7-12 SEPTEMBER 2014

FORUM ACUSTICUM
KRAKÓW 2014

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How much diffusers is required?

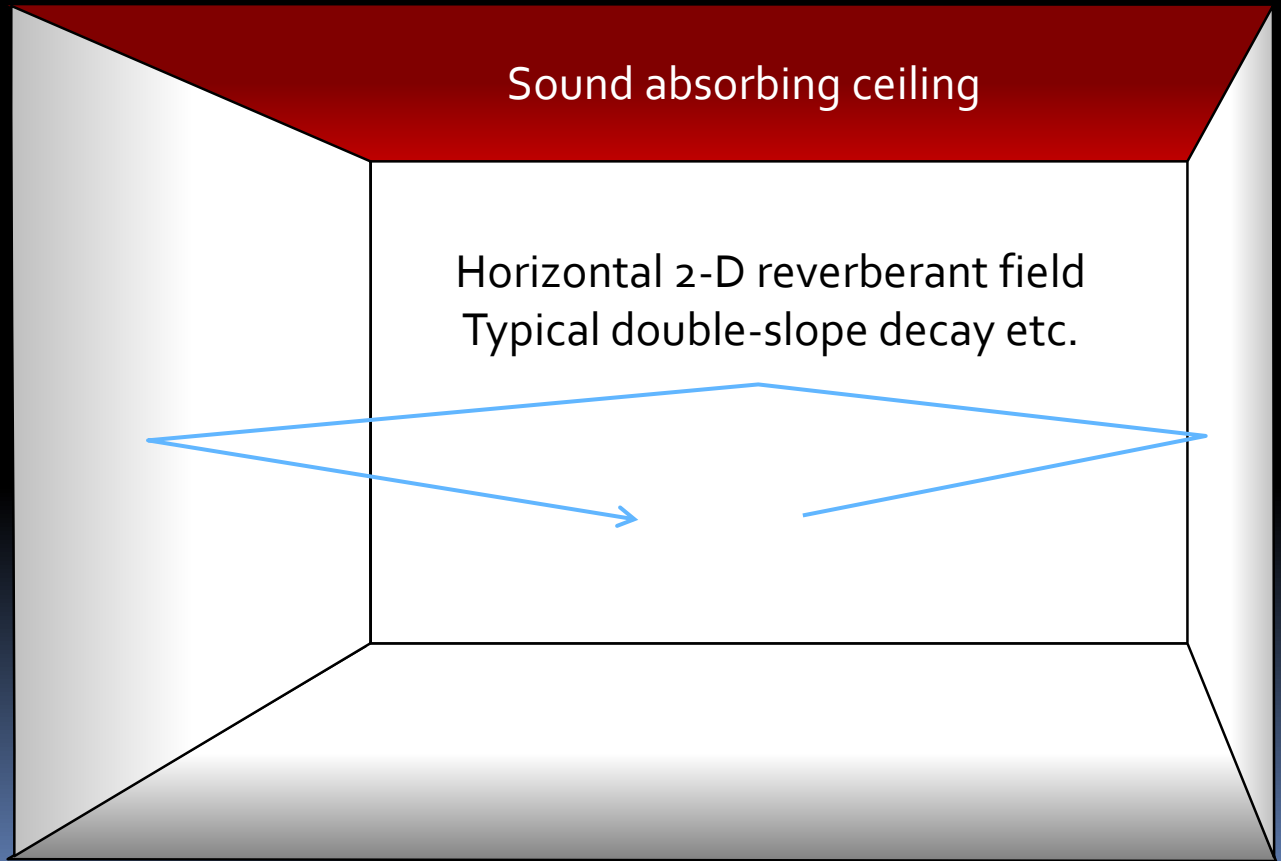
SOFTENING THE HARD CASE

FA 2014, Krakow, September 8th 2014

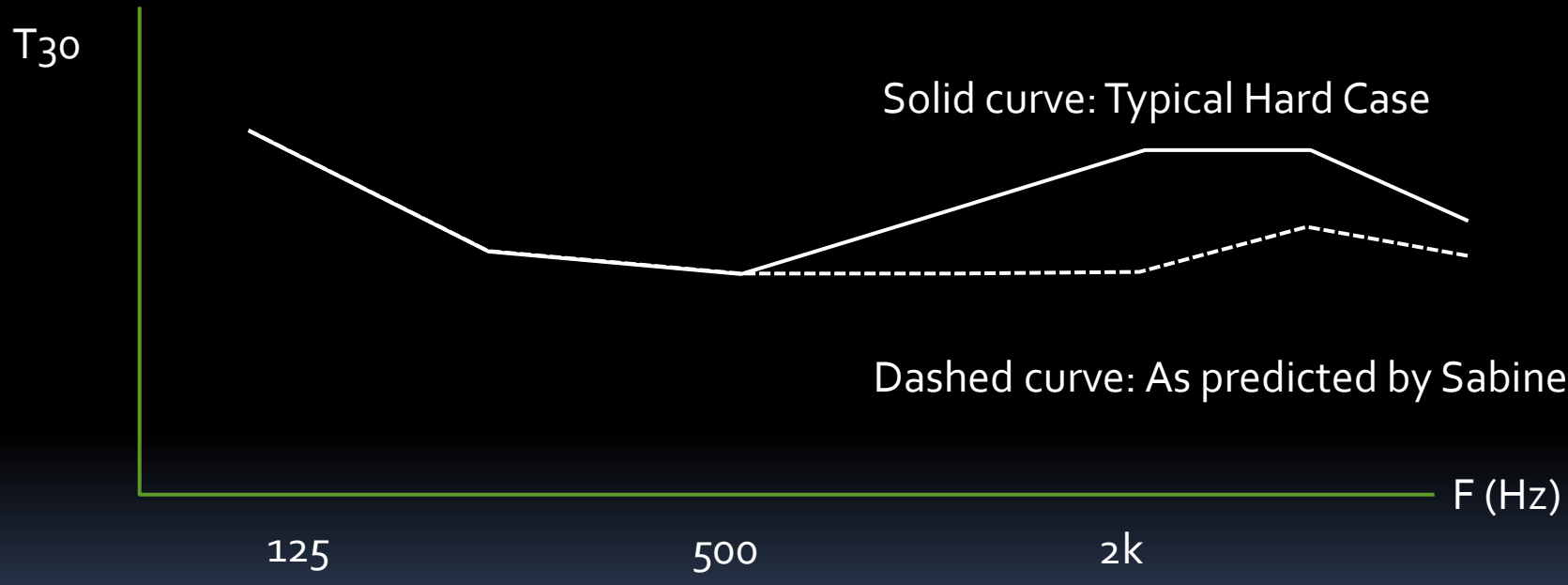
Outline

- Hard Case problem:
  - Ceiling absorber creates 2-D reverberant field
  - How much diffusers are required on walls, to soften the Hard Case, i.e. to acheive RT as predicted by Sabine's Formula
- Scale model experiments
- Full scale experiments

Recall FA2011:The Hard Case



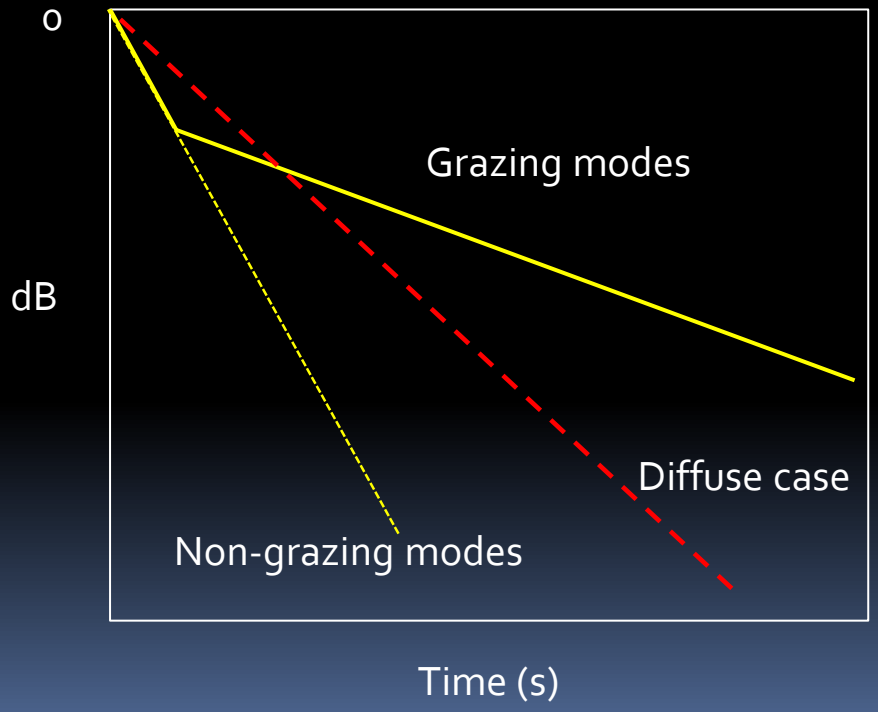
Typical T30-spectrum



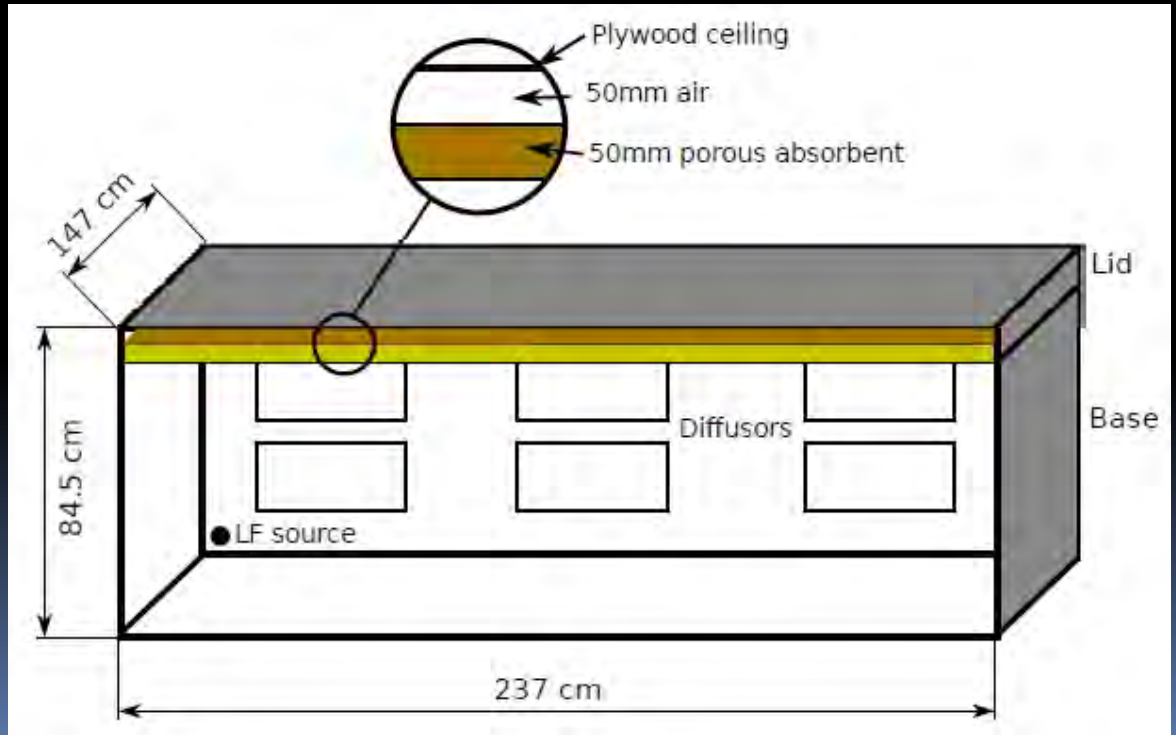
High frequencies: Expected 2-D behaviour

Low frequencies: Unexplained, but welcomed, absorption

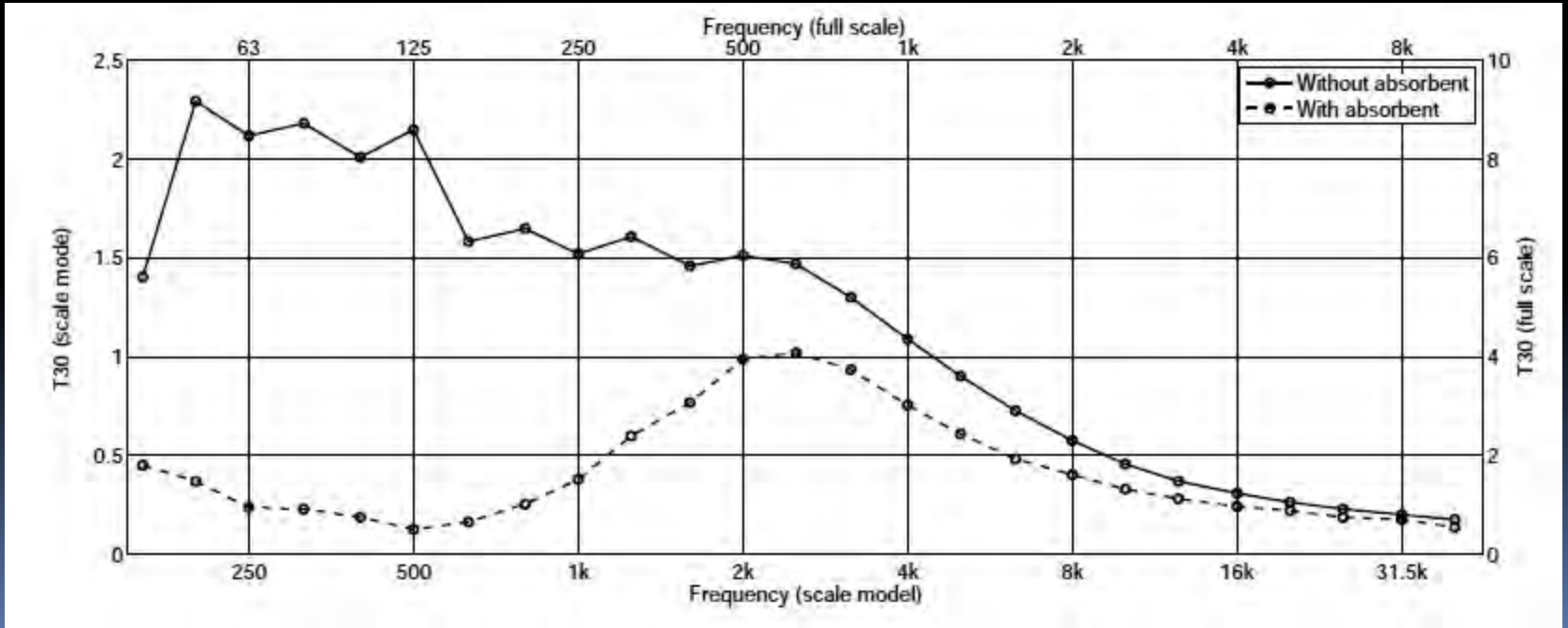
Curvature (Double slope)



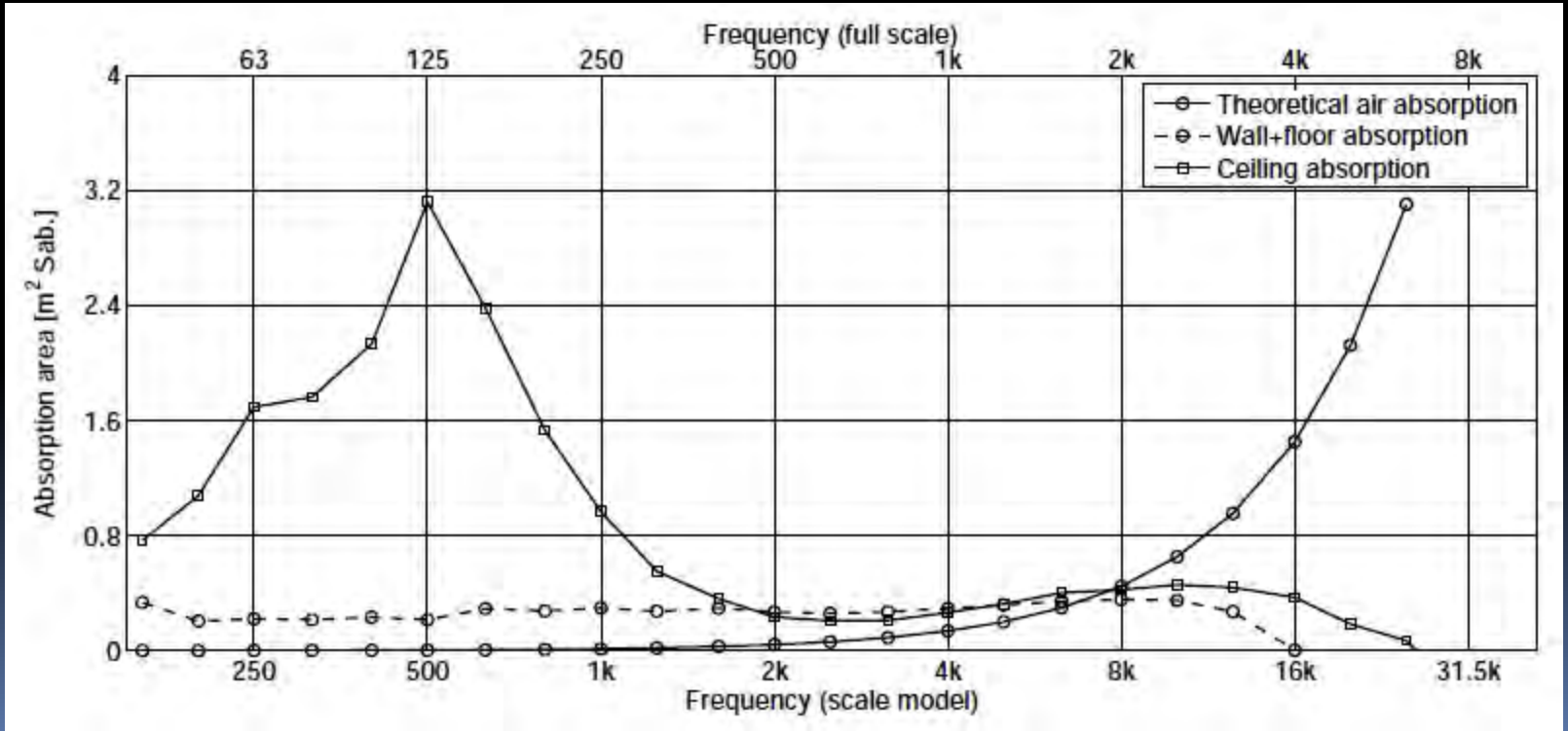
Scale Model experiments (J.Vennerød, NTNU)



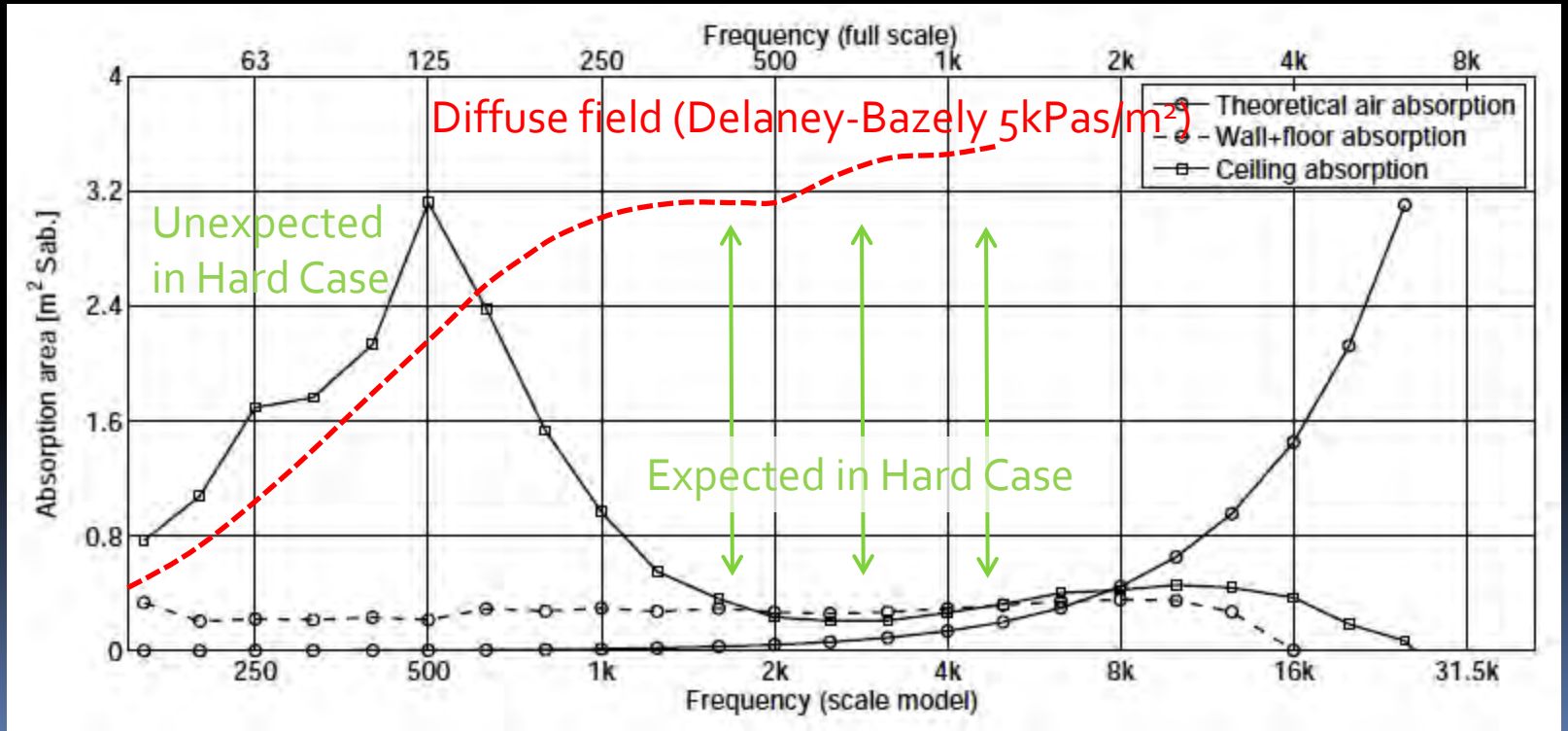
w/wo ceiling absorber



Calculated Sabine absorption

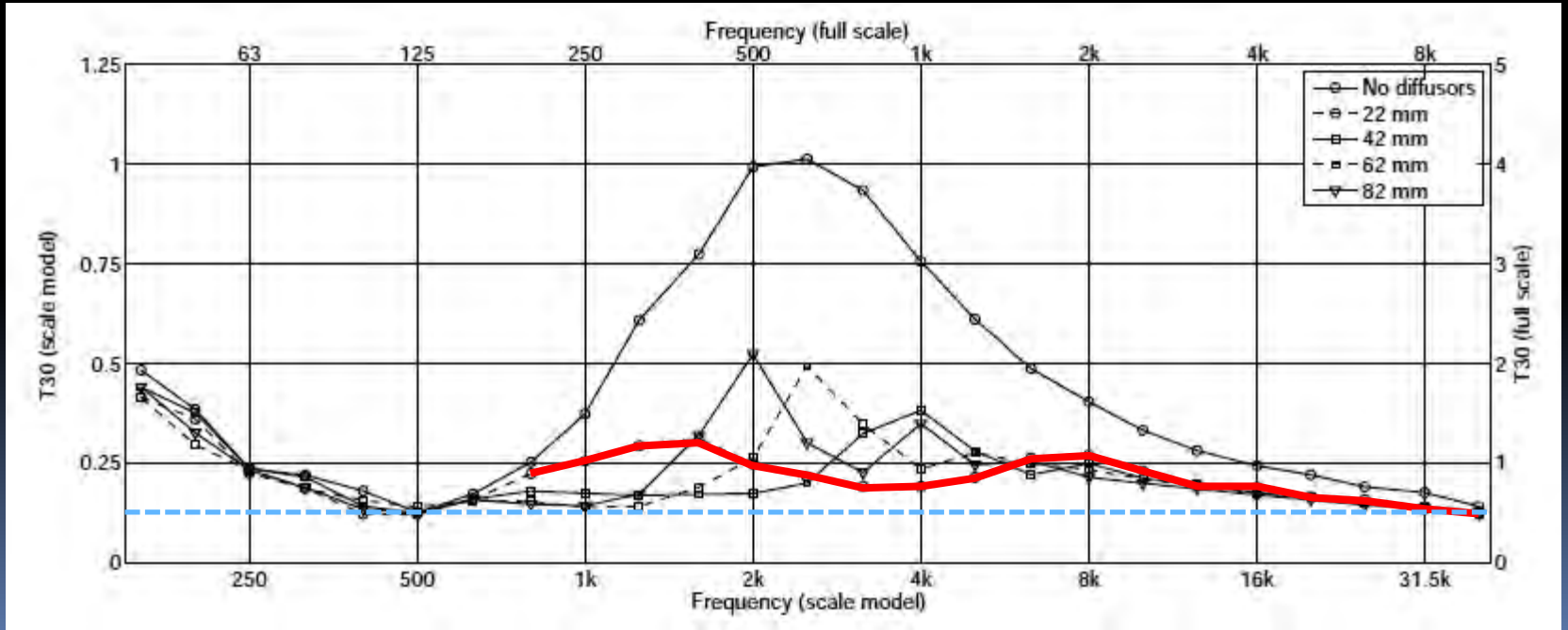


Unexpected low-frq behaviour



Introducing wall diffusers

D=22mm thick rectangular plates (red curve) covering 22% of the wall surfaces make a strong difference from 800Hz upwards => k*D=0.33
Full ceiling potential (α=1.0) is represented by the dashed blue curve



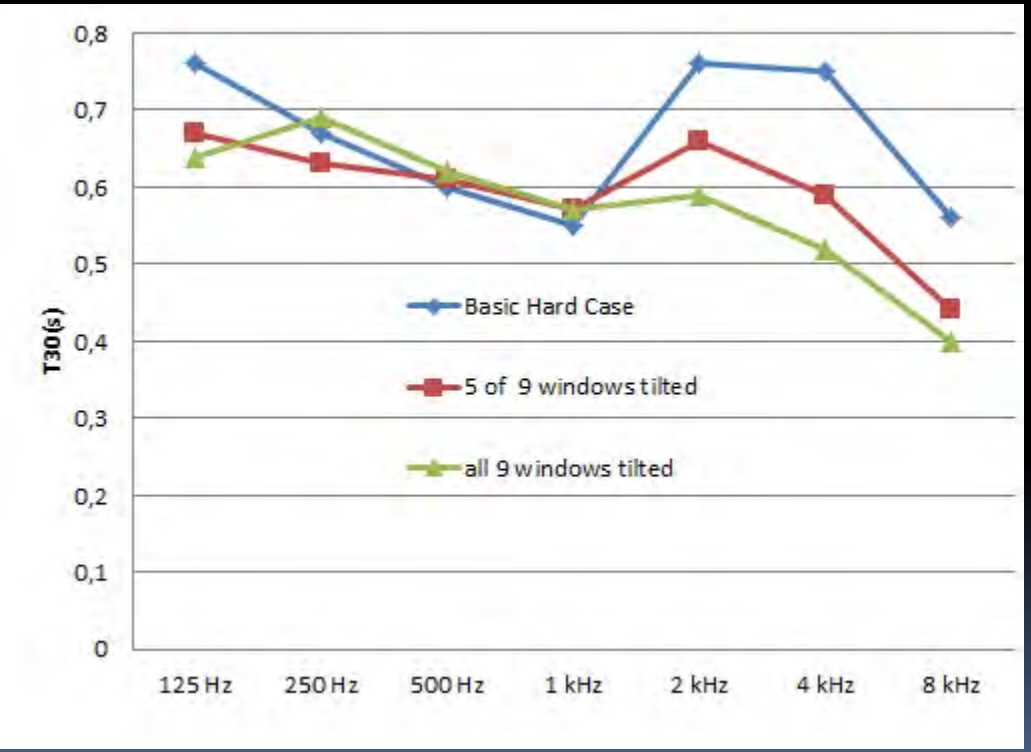
Scale model Hard Case

- Hard rectangles mounted to empty walls make the same impact on T30 as if they were perfect absorbers

Full scale Hard Case experiment

Windows tilted inwards Δx=14cm at the top edge => 4.8 degrees from vertical plane

Results from tilting windows

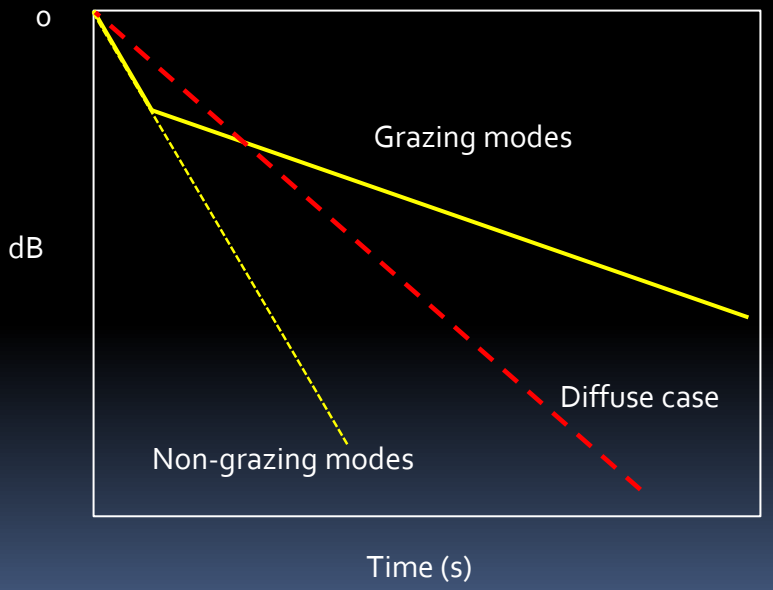


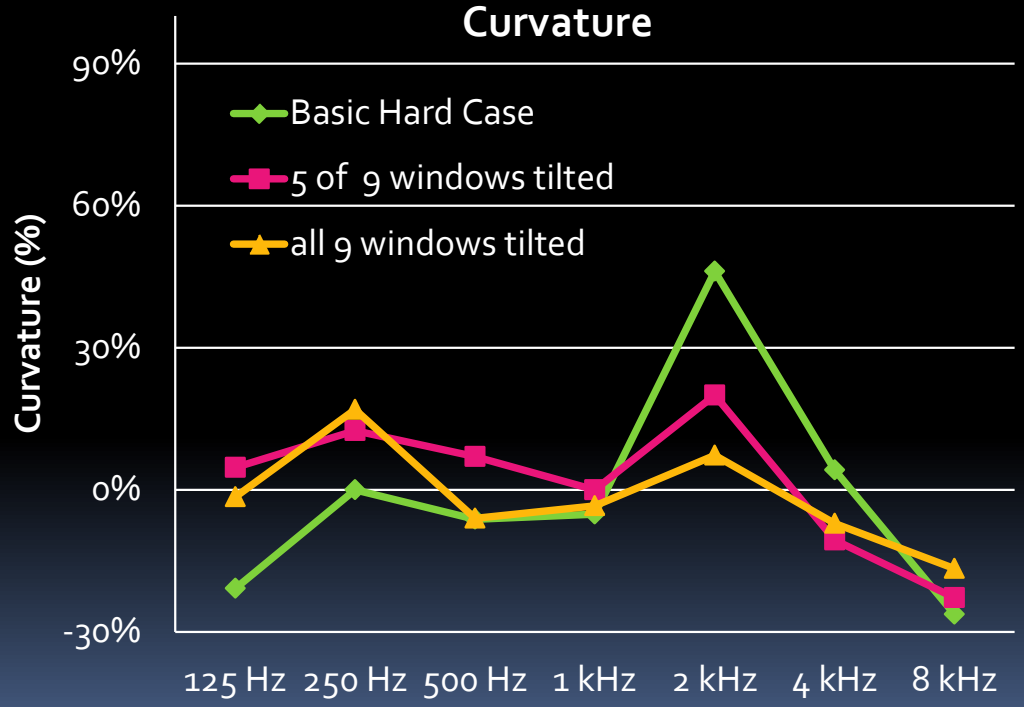
Blue curve: No windows tilted
Red curve: 5 of 9 windows tilted
Green curve: all 9 windows tilted

Apparent differences in absorption area in m²Sa	2kHz	4kHz	8kHz	dS (m²)
Windows closed (ref.)	0	0	0	0
5 of 9 windows tilted	5	10	7	6.5
All 9 windows tilted	10	16	13	13.5

dS = total area of tilted windows

Curvature (Double slope)





Full scale Hard Case

- Frequency dependent behaviour like in scale model
  - -> not a room-wavelength effect
  - suspicion turns to aborber
- Tilting of the windows make greater difference in apparent absorption area (m^2Sa) in 4kHz than if the windows instead of being tilted were covered with a perfect absorber
- Suggested explanation: Tilted surface redirects horisontal rays, producing vertical components that are absorbed by the ceiling

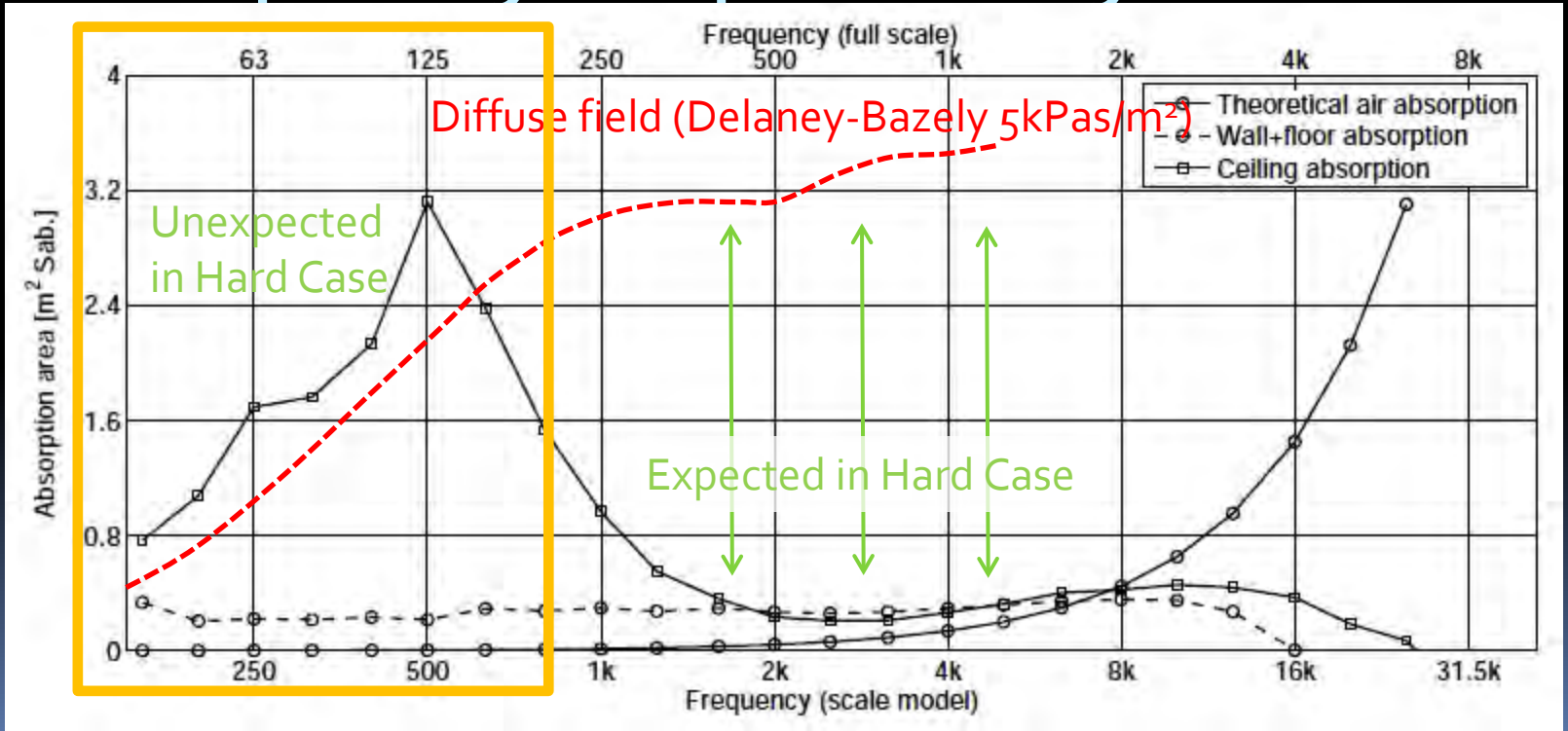
Avoiding the Hard Case

- Safe Case: Planning for Sabinian conditions:
  - Perfect distribution of absorbtion area
  - A/6 on each of 6 surfaces: walls, ceiling and floor
- More practical
  - A/3 in each direction x, y, z: A/3 in ceiling, and
  - total A/3 on short walls, and total A/3 on long walls

How many hard elements are required to soften the Hard Case?

- Assuming absorption area A in ceiling, and hard, scattering elements on walls area total
- Necessary total element area is
  - $S \geq A/3$ on short walls
  - $S \geq A/3$ on long walls

Further work: Explain frequency dependency



Conclusions

- Hard Case can be softened with hard elements, frequency range $k\Delta x > 0.33$
- Added diffusers act like absorbers
- Suggested «safe» planning:
  - A in ceiling, and hard, scattering elements surface area total $S=A/3$ on short walls and total $S=A/3$ on long walls
- Further work: Investigate unexplained low-freqency absorption in Hard Case

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Thank you

More info?

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

www.akutek.info

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