ACOUSTIC ENHANCEMENT

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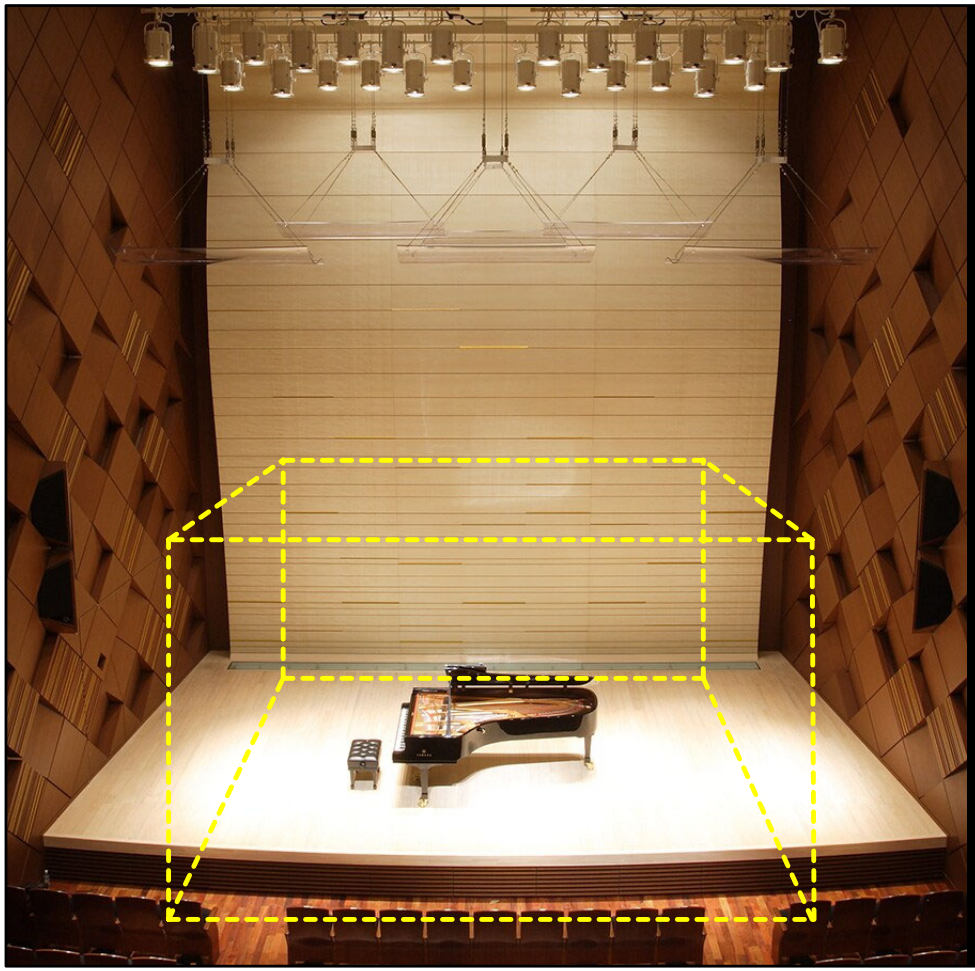
System Engineering Group

Vienna 2025

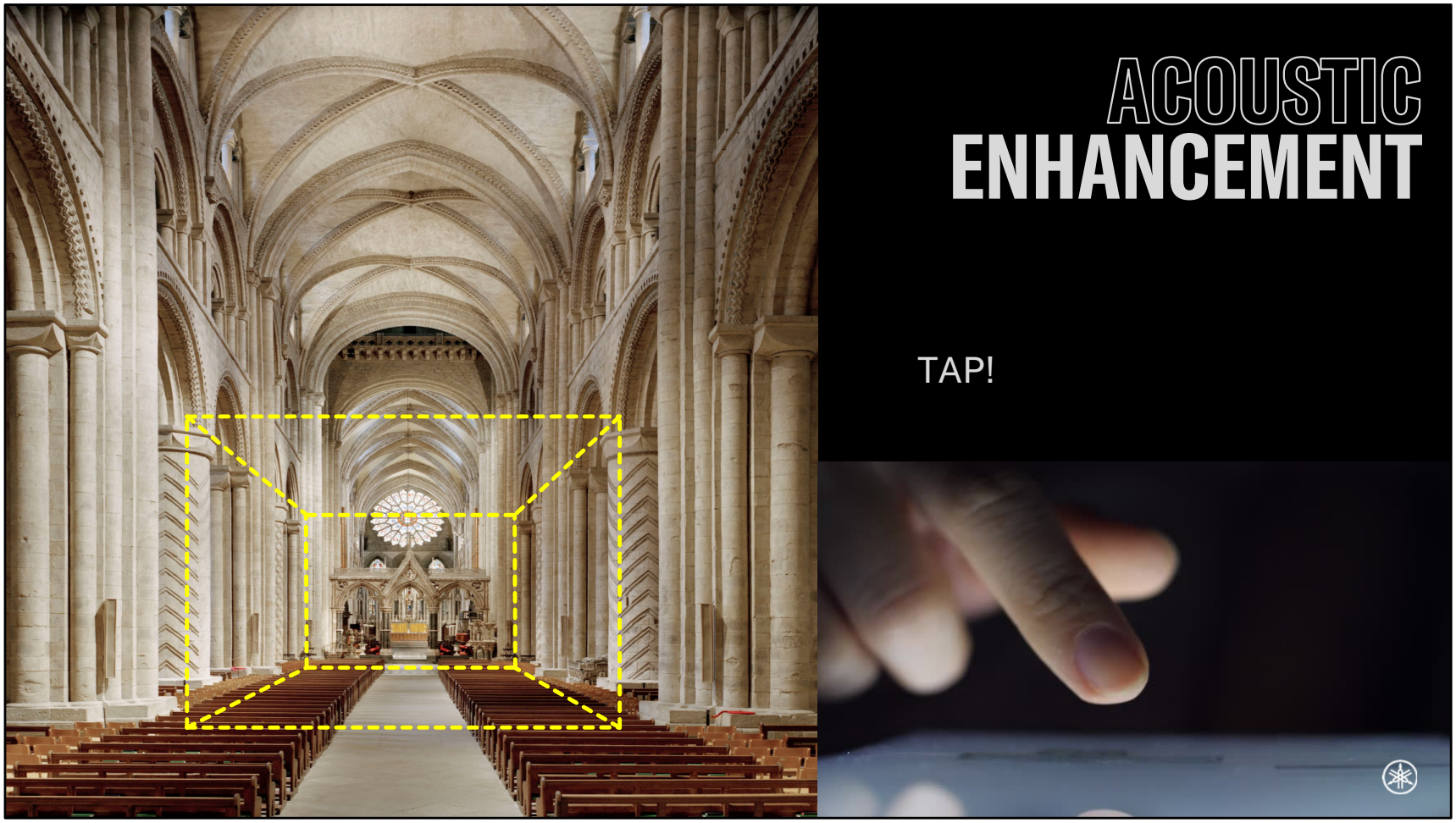


ACOUSTIC ENHANCEMENT

of an existing room
to create richer reverberation
and a livelier sound experience

[Hall preset]

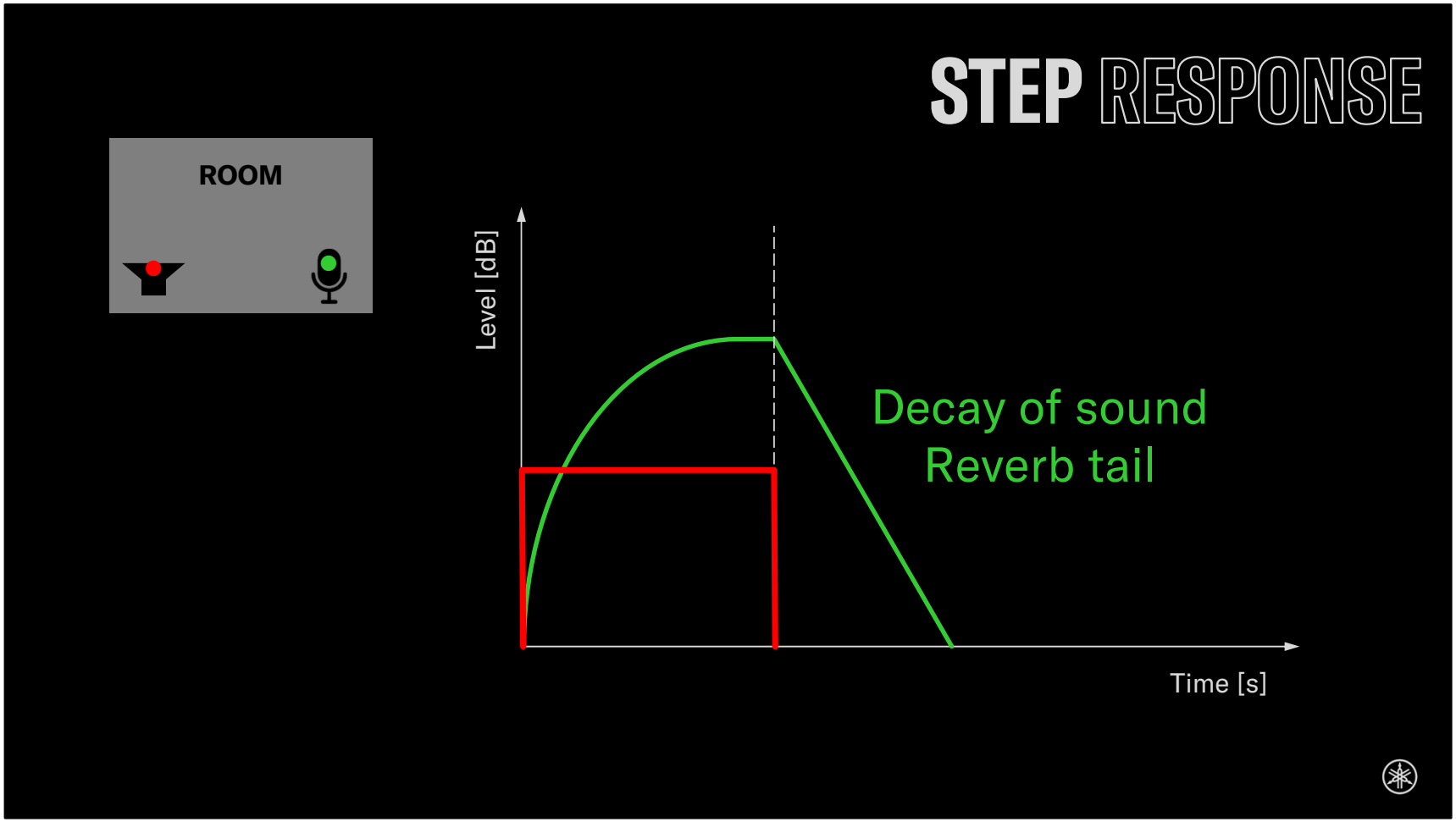
We work on a not so much alive room, to give it atmosphere of a nice sounding reverberant venue.



[Church preset]

One tap on a controller screen and thanks to electricity, our room acoustics changes to something else.

How does it work?



A speaker and a mic in a room.

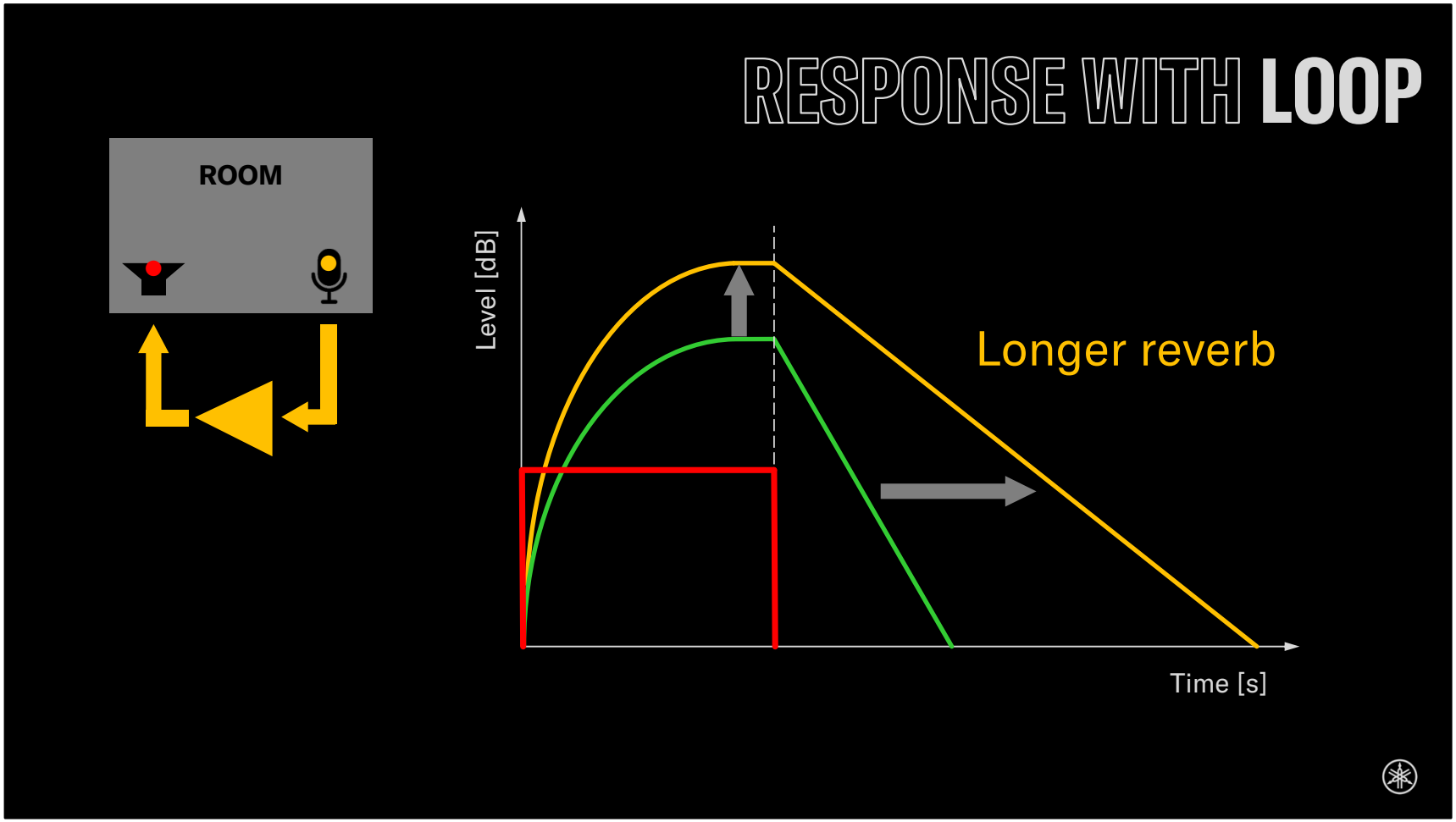
Far away—in the **diffuse field**.

A steady sound on.

It gets louder because sound reflects, stays inside and accumulates.

It gets steady because everything absorb sound a bit—a balance between emitted and absorbed energy.

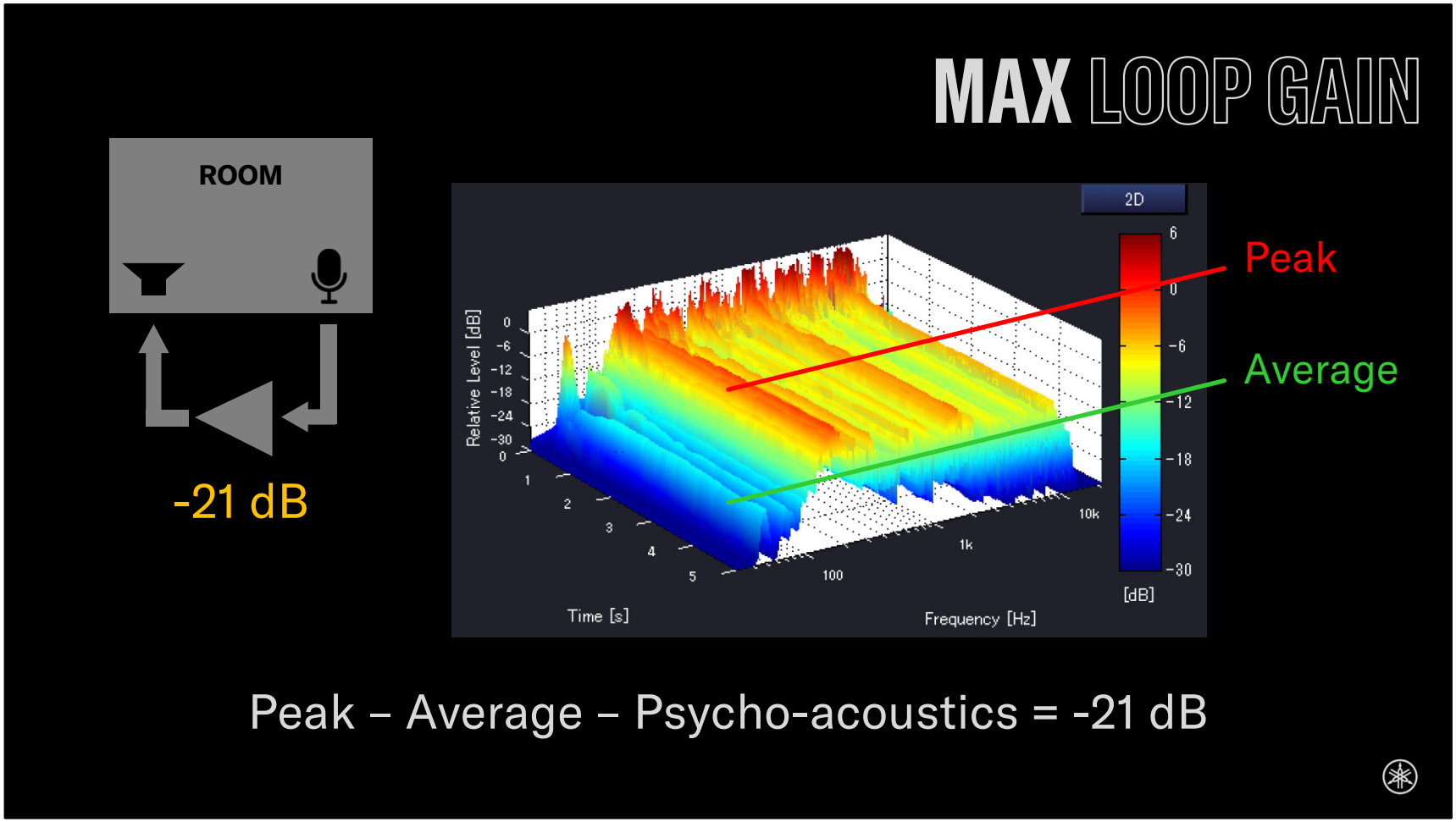
When we switch off the speaker, we experience decay of the reverb tail.



If we capture and amplify sound in the diffuse field, **we add energy** and when the speaker is cut, the decay is longer—longer reverb.

That's the way it works, thank you. :)

That was quick.

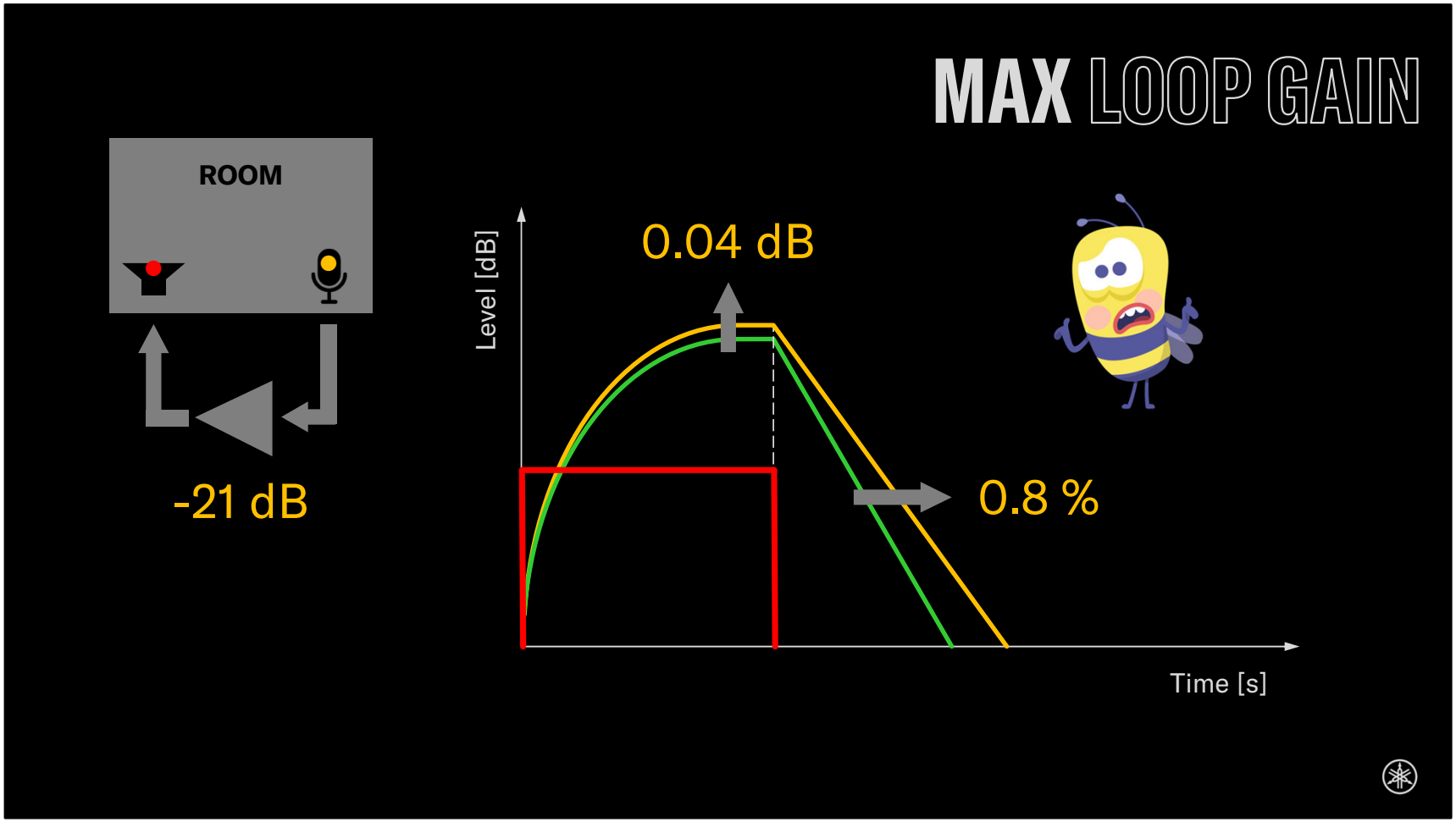


Maybe not so fast.

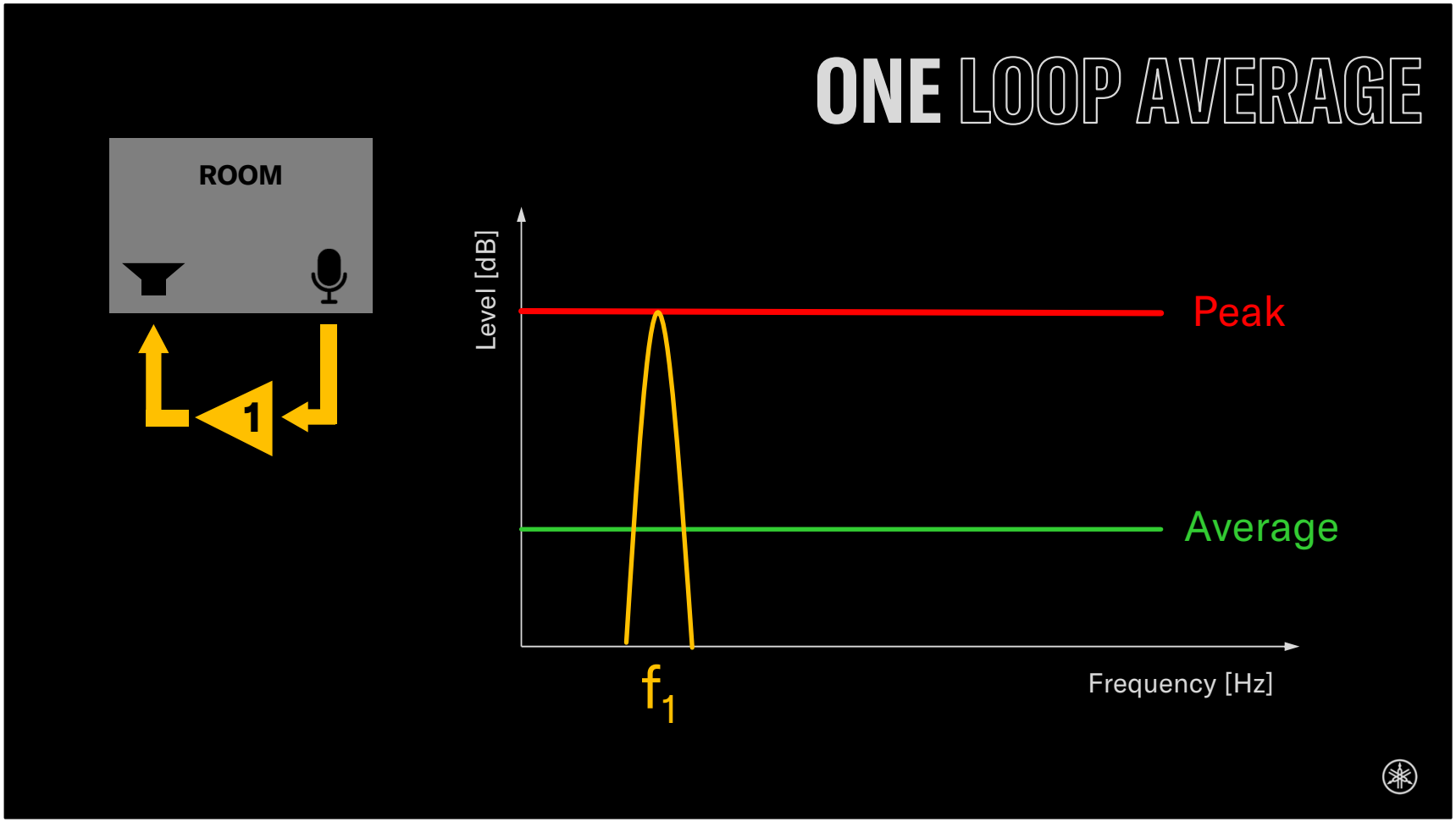
Such a loop may cause **ringing—electro-acoustic feedback**. This is bad.

To avoid the ringing, we have to keep the amplification gain low enough.

A study revealed that it has to be about -12 dB to be stable, and another -9 dB, so our ears are happy—the psychoacoustics. There it is **the -21 dB loop gain**.



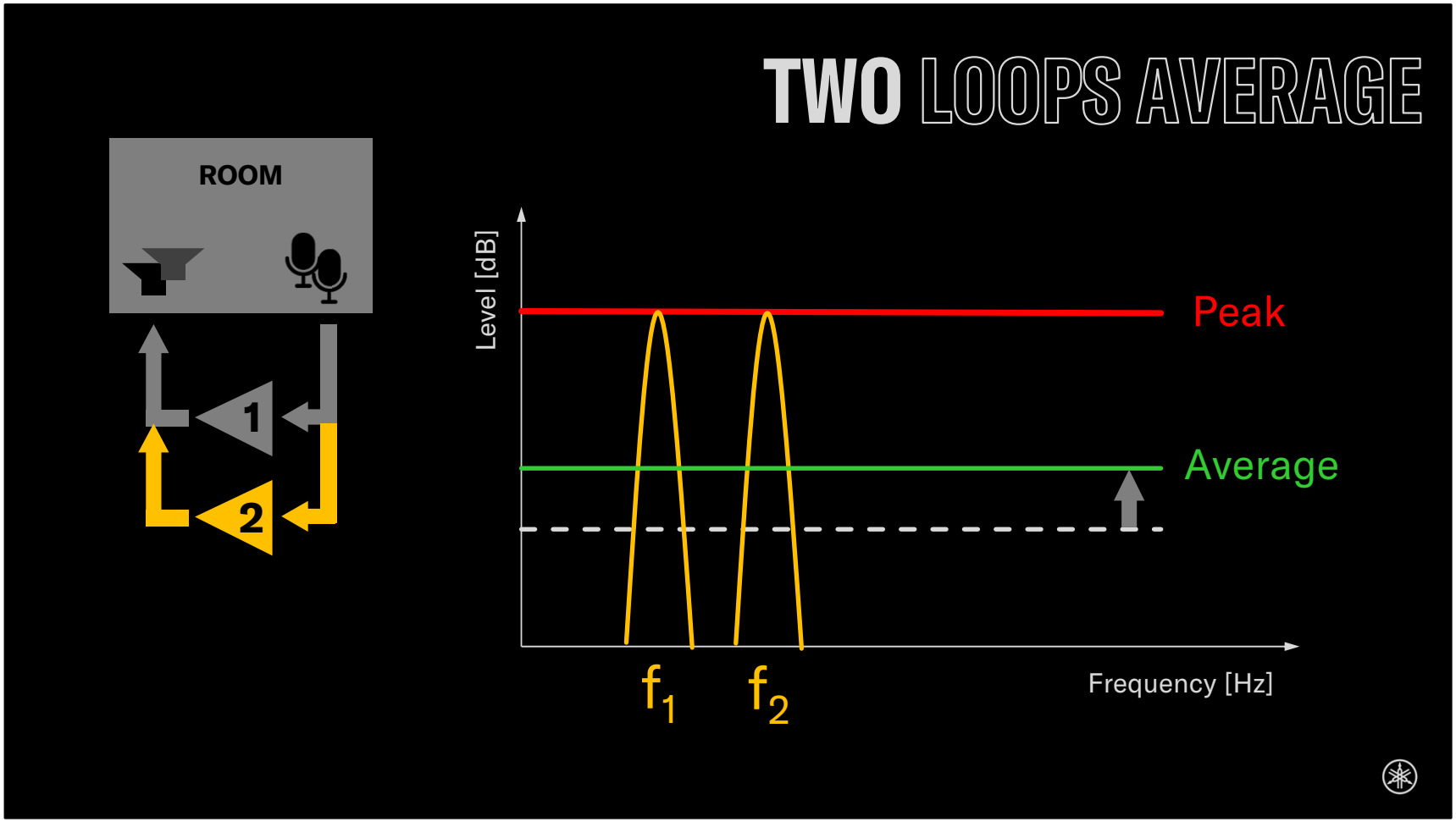
With gain as low as -21 dB, we get very little of the extra reverb length.
We want more. What to do about that?



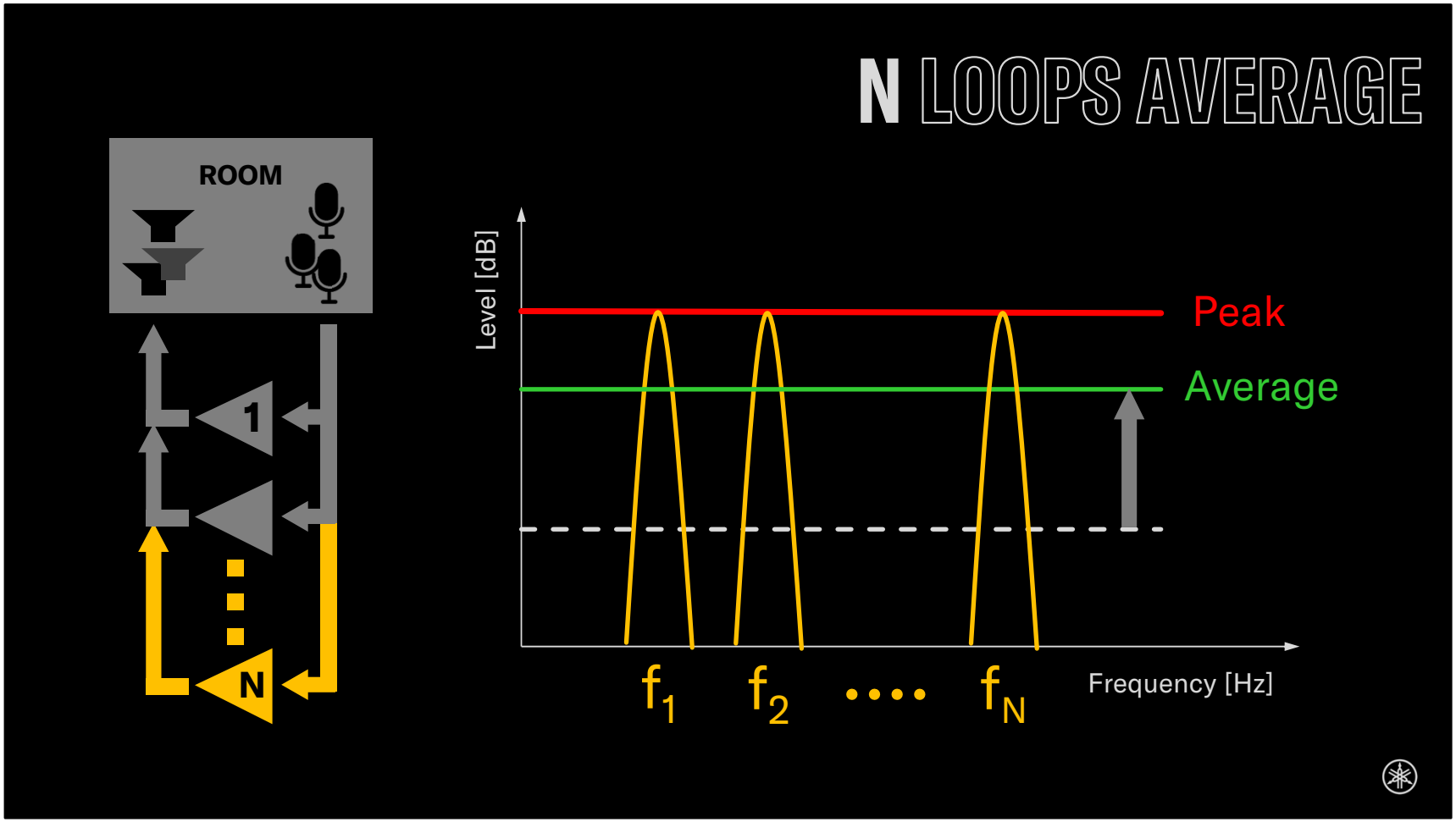
This is a simplified visualisation of a loop.

We can tell its peak frequency, peak level and **average level**.

The average level represents energy, which we want more.



If we add another amp, speaker, and mic at **different positions**, we get a different loop which has **different properties**.
Peaks have **different frequencies**, but the peak level stays the same, and **the average level is going up!**
This is what we need.

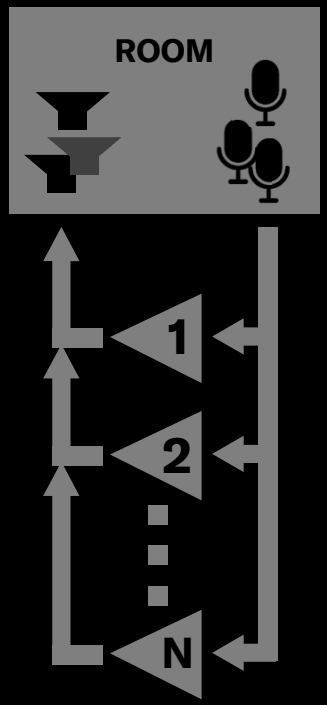


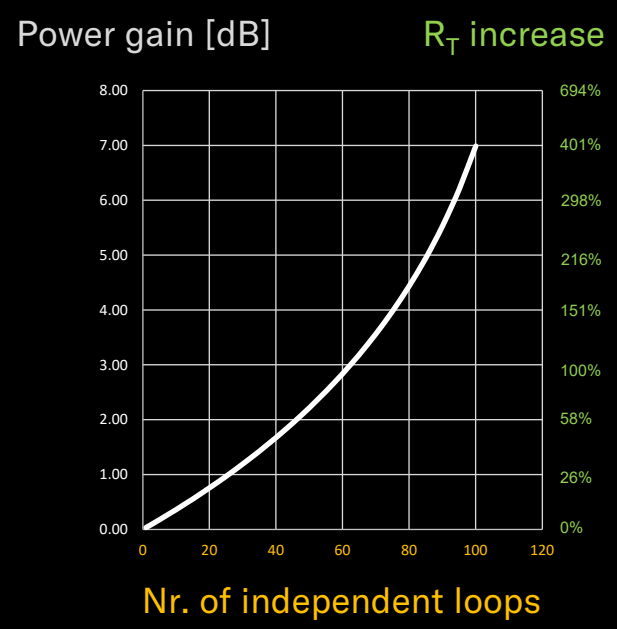
More!

And more!

The average level is getting closer to the peak level, which is good.

MULTIPLE LOOPS



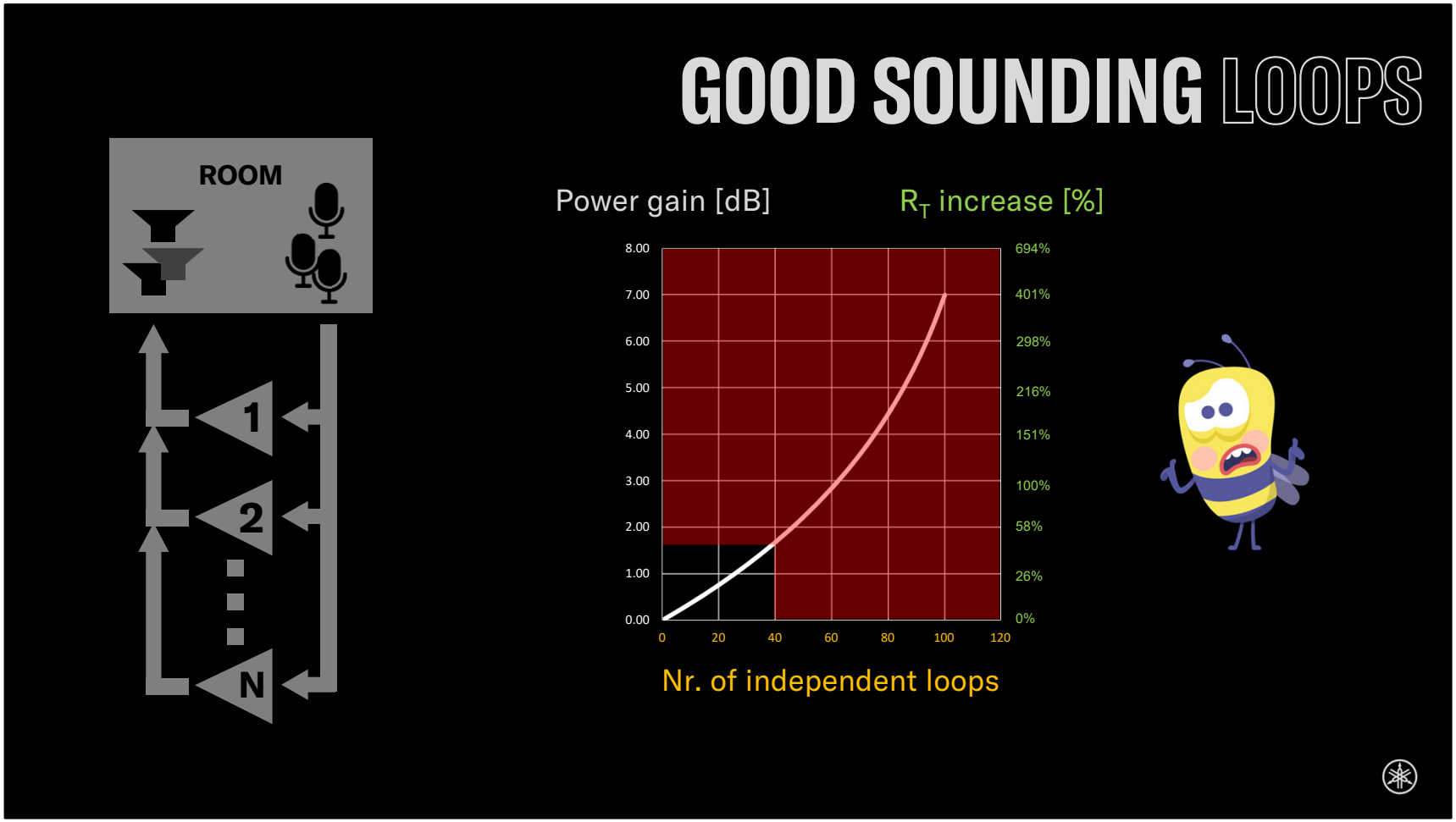


This is how the loop quantity raises power gain.

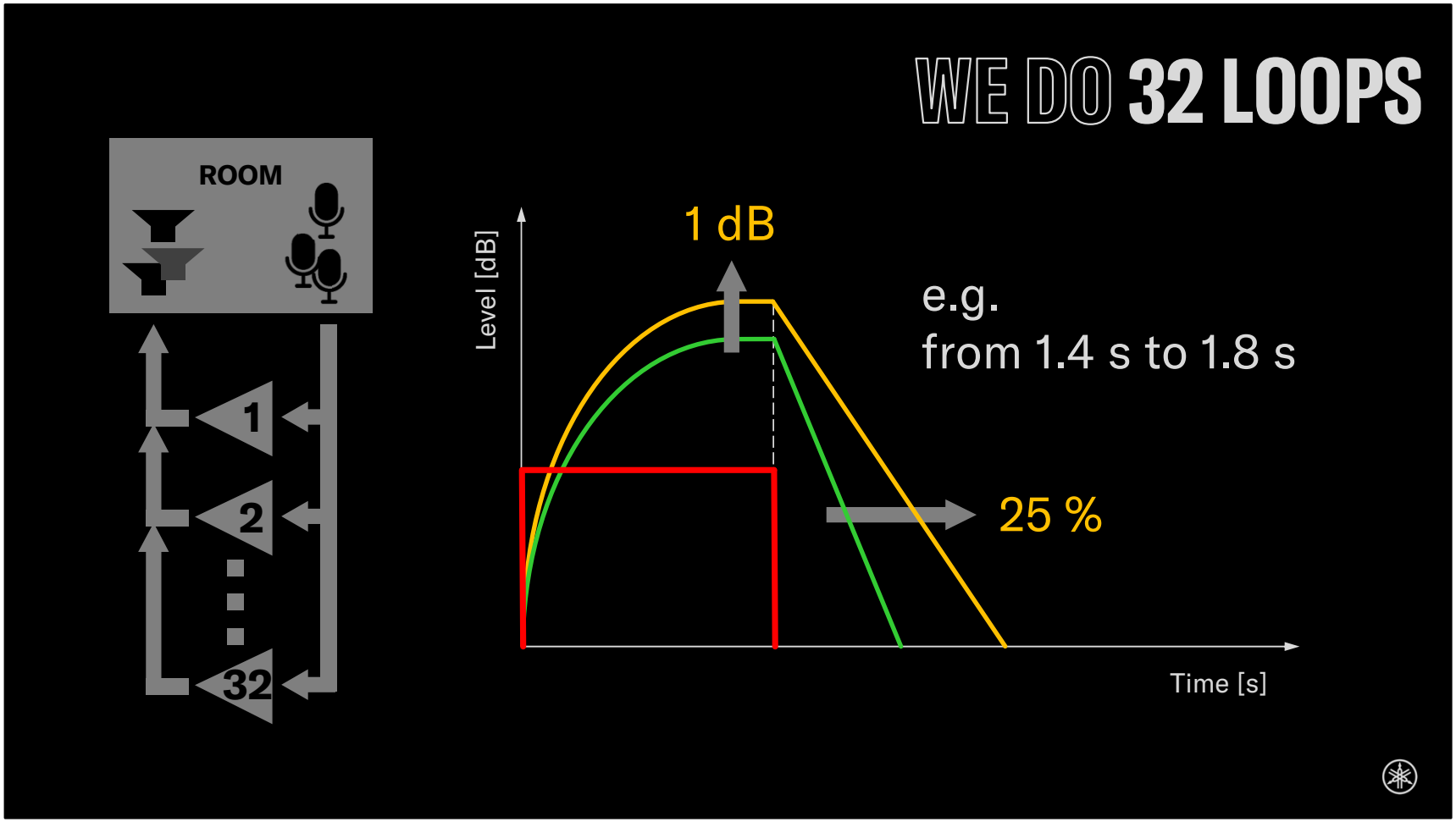
Let’s keep in mind that each loop needs to have different peaks—a different transfer function, and mics need to be far away from speakers—be outside the critical distance, work in the diffuse field.

With so many devices, conditions get difficult to fulfil.

Peaks starts to overlap, and mics get closer to speakers.



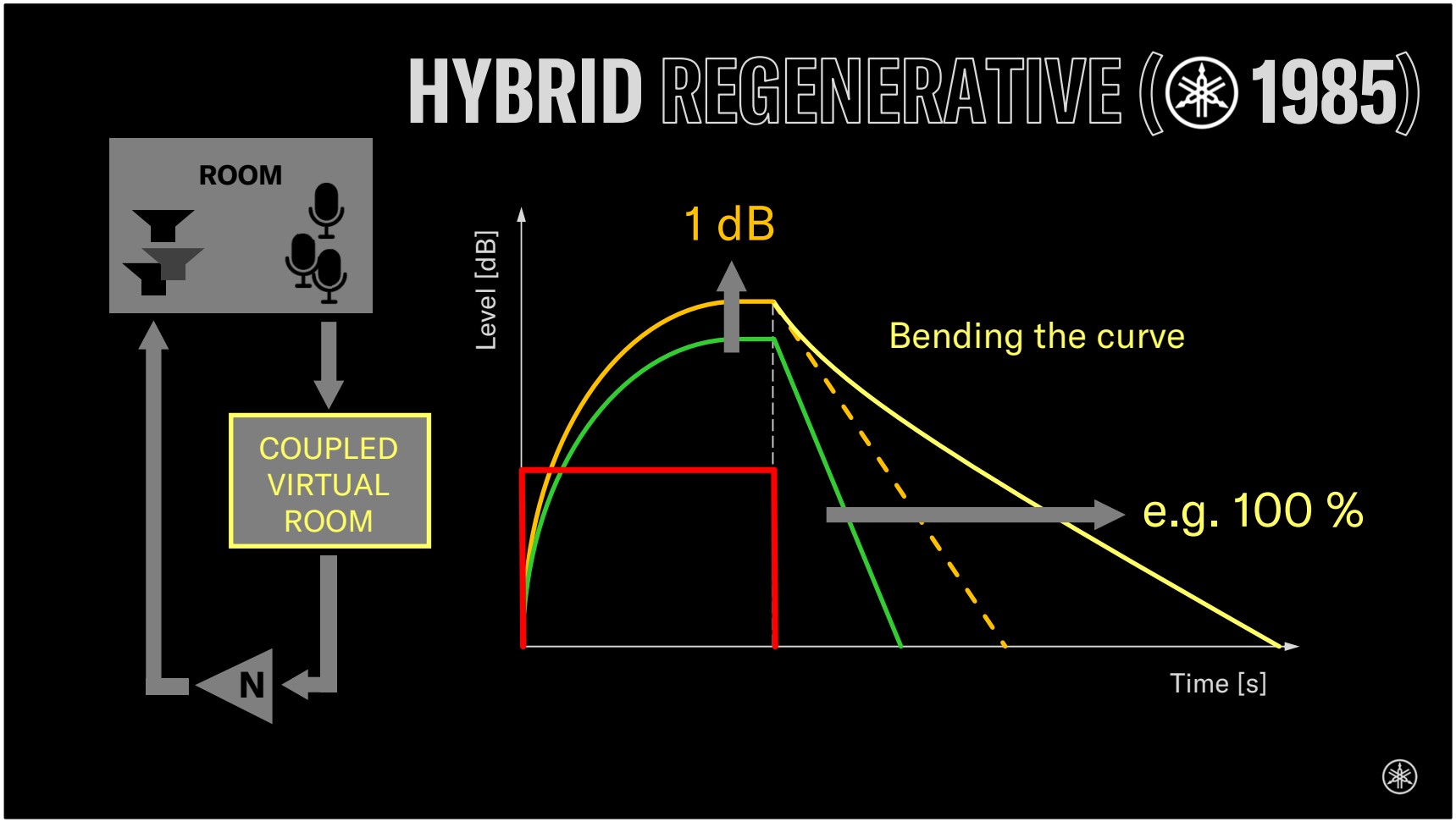
With higher energy and lower quality, the room start to sound like a bathroom. We don't put a symphony in a bathroom.
The threshold of that phenomenon lays around 40 independent loops.
That way, we do roughly **1.5 dB of power gain**.
What does it mean?



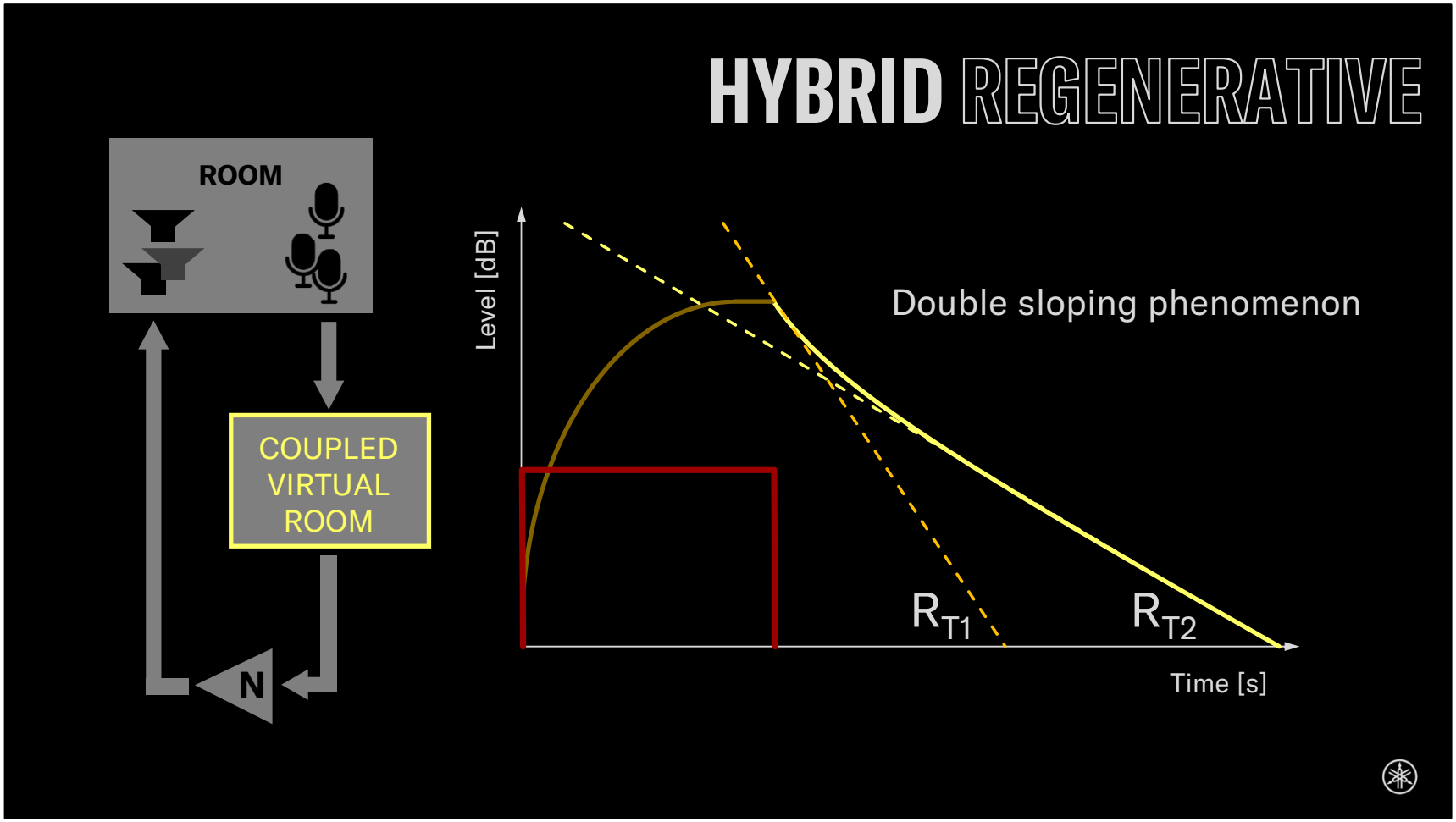
The system here has 32 loops. There are not so many mics, but that's our own trick. We're swapping them periodically. Four such loops gives us 16 different configurations: four mics multiplied by four independent speaker sets. Thanks to carefully chosen cross-fade, we can't hear changes.

From 32 loops we get **1 dB of power gain, which gives 25% of reverb time increase**.

This is something we can use for a concert hall, and we call it **REGENERATION** because we are regenerating reverberation existing in the room. This is good, but we want more, so we invented more.



To each loop, we're injecting a **coupled room**—convolution with **impulse response** of a beautiful sounding venue.
The decay curve bends up, and the reverberation time can be increased beyond our needs.



If we look closer, we find that there are **two decay slopes**. One is our room, and the other is the coupled room.
If we amplify enough, we minimise the curve's transition area, and the reverberation feels natural.
But if we don't, both rooms can be heard, like a reverb of a corridor through an open door.


STAGE SUPPORT
Opera at the Castle, Szczecin, Poland


STAGE SUPPORT
A. DVOŘÁK
STABAT
Podlaska Opera and Philharmonic, Białystok, Poland


OPEN AIR ACOUSTICS
Waldbühne Berlin Amphitheatre, Germany

ARCHITECT'S GRID

Reverberation Time $R_T = f(V,\alpha)$

Field Strenght $G_{10} = f(V,\alpha)$

Both depend on

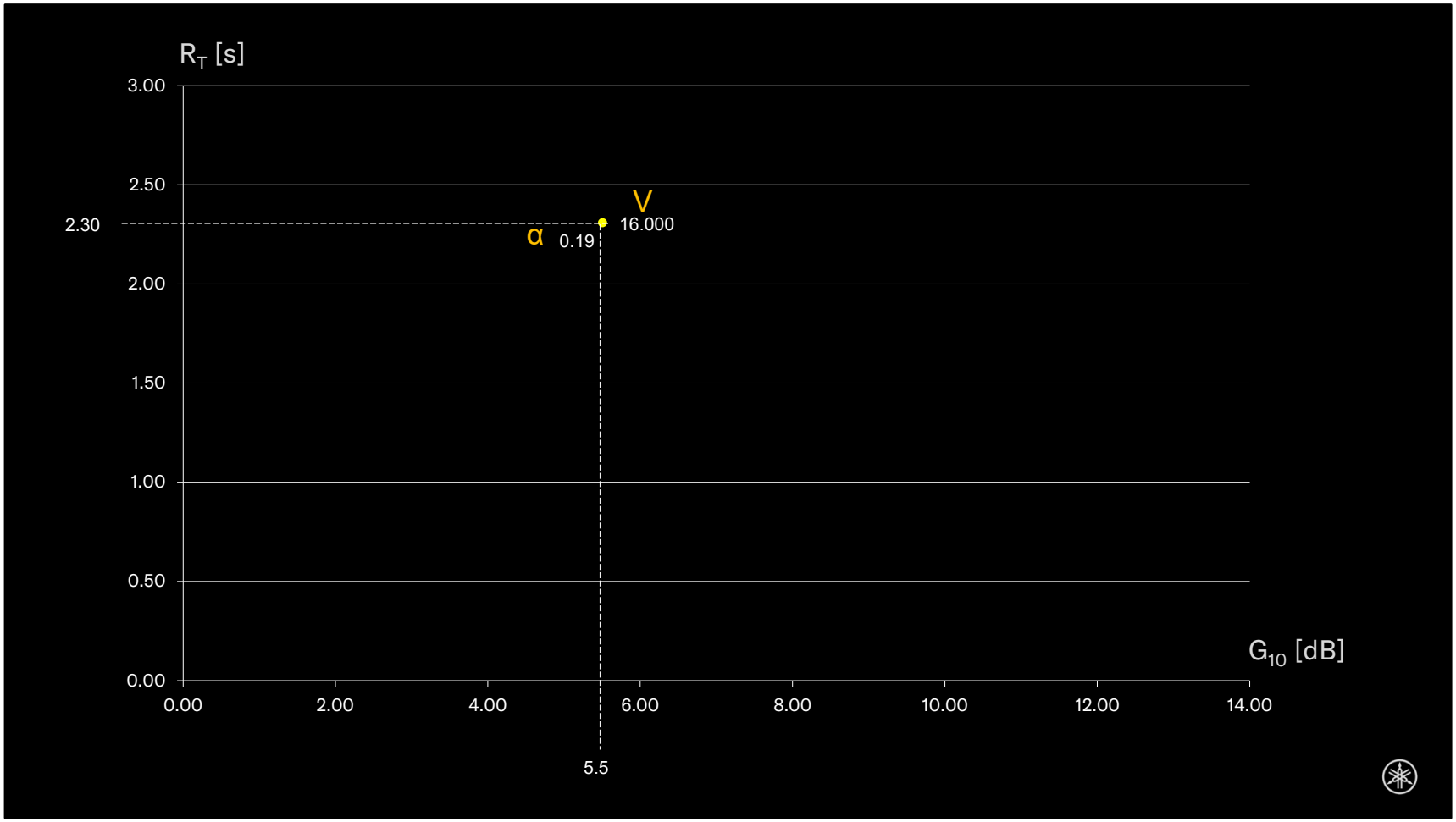
V olume and α bsorbtion

I will show another graph.

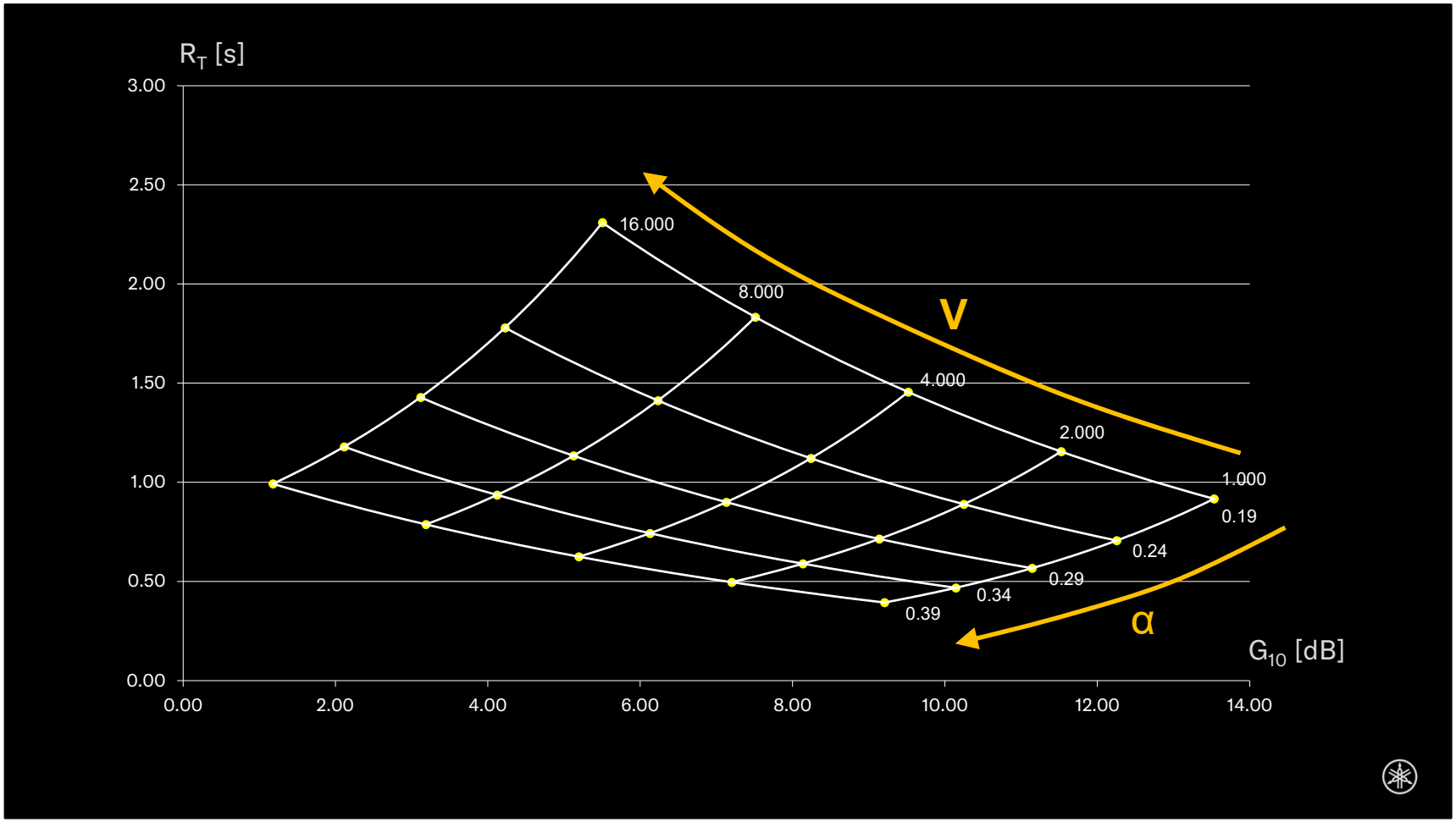
Talking about loops I mentioned power gain. That was about a kind of loudness.

Here we have the **acoustic field strength**, which tells how loud is a room.

For simplicity, we can say that reverb time and field strength depend on how large is the room and how absorptive its walls are.



Let’s get familiar with the graph.



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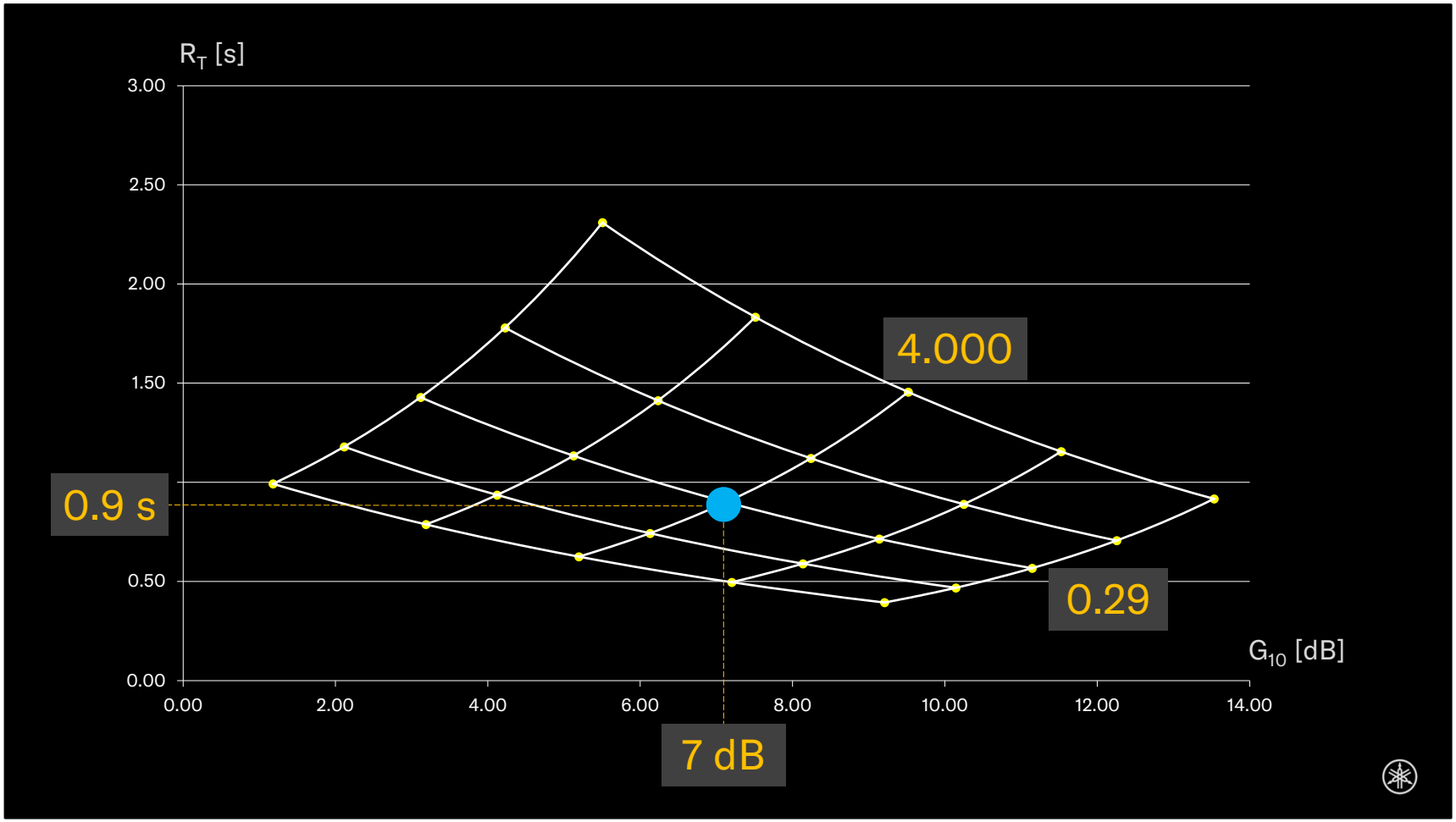
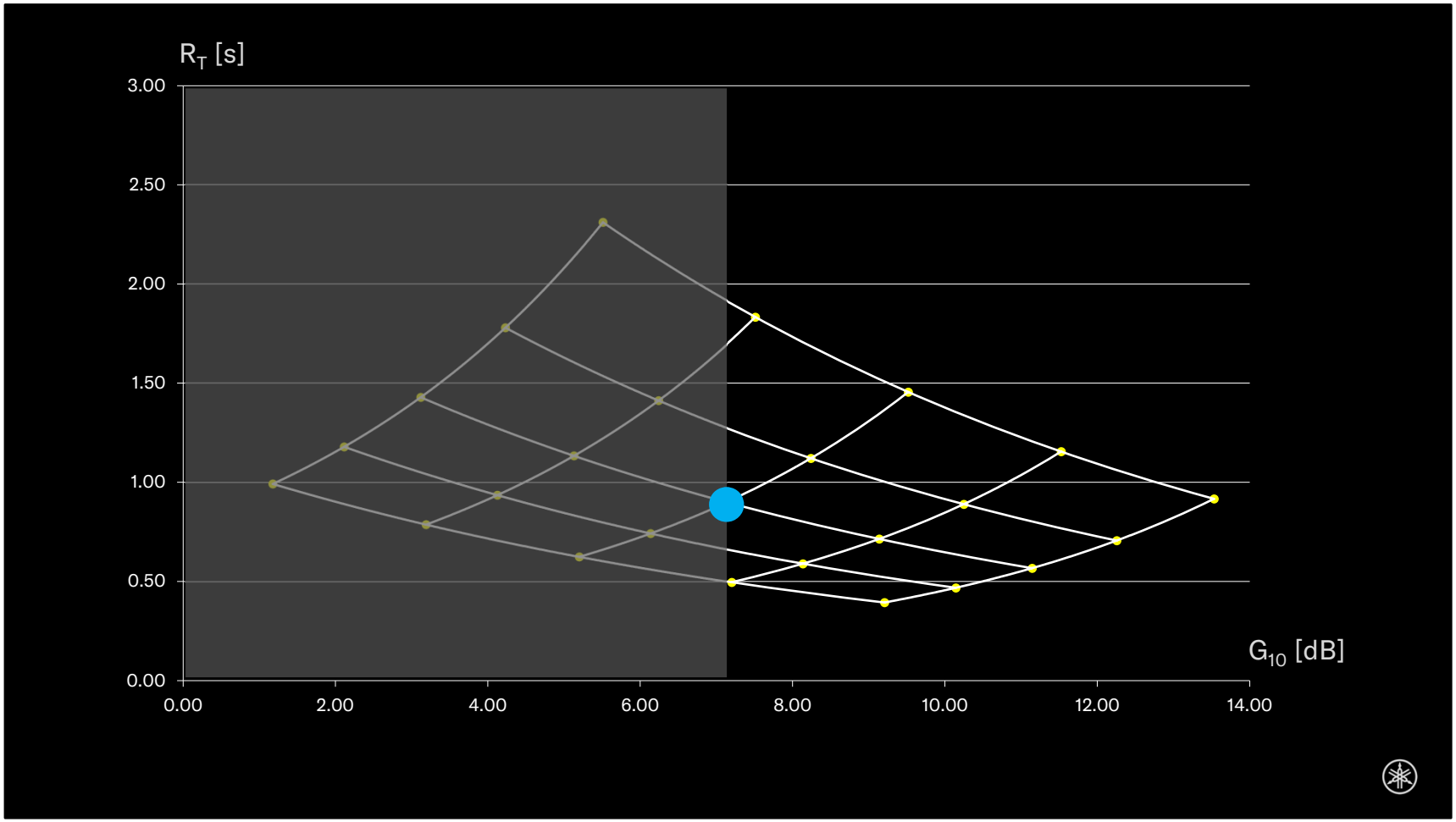
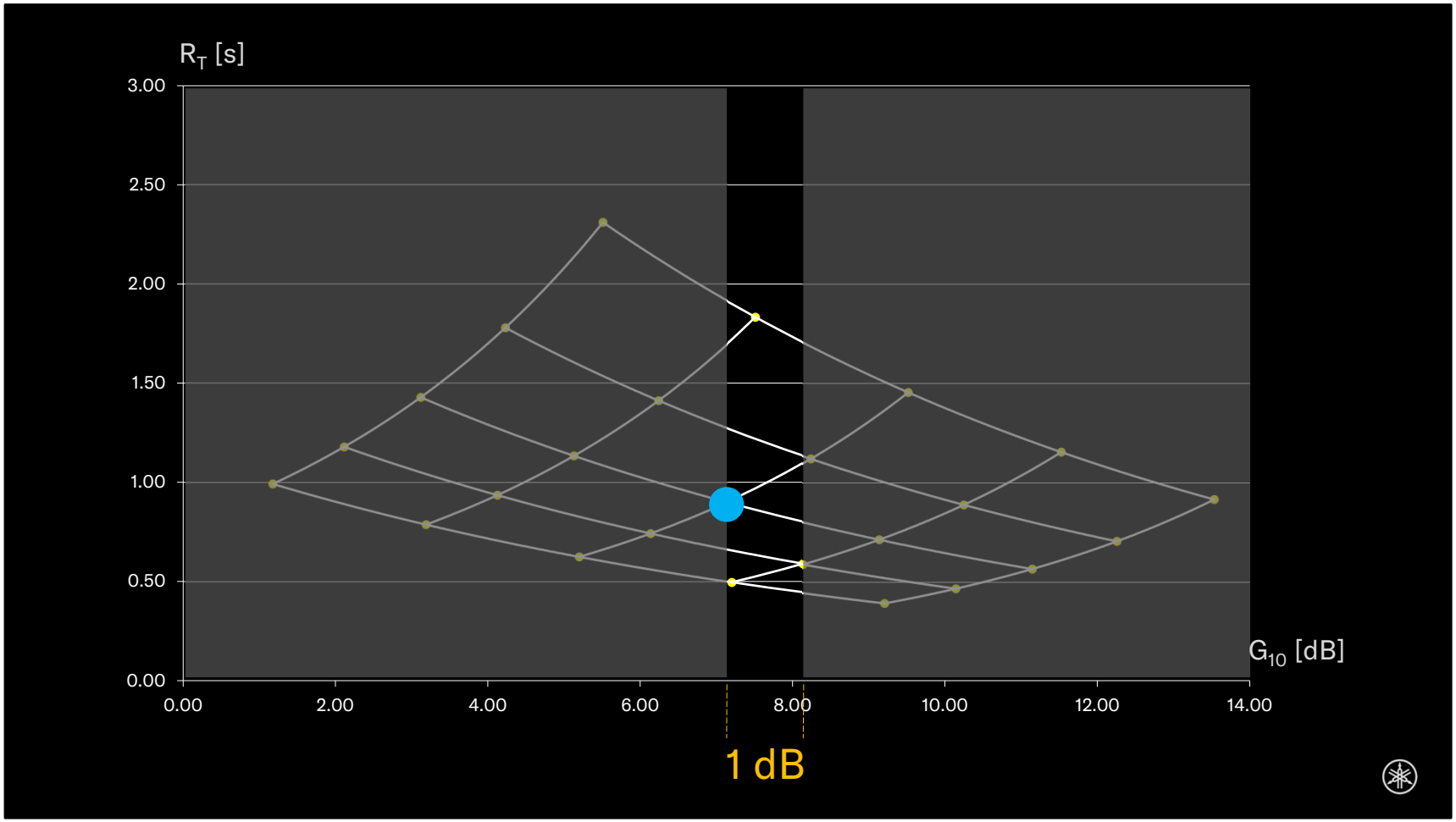


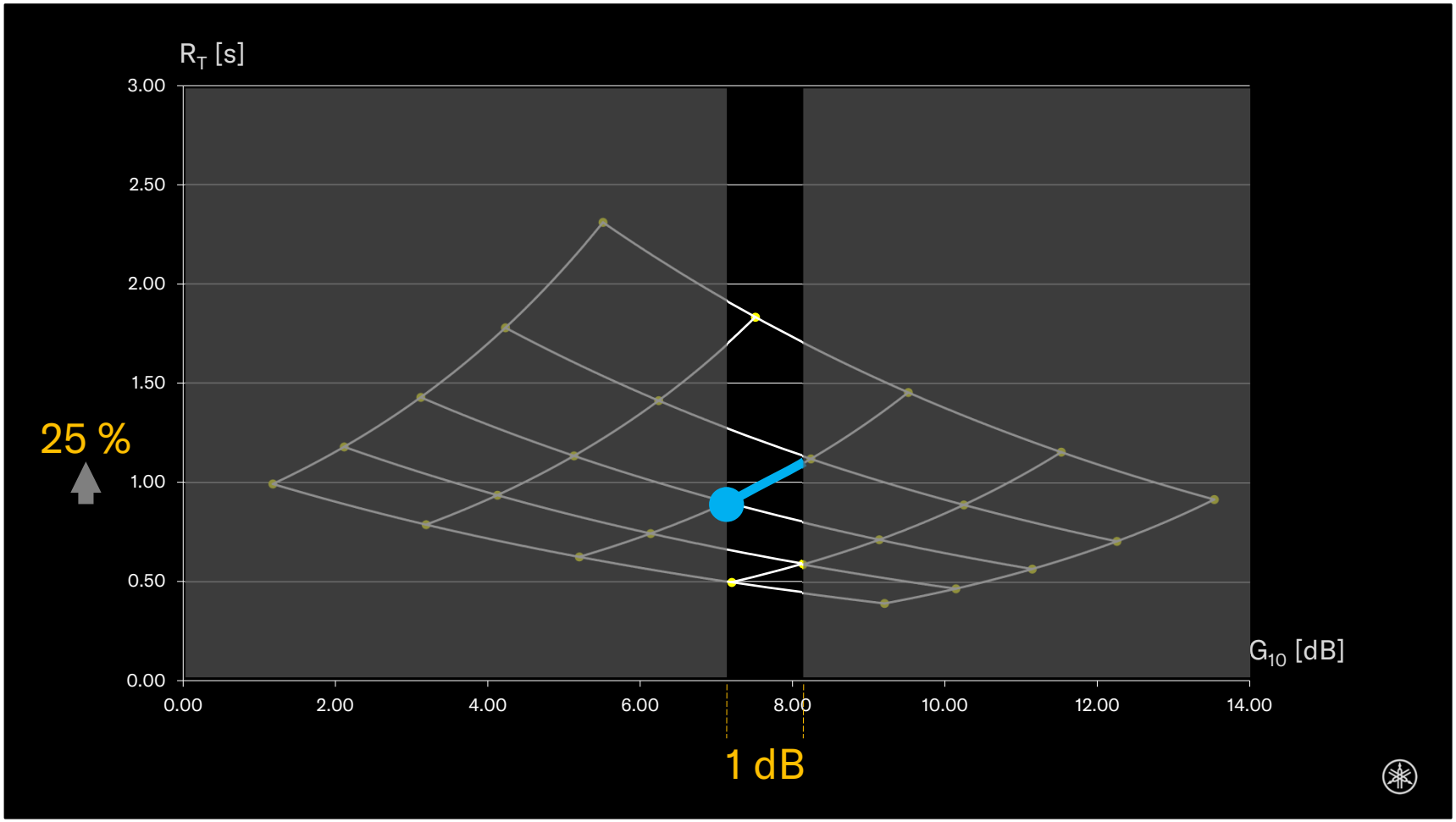
Now let’s define a room.



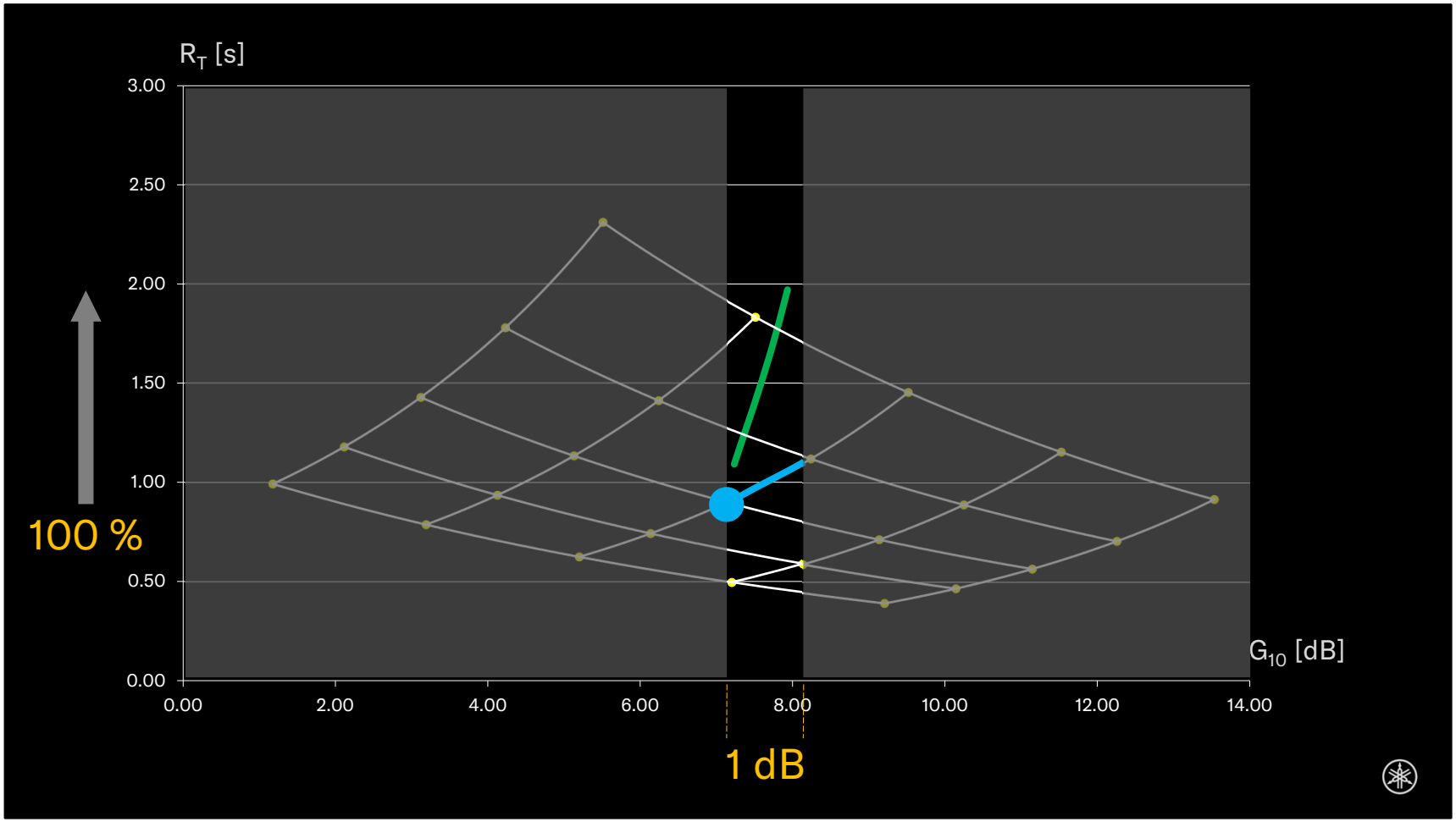
We want to **add** the hybrid-regenerative acoustic enhancement system.
It will **add energy**, so we can't go to the left.



We don't add more than 1 dB, to avoid the bathroom effect.



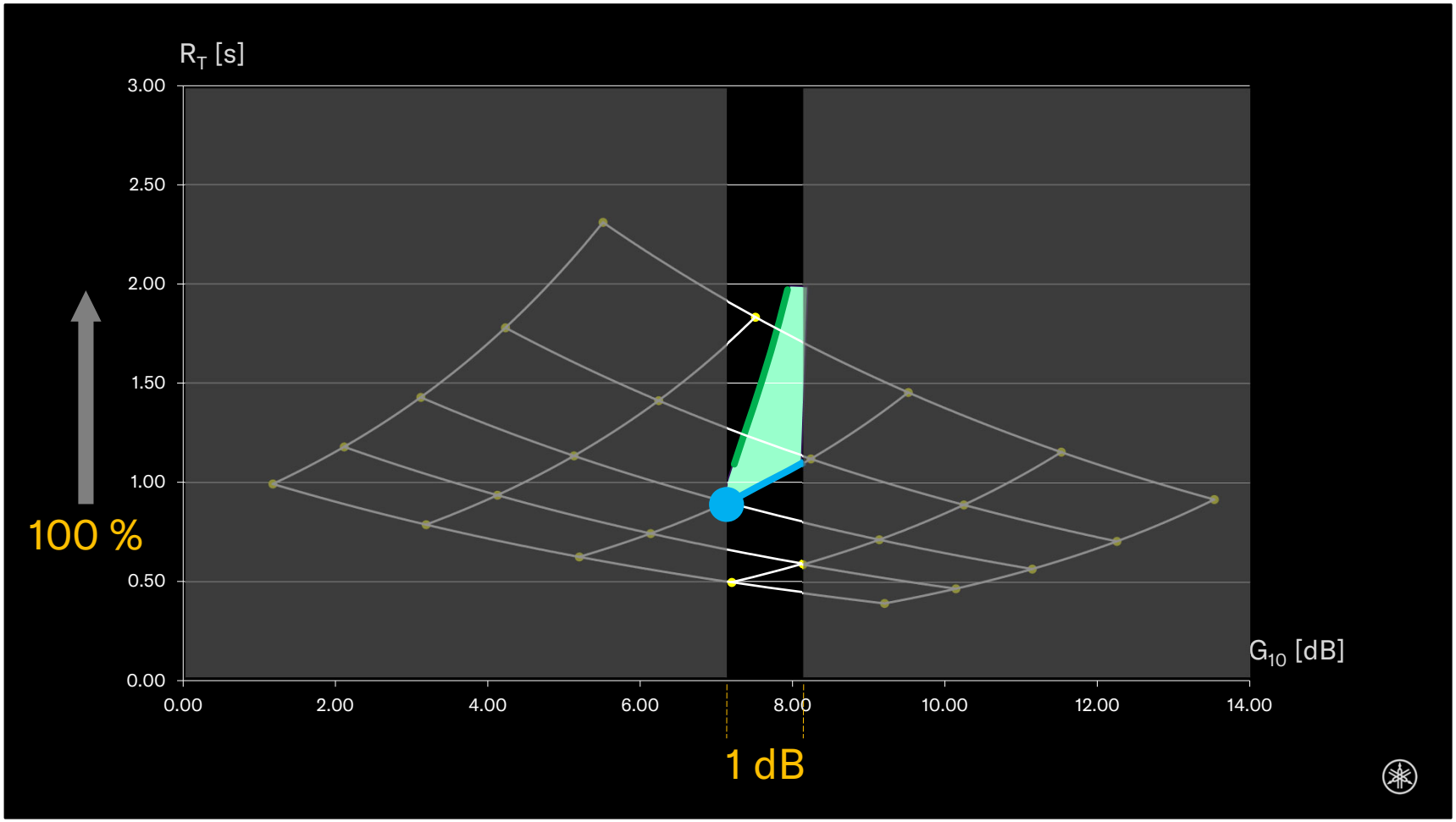
The pure regeneration, I was referring to in the beginning, allows a change along the blue line.



Now, adding a coupled room, the hybrid solution, we make reverb longer.

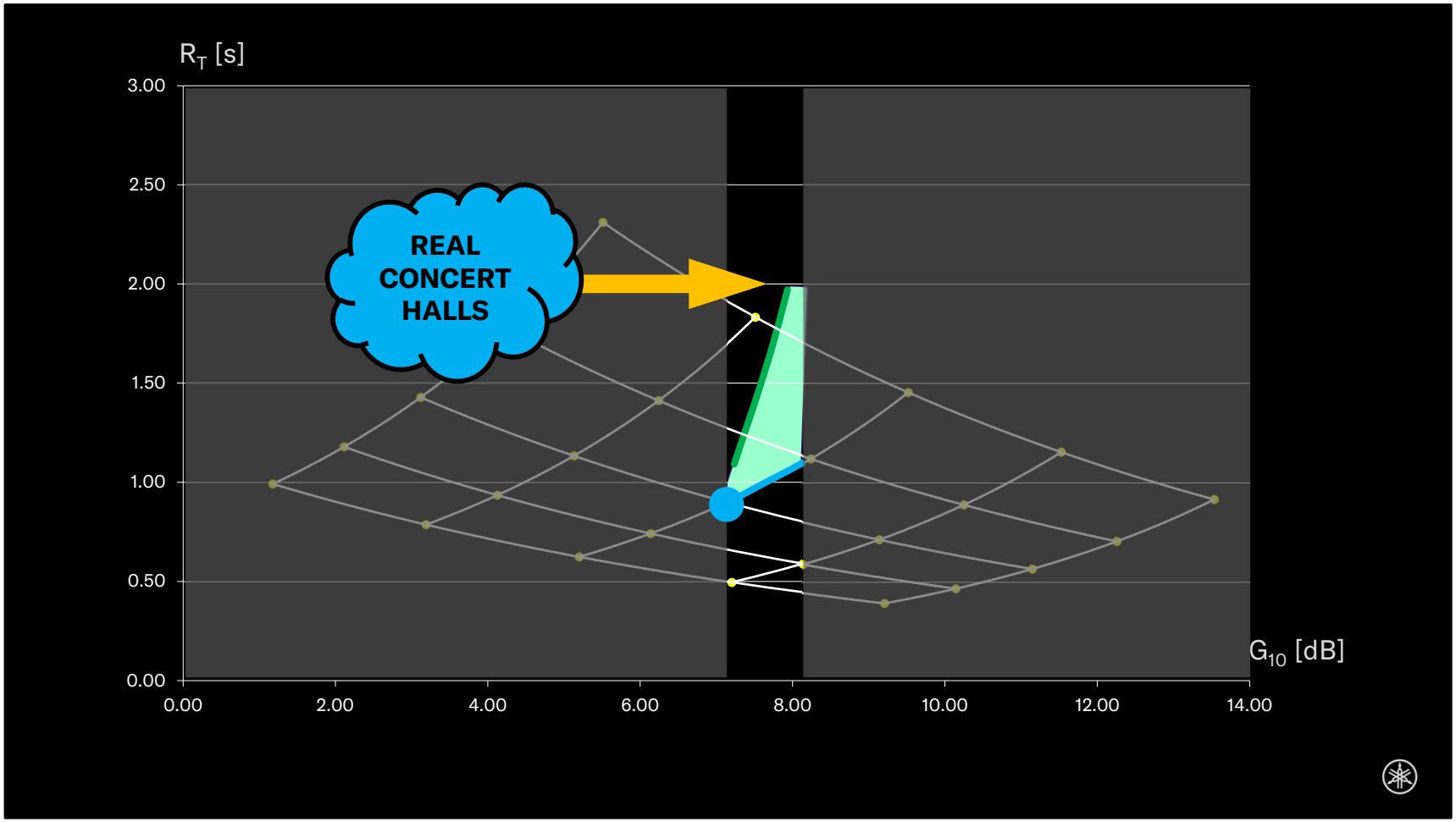
The green line is the border of the double-sloping effect.

On the left, it's bad.



The light green is for us to play with.

Let’s spend a week tuning and tweaking.



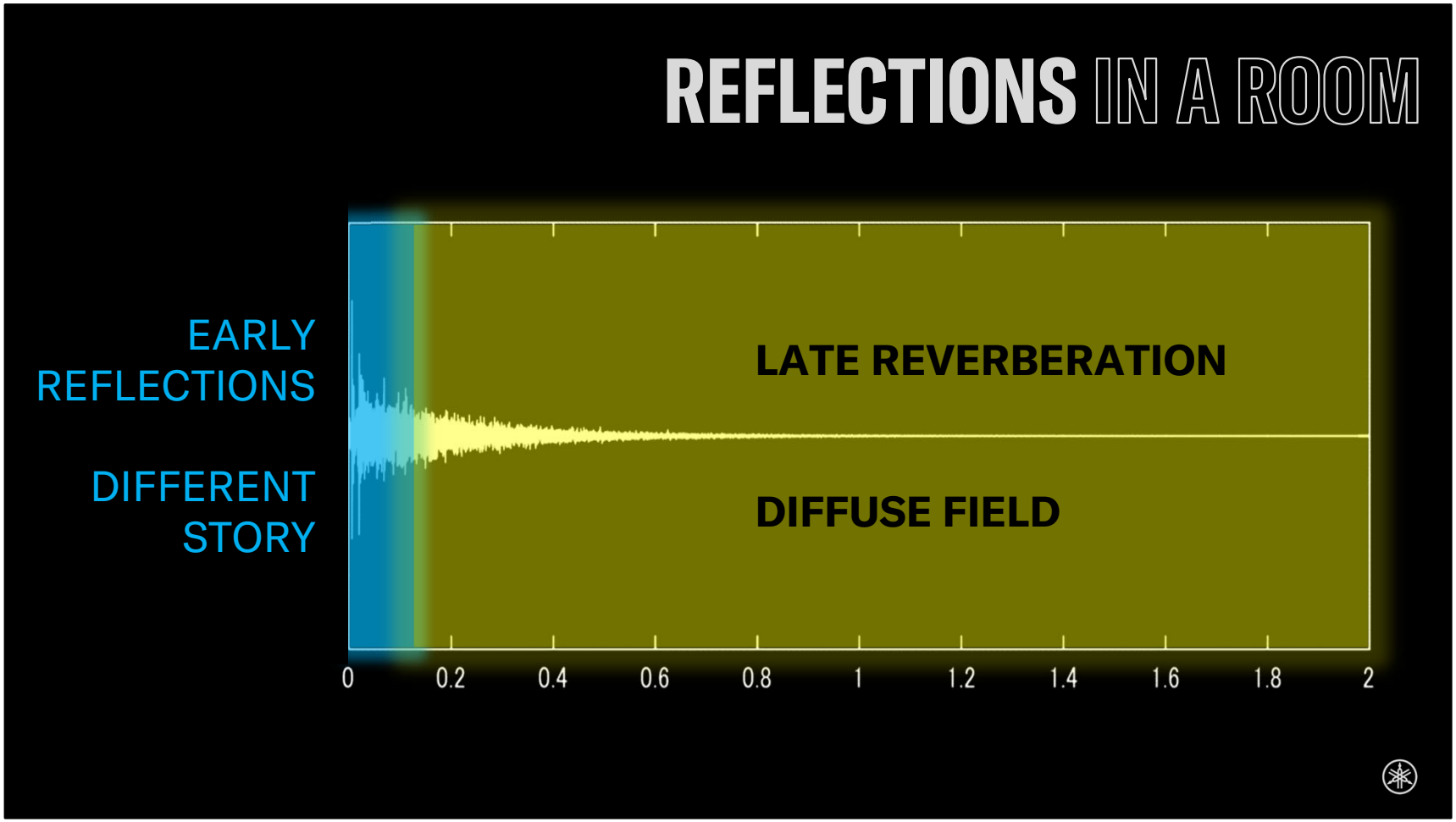
And again, how does it relate to real venues?

Real concert halls have long reverbs and low field strength. That's how acoustics works.

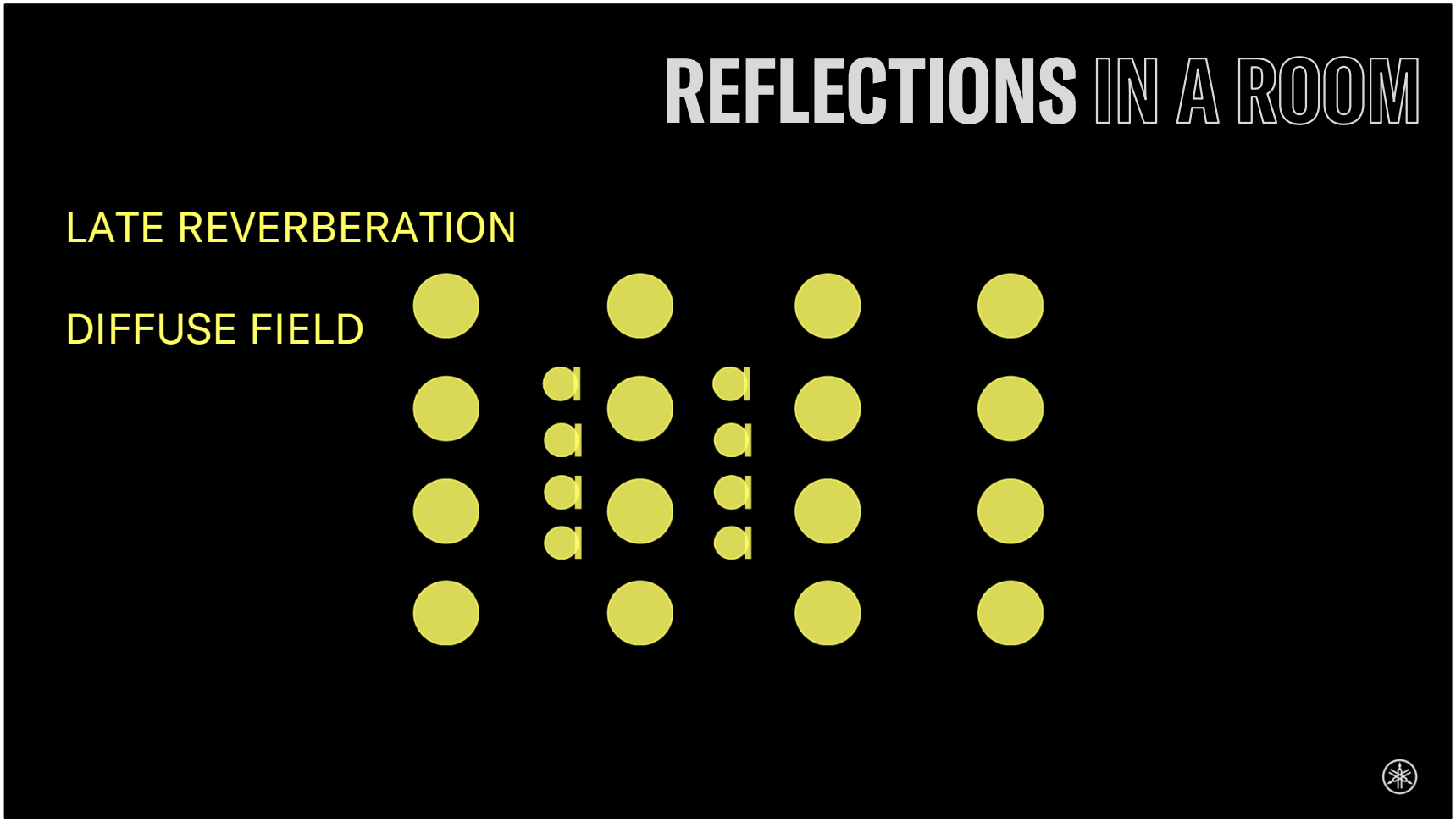
Smaller rooms are louder, and this is a difference we have to live with.

We cannot make them quieter electroacoustically. That's up to the classic acoustic treatment.

Is it all? Not just yet!



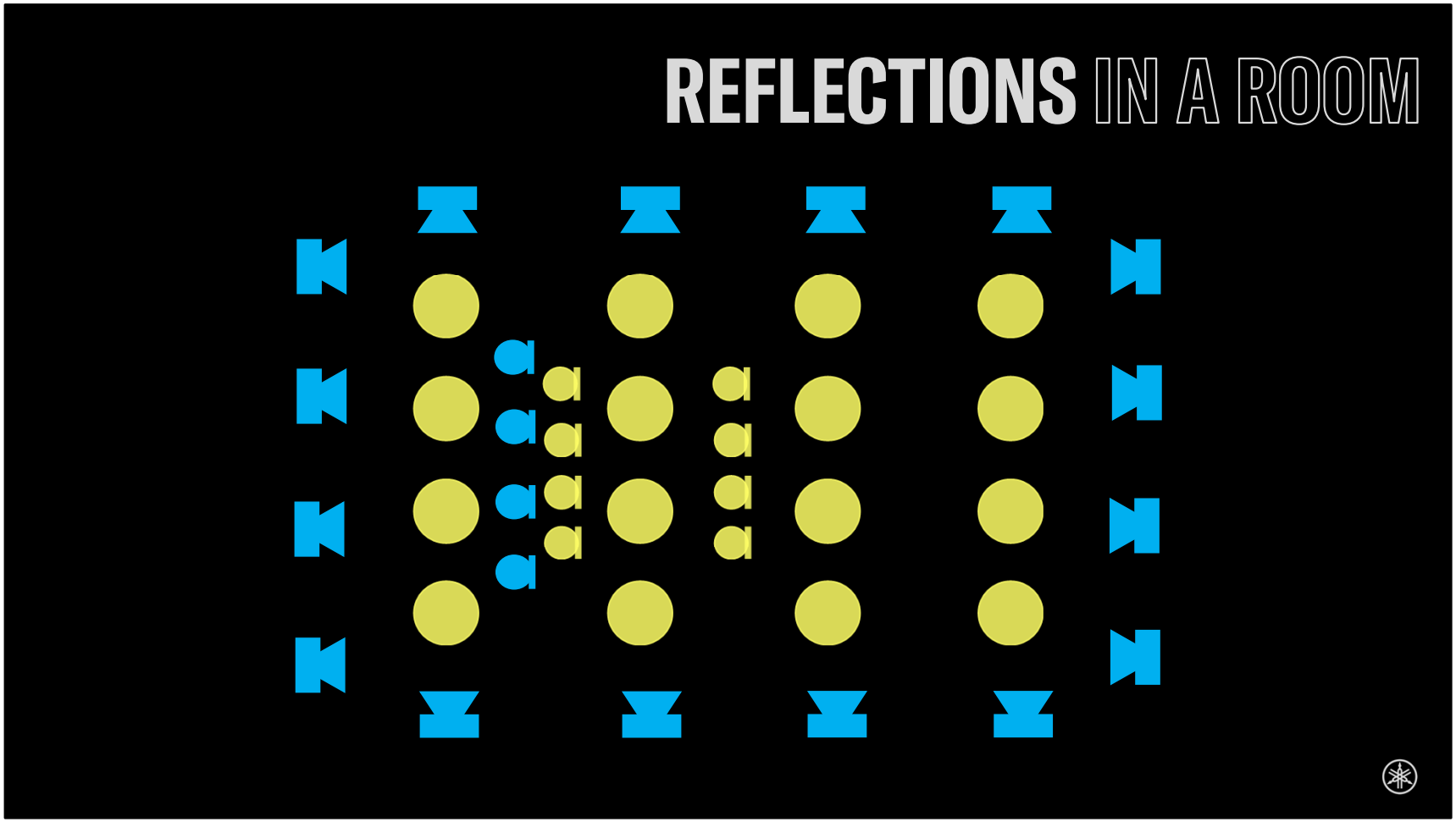
Reverberation consists of many reflections. Our brains react differently to the first few strong ones and the later many.
So far, I talked about the late reverberation and diffuse field.
Now it's time for early reflections.
Thanks to them, our brain knows the room's size, shape, and we feel immersed in the sound.



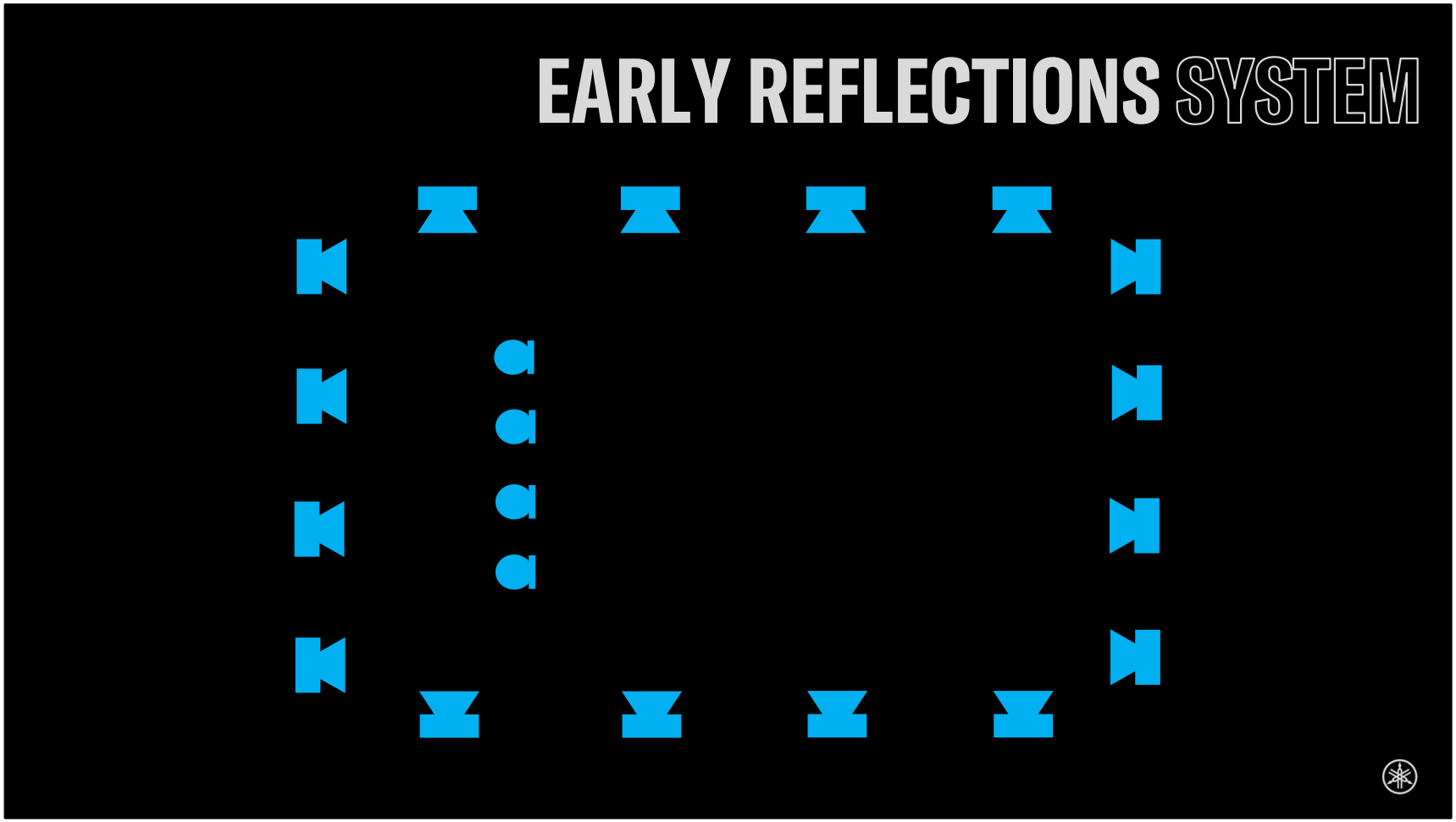
This is an example of the late reverb set, usually in the ceiling because it's natural to feel it from above, and obviously, we escape sound sources.

Remember the critical distance and diffuse field rules.

Let's add the early reflection system.



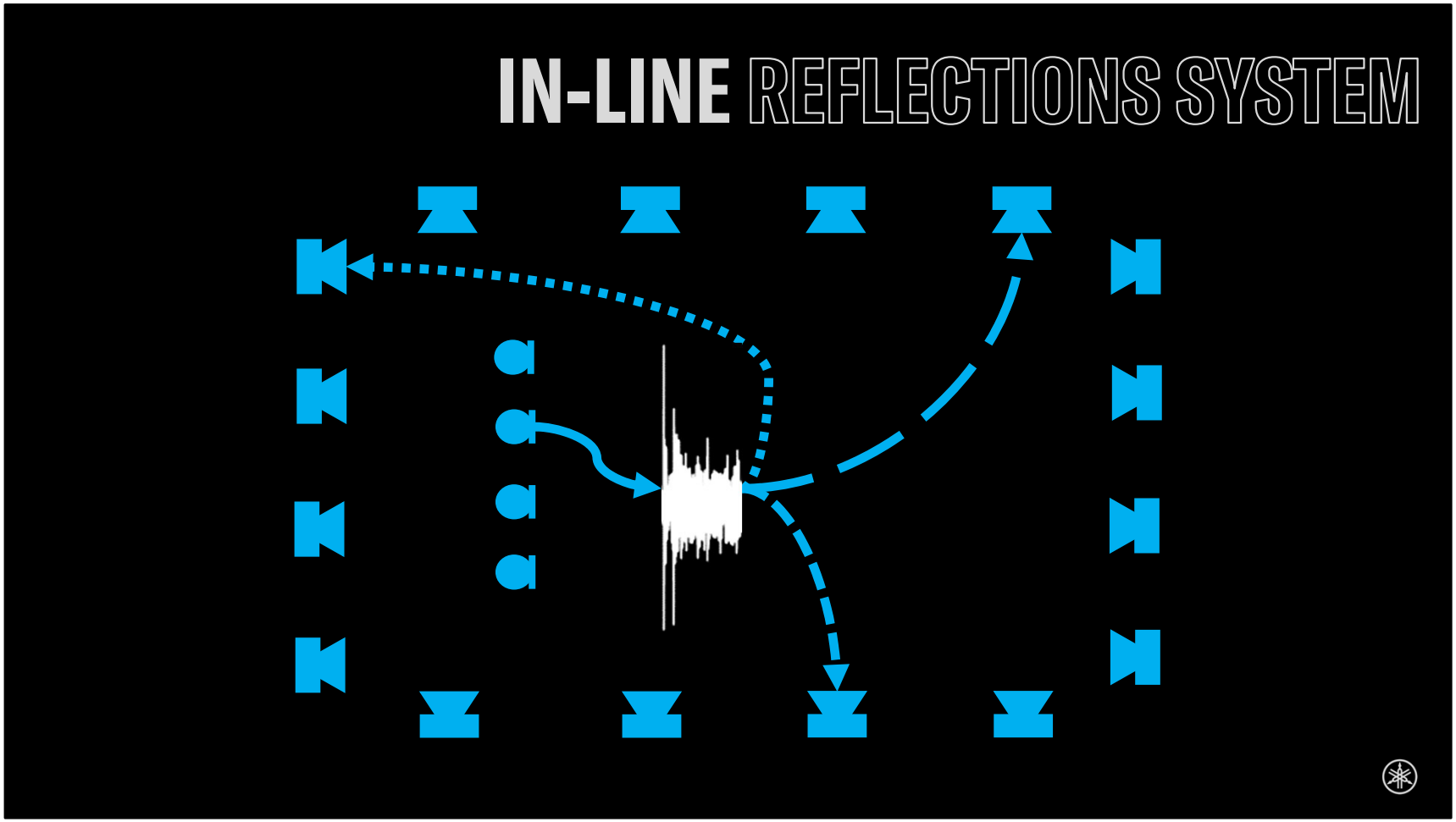
And focus on that.



This time, we need to create new, strong reflections. Therefore, we want to work within the critical distance, using a direct sound.

Speakers surround us along walls because most reflections do.

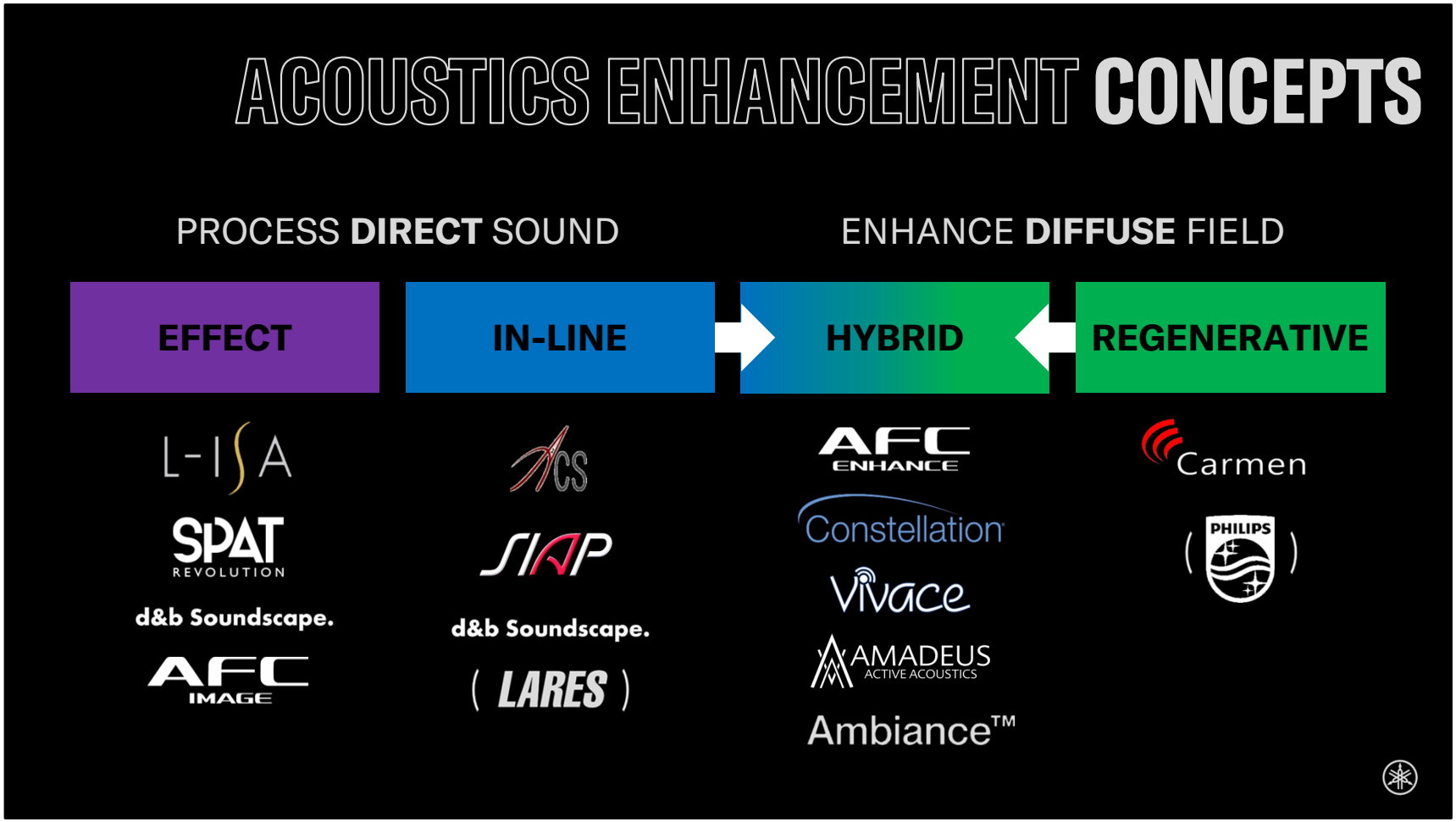
Directional mics pick sound from closer distance.



Signals from mics are convoluted with the early part of impulse responses, delayed, and played back to the room. Delays are calculated to resemble the size and shape of the hall we emulate. Similarly to the late reverb system, we use multiple impulse responses, taken from respective points of the original hall.

We call it an in-line system because it's more like adding an effect using a PA. That way we have **the hybrid-hybrid** regenerative solution, but we skip one hybrid so doesn’t sound silly.

Now, as we organized what is what, let's see how people enhance acoustics.



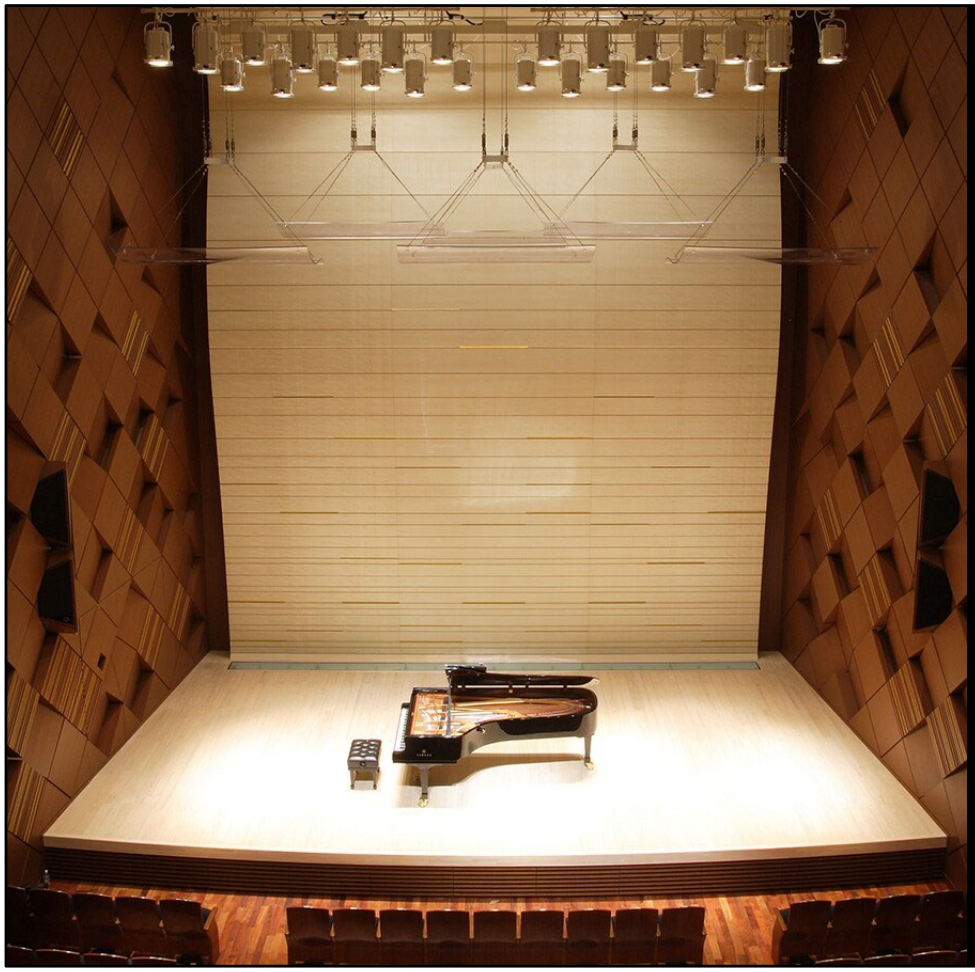
1. The **effect** approach is like on a mixing console. We just add reverb plugin to mixed sounds. If speakers surround us, it can feel like a new reverberation in the room, **but only for sounds we have in the console**.

2. The **regenerative** solution is the pure first part of my presentation, which was about amplifying the diffuse field only.

3. The **in-line** systems are similar to the mentioned early reflection solution. Mics pick up sounds and a reverb plugin creates reverb tails, which are played back via a **PA** system.

4. And finally, the **hybrid** systems, which are based on our method, which I tried to explain just before.

From the larger perspective, there are two ways. One imposes a new acoustics by adding reverb effect to **direct sound**. The other enhances the already existing **diffuse filed**.



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Thank you