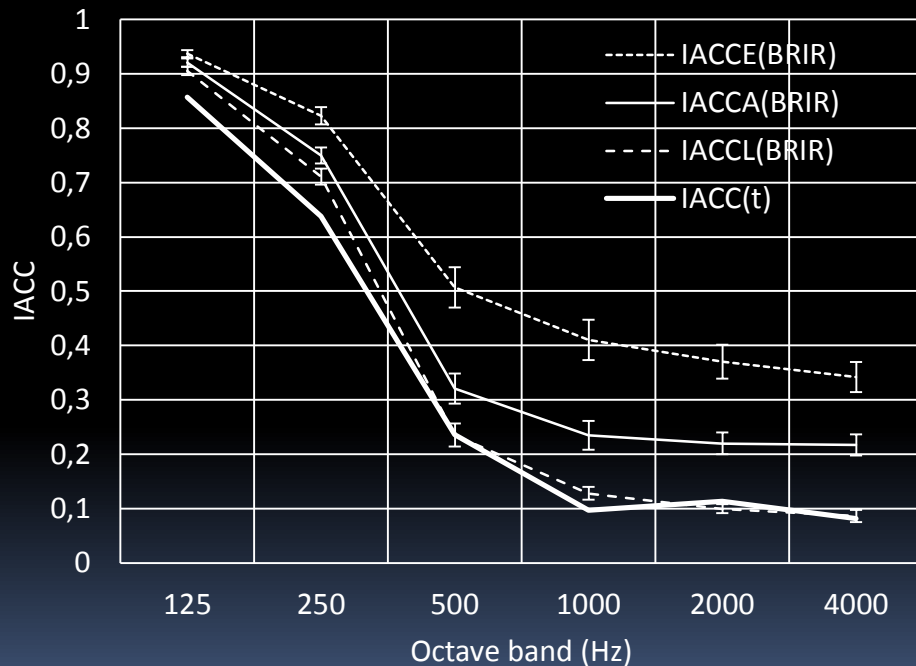


# 10 big halls: 95% confidence means



We see significant differences between halls

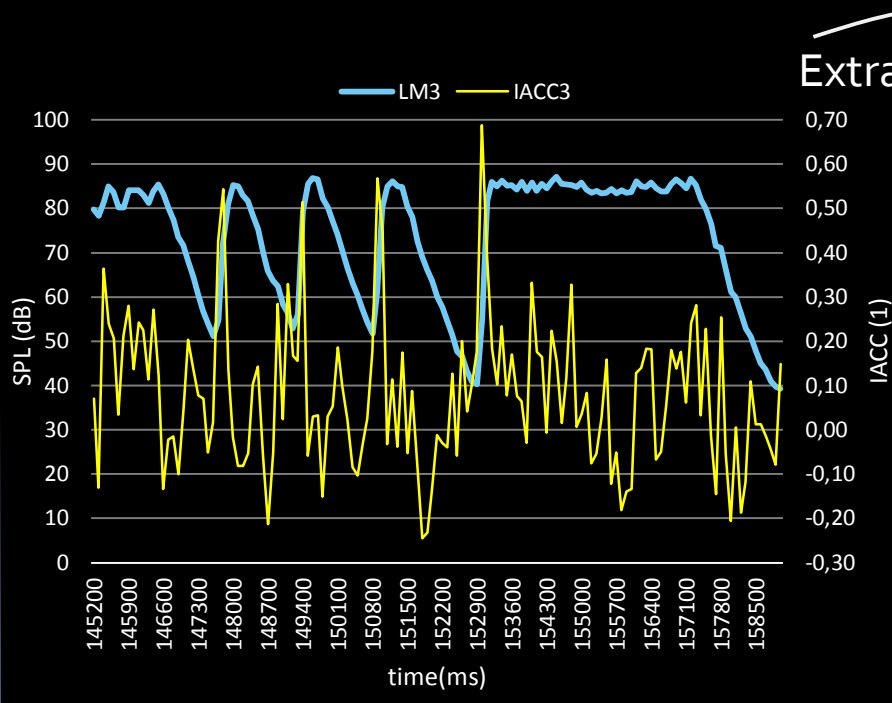
# Comparison with BRIR



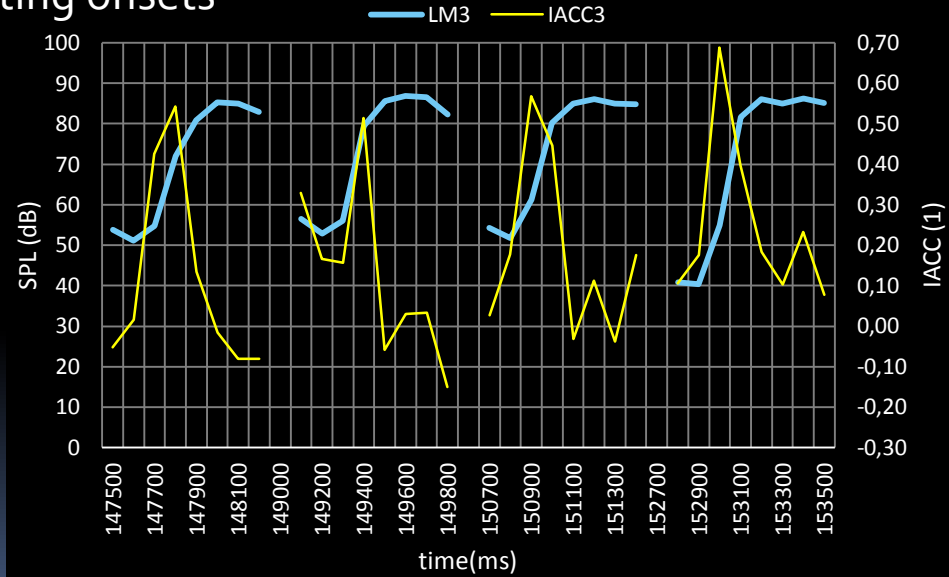
Average IACCt spectrum (all halls)  
is almost equal to IACCL spectrum  
(average from BRIR of 45 halls)

# Boston Symphony Hall – Brahms 1st

Stop chords – Can we separate IACC(early) and IACC(late) from transients?



Extracting onsets

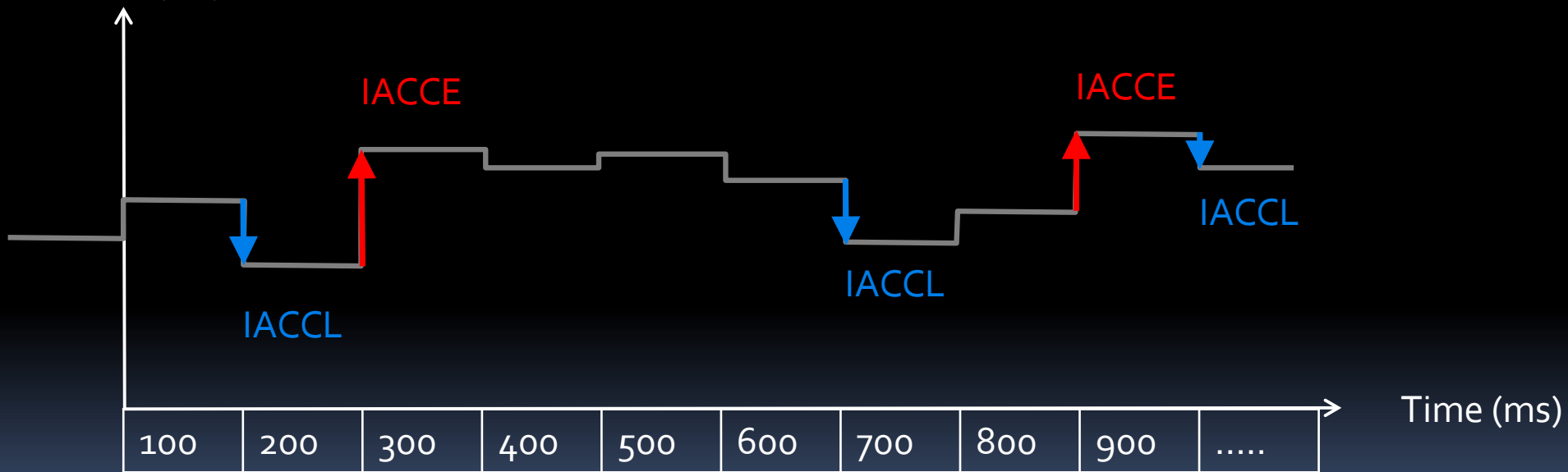


# Detecting «Early» and «Late» parts

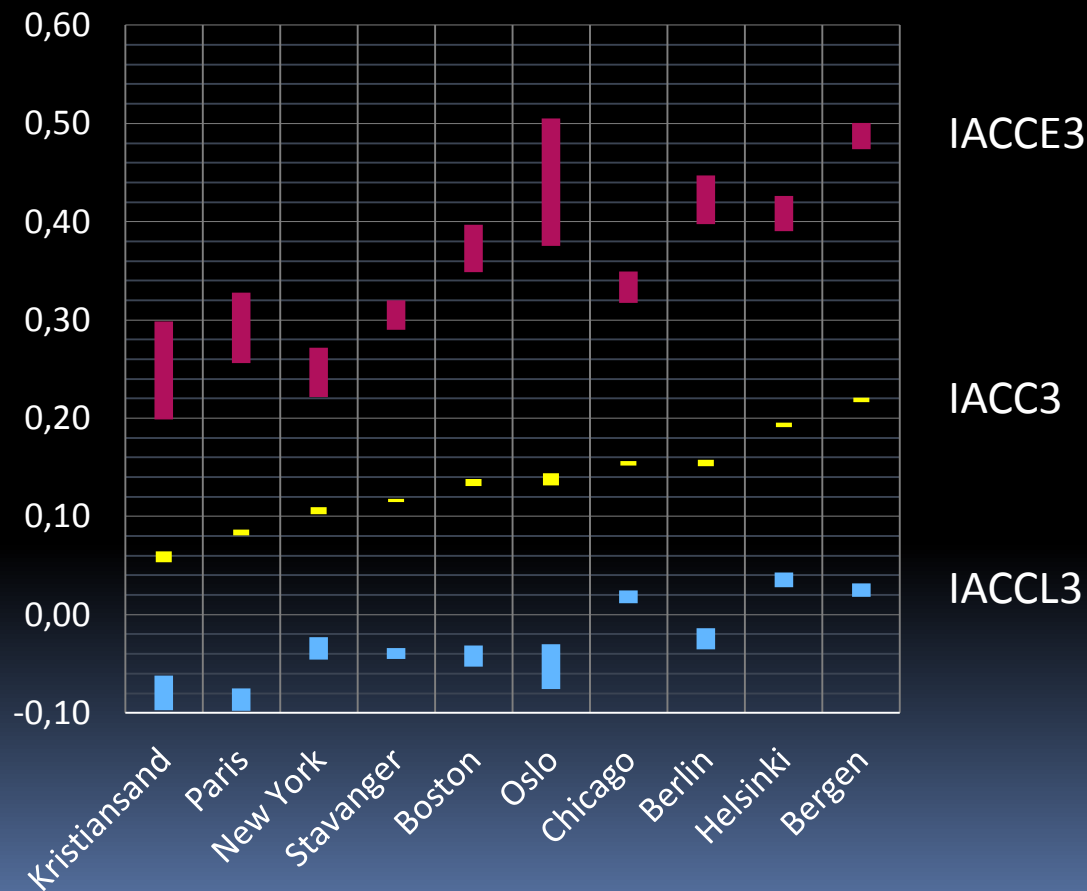
Qualifiers, example:

↑  $\leq +6\text{dB}$     ↓  $\leq -3\text{dB}$

SPL (dB)



# 10 big halls: 95% confidence means







# Thank you

More info?

The www center for search, research and open sources in acoustics

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