Demonstrating Electromagnetic Properties of a MADMAX prototype booster

Jacob Egge

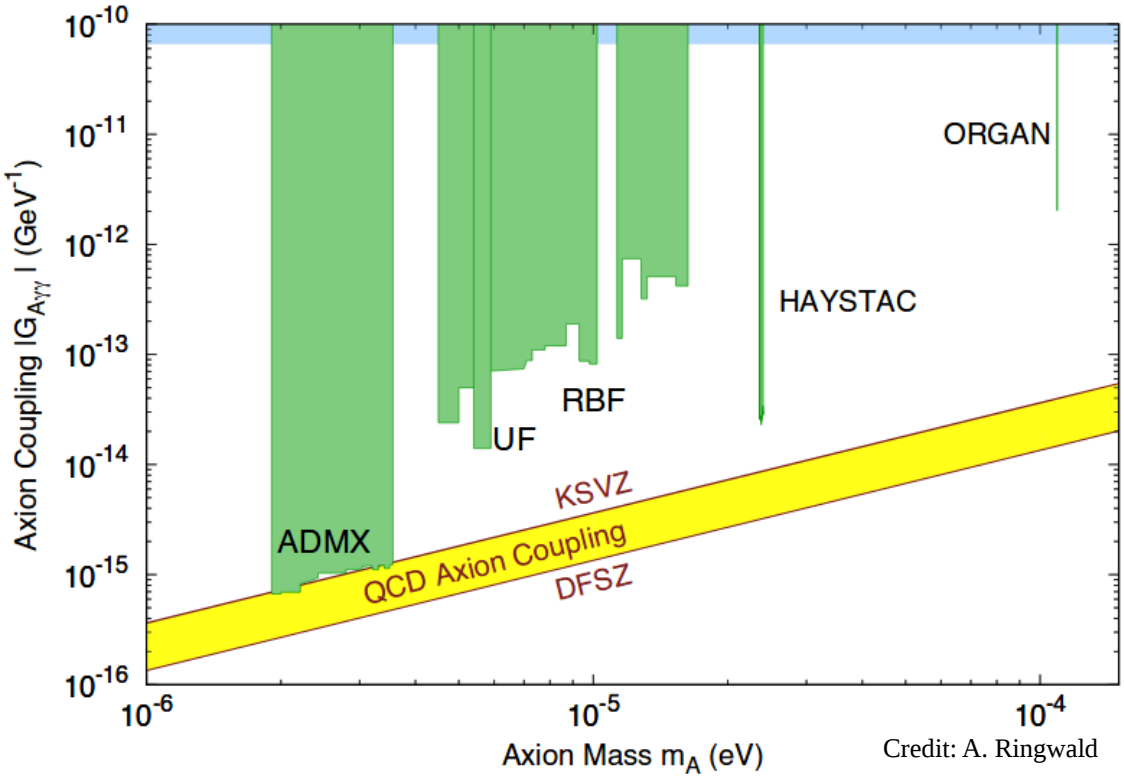
for the MADMAX collaboration

Axions

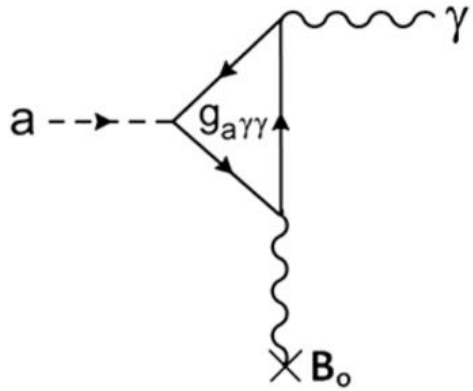
MADMAX: **MA**gnetised **D**isk-and-**M**irror **A**xion e**X**periment

- Solution to the strong CP problem
- Dark matter candidate

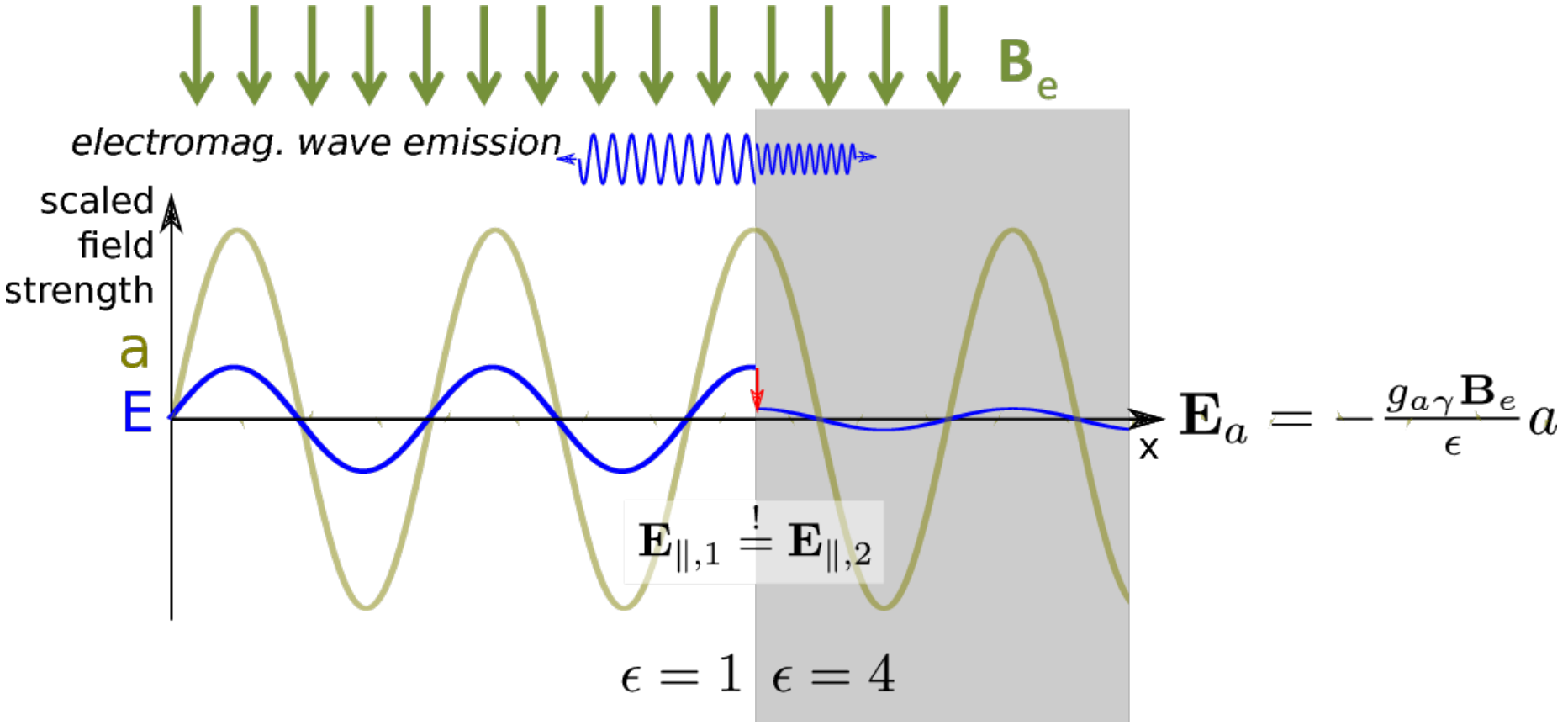
$$\mathcal{L} = -\theta \frac{g_S}{32\pi^2} G^a_{\mu\nu} \tilde{G}^{\mu\nu}_a$$



Credit: A. Ringwald



Basic Principle



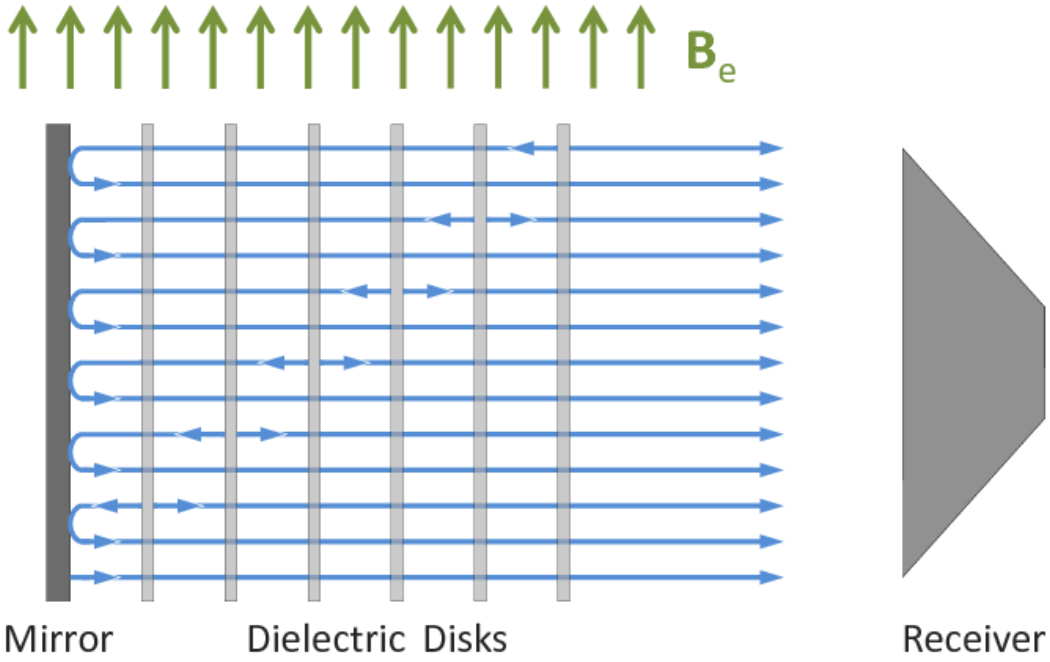
$$P/A = 2.2\times10^{-27}\, W\, m^{-2} \left(\frac{B_e}{10\,T}\right)^2 C_{a\gamma}^2 \cdot f(\epsilon_1, \epsilon_2)$$

tiny power
→ boost needed

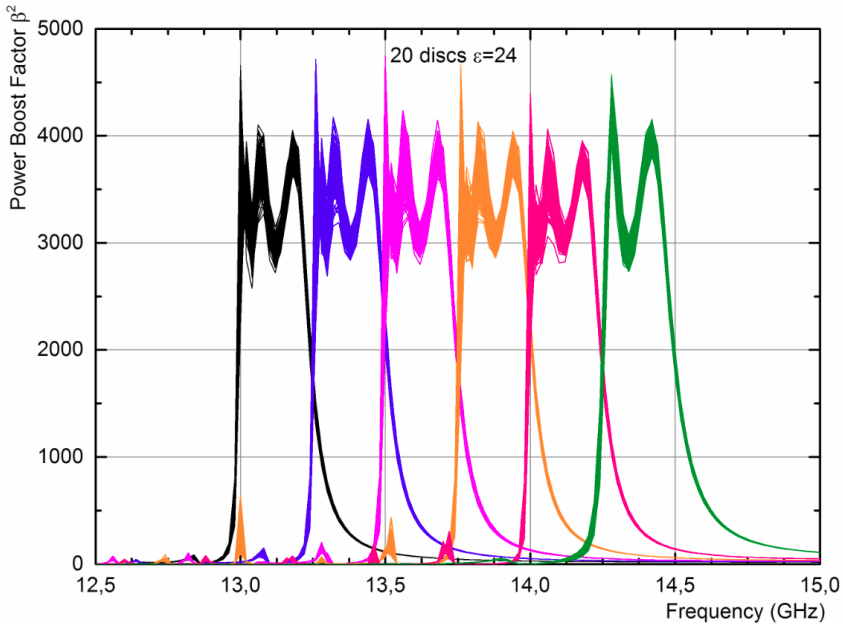
Basic Principle

Solution: Use many discs

- Resonance and constructive interference of emissions



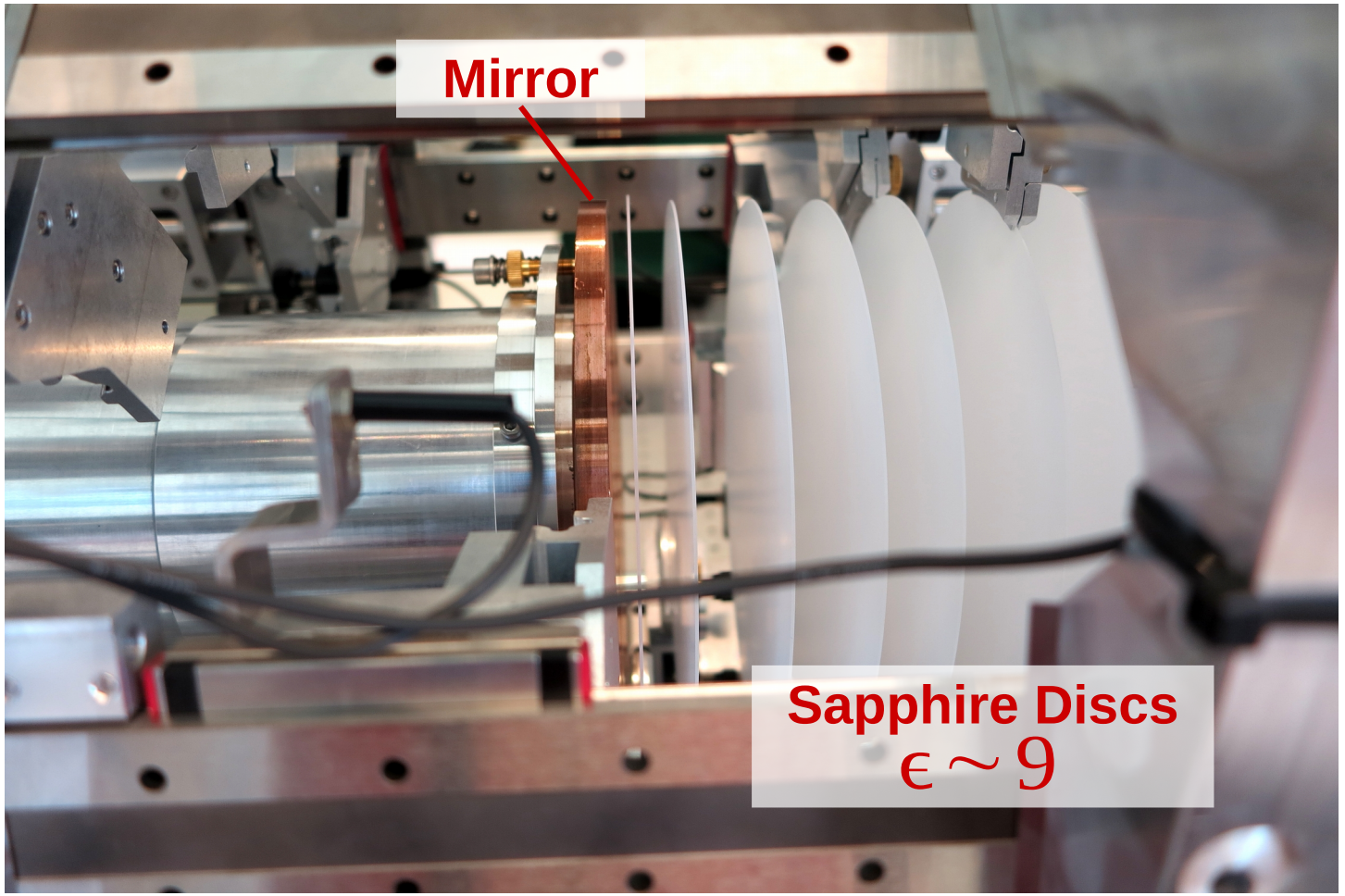
Boost factor (β^2) simulation



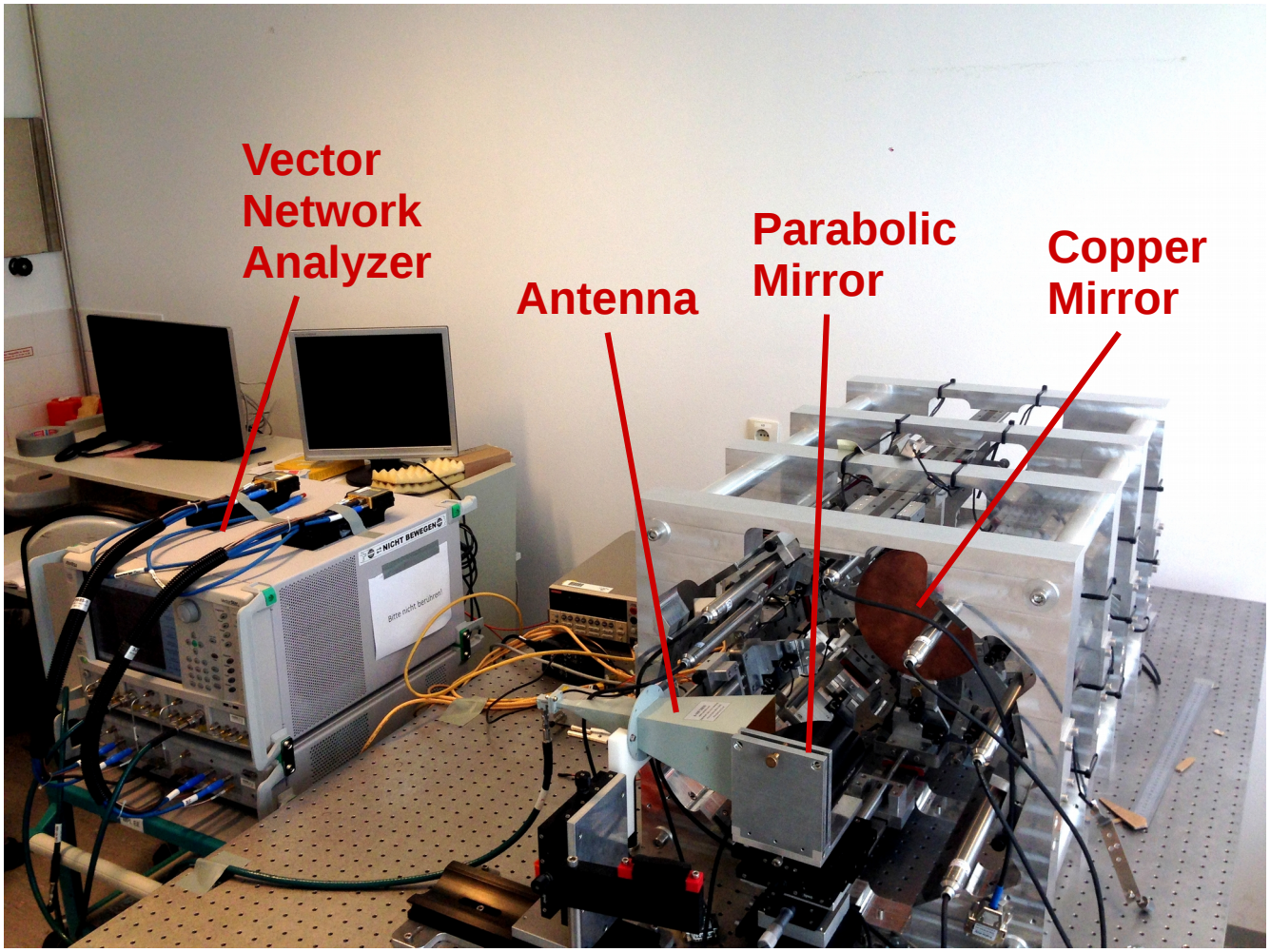
$$P/A = 2.2\times10^{-27}\, W\, m^{-2} \left(\frac{B_e}{10\,T}\right)^2 C_{a\gamma}^2 \cdot f(\epsilon_1, \epsilon_2) \cdot \beta^2$$

$\beta^2 = \frac{\text{Power of booster}}{\text{Power of single mirror}}$

20 Disc Setup



20 Disc Setup



- 20 disc seed setup
- No magnetic field
- Test electromagnetic response with a Vector Network Analyzer

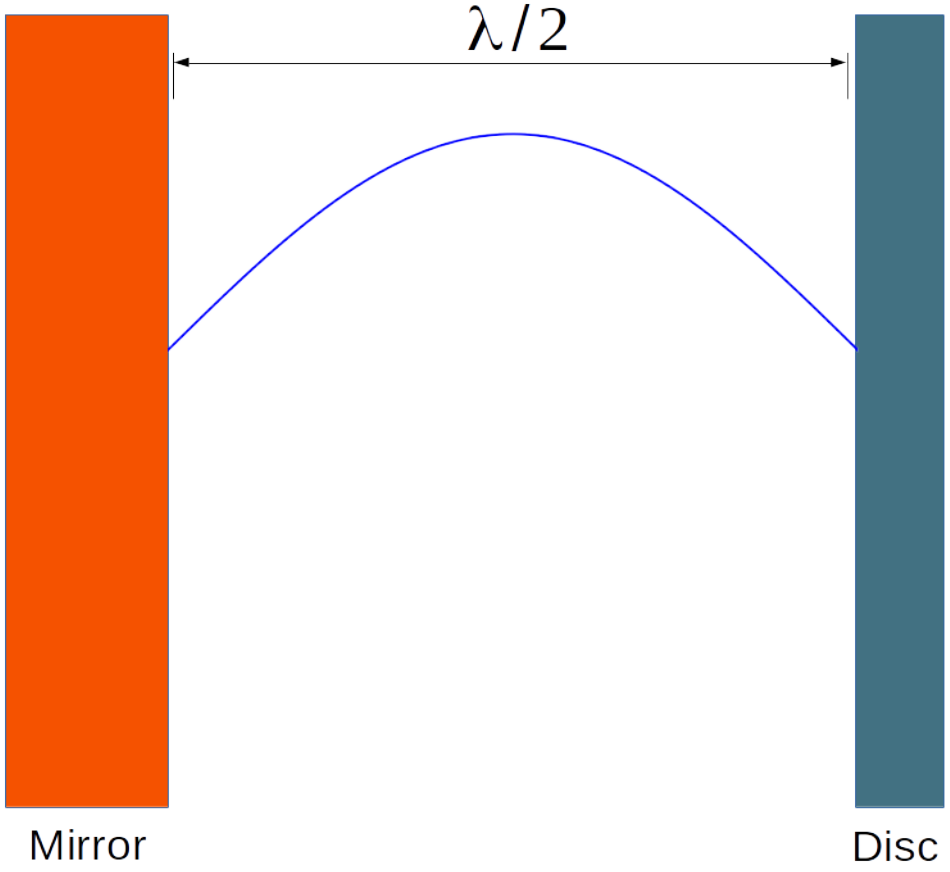
One Disc System

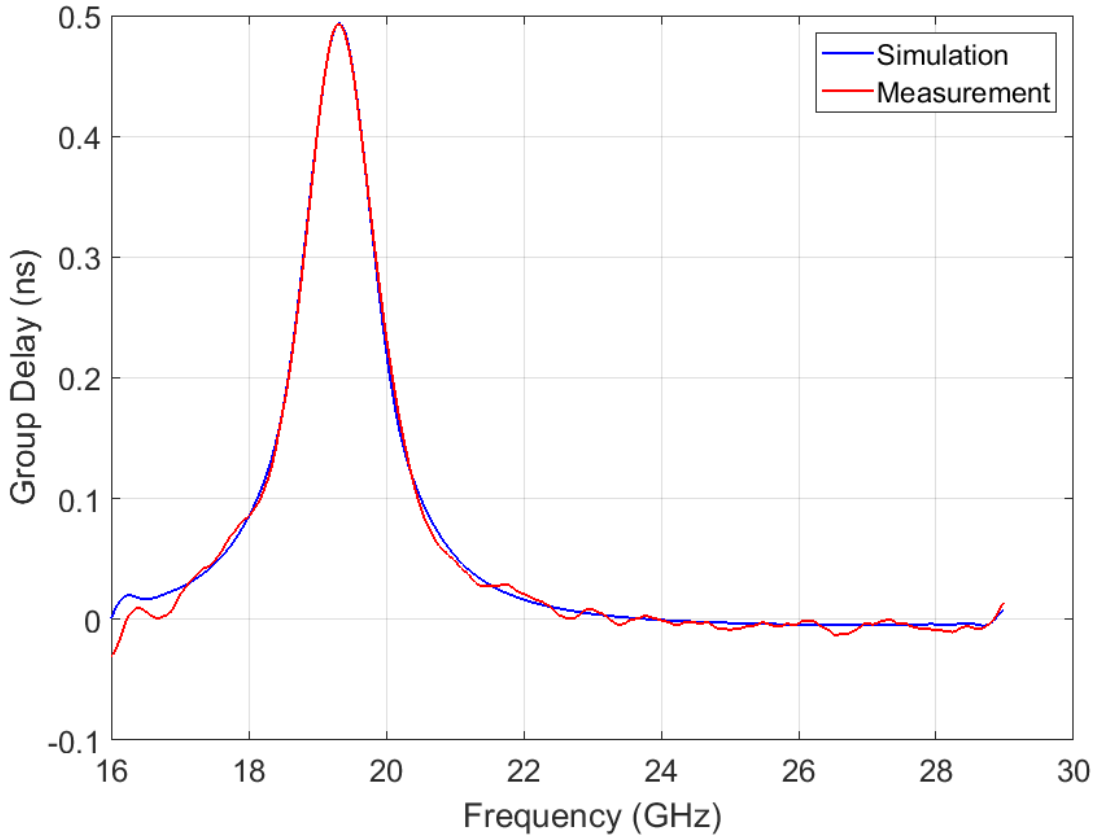
System characterization via Group Delay:

$$\tau_g = -\frac{d\phi}{d\omega}$$

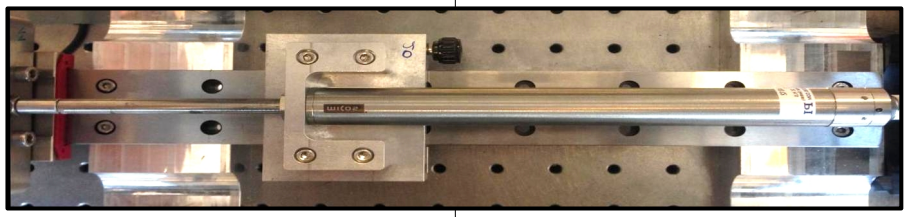
Phase

Angular Frequency

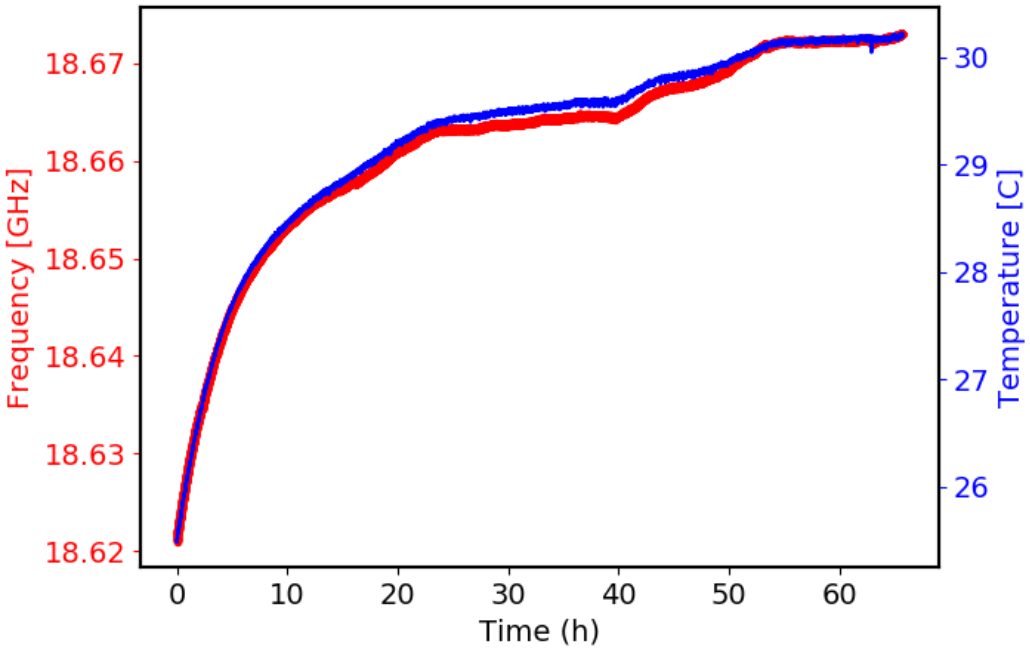




Mechanical Precision

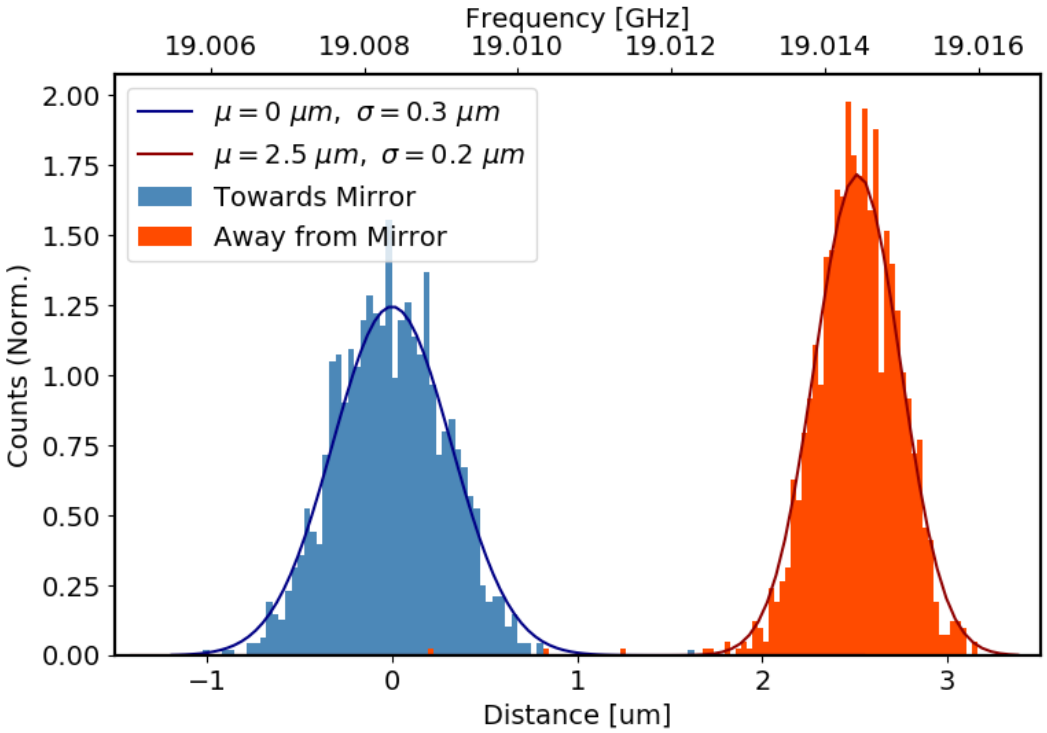


Temperature Response



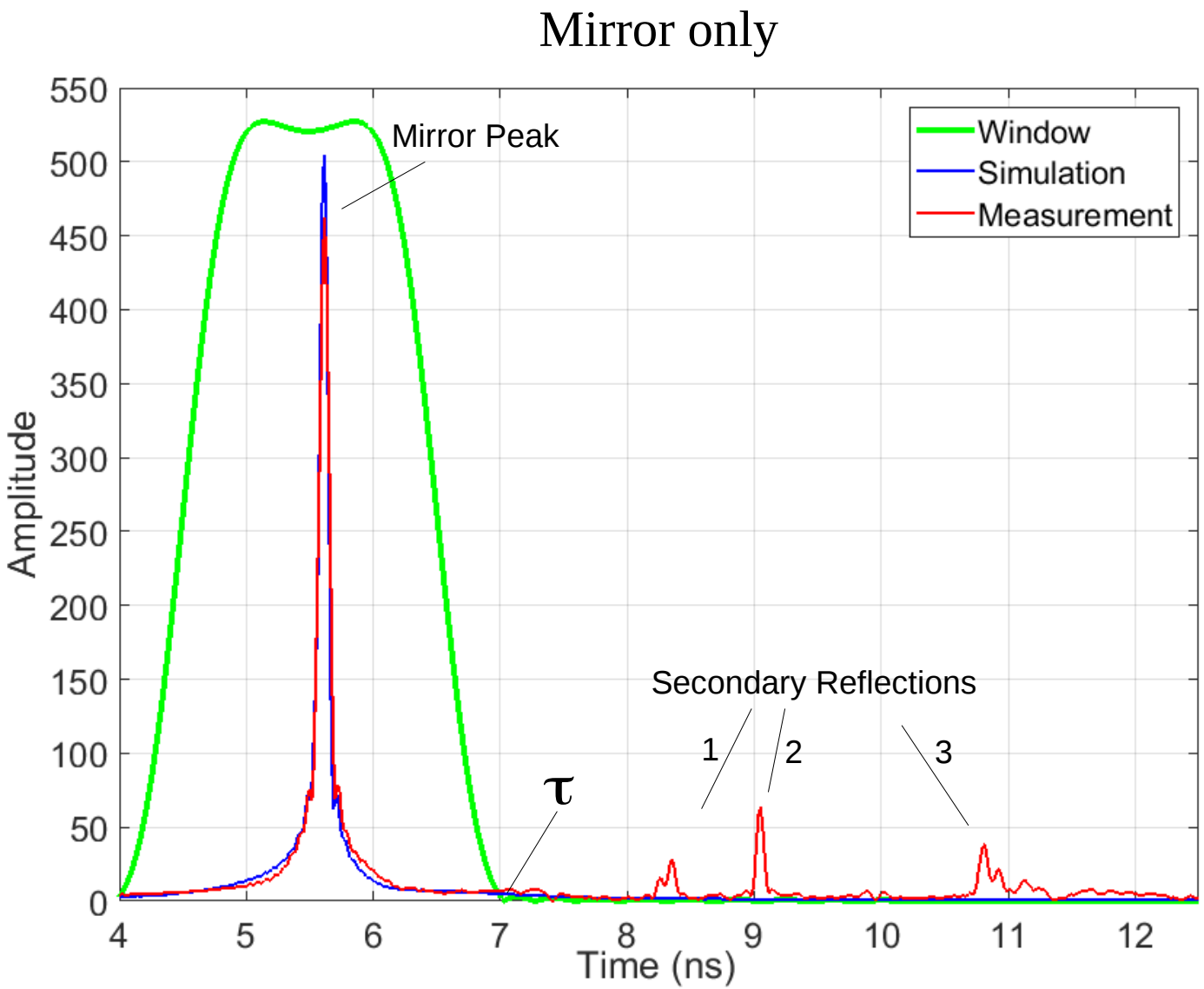
- Thermal expansion changes disc distance

Motor Hysteresis



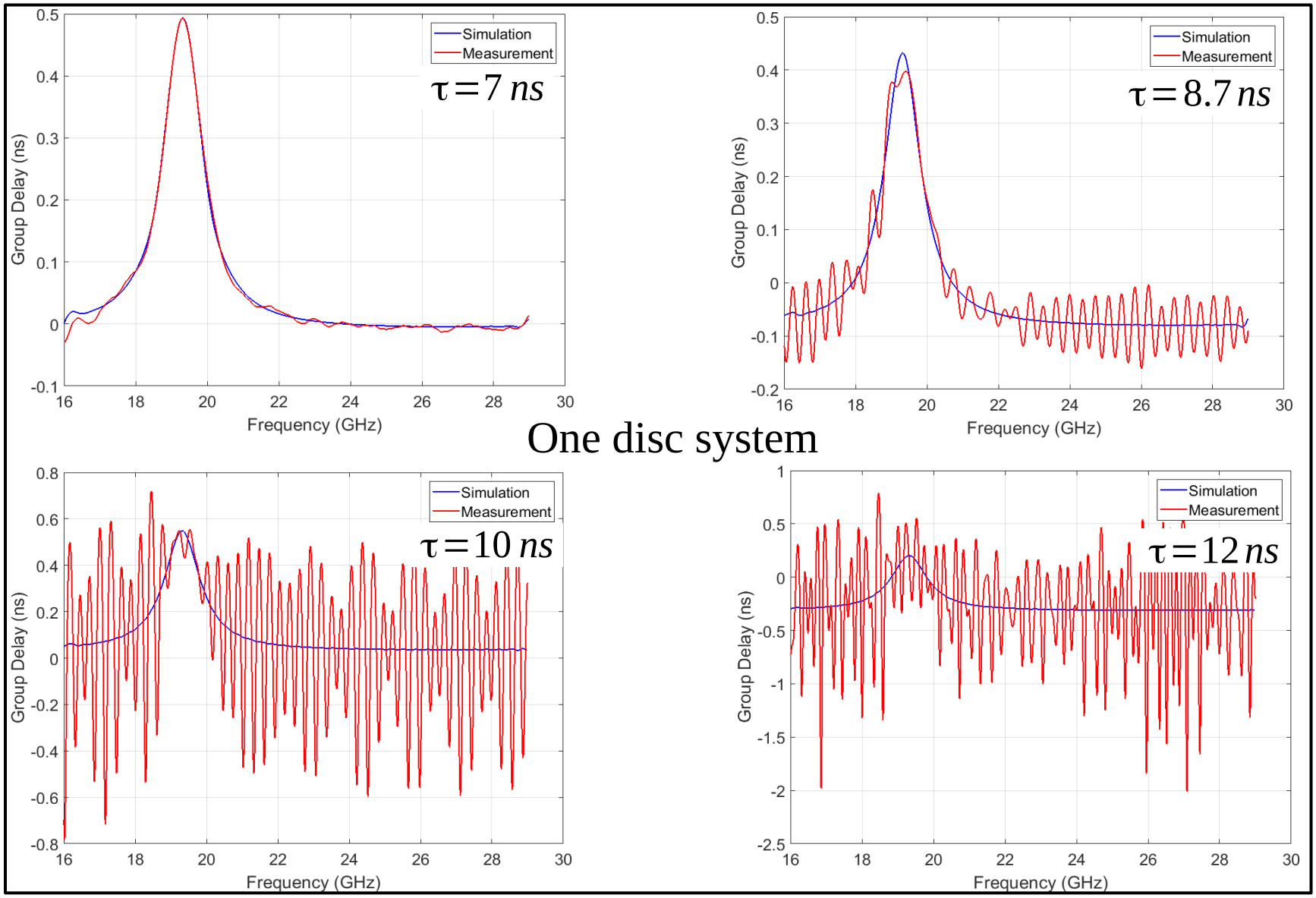
- Command motor to the same position coming from different directions

Reflections



- Additional unwanted reflections in the system
- antenna mismatch, surroundings, ...
- Removal by time gate
- But: In a many discs system signal and unwanted reflections overlap

Reflections



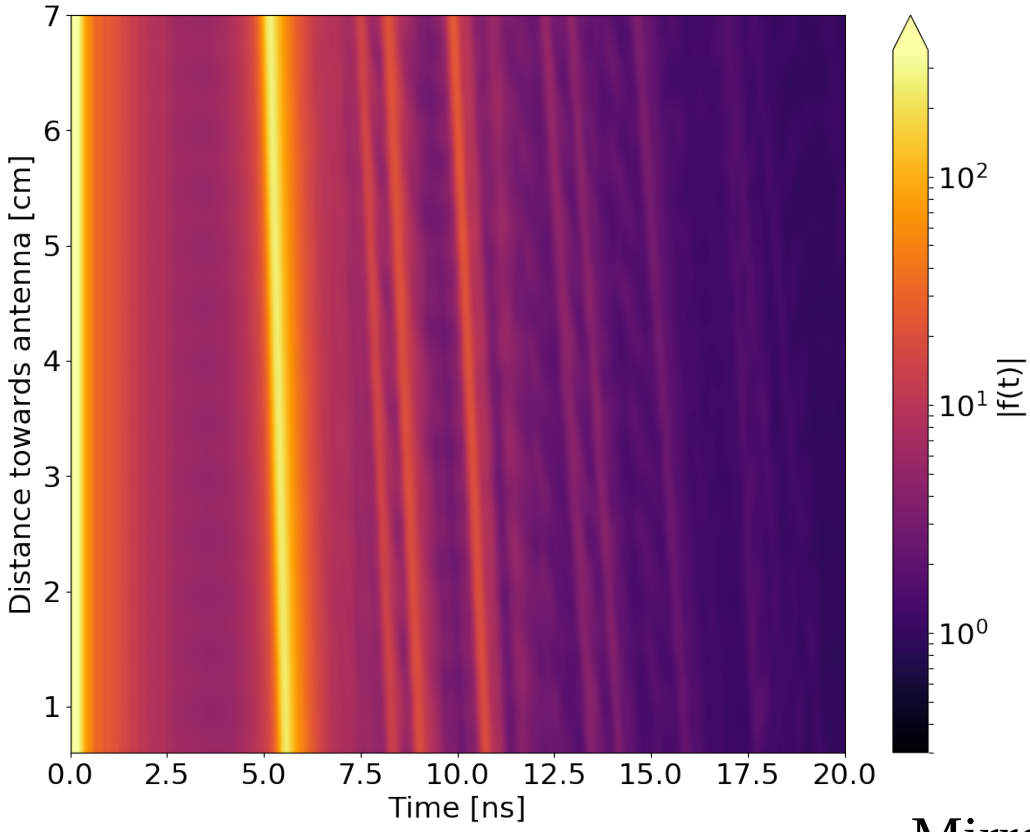
One disc system

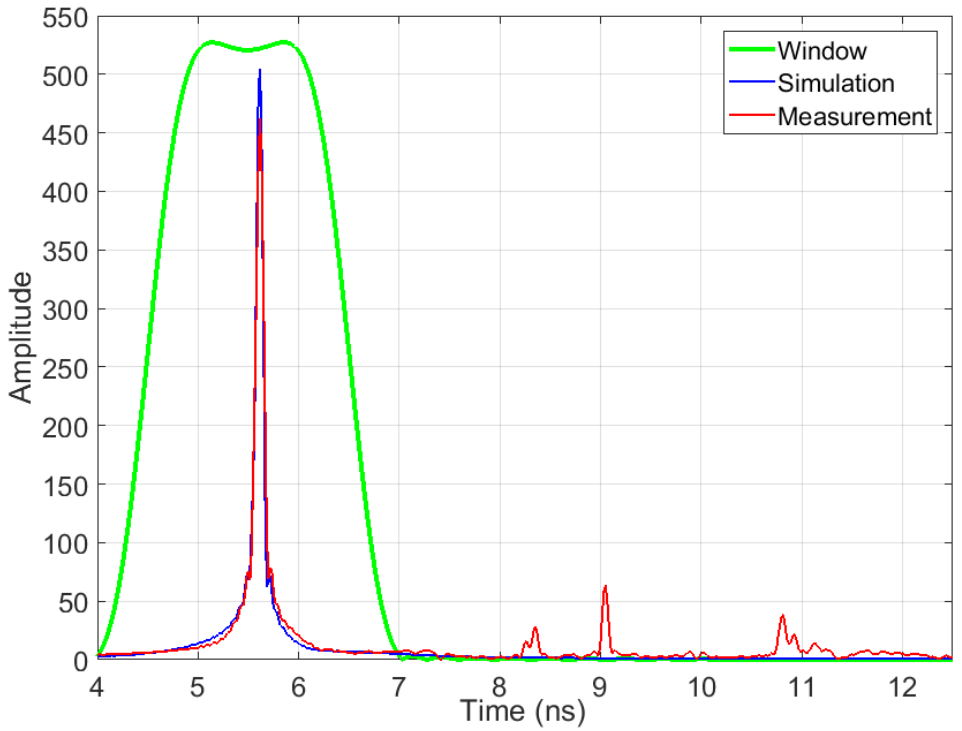
→ Necessary to model additional reflections

Reflections

Idea: Include reflections in simulation

Measurement



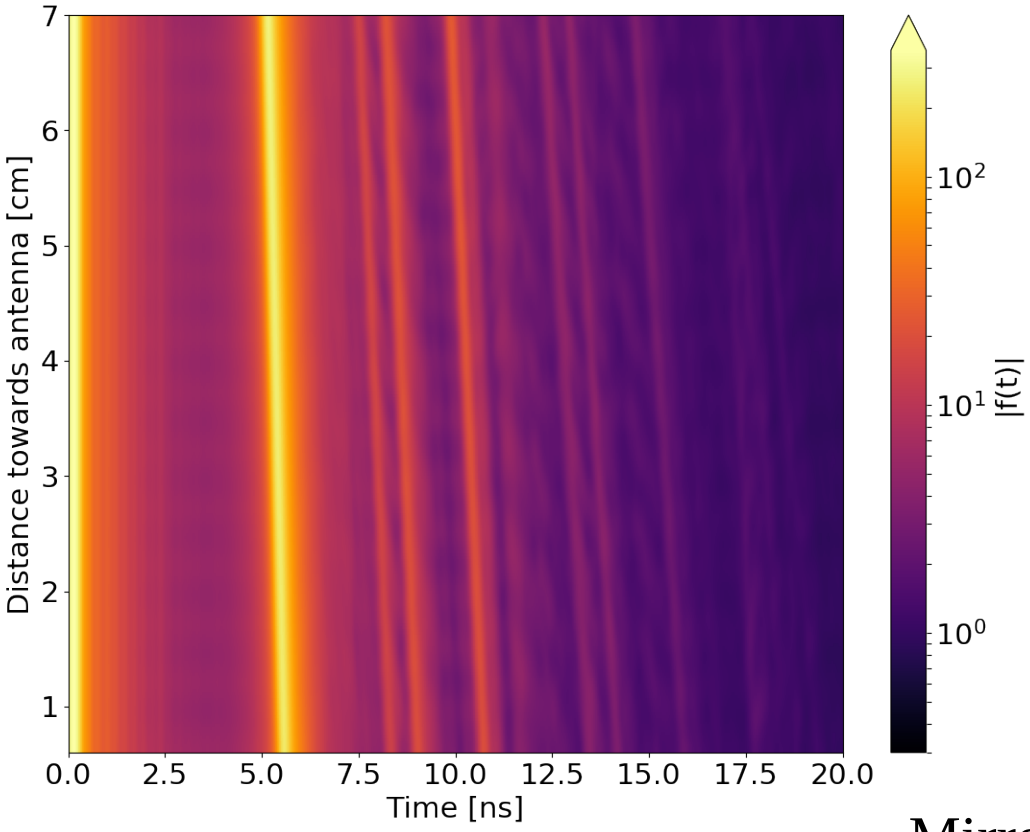


Mirror only

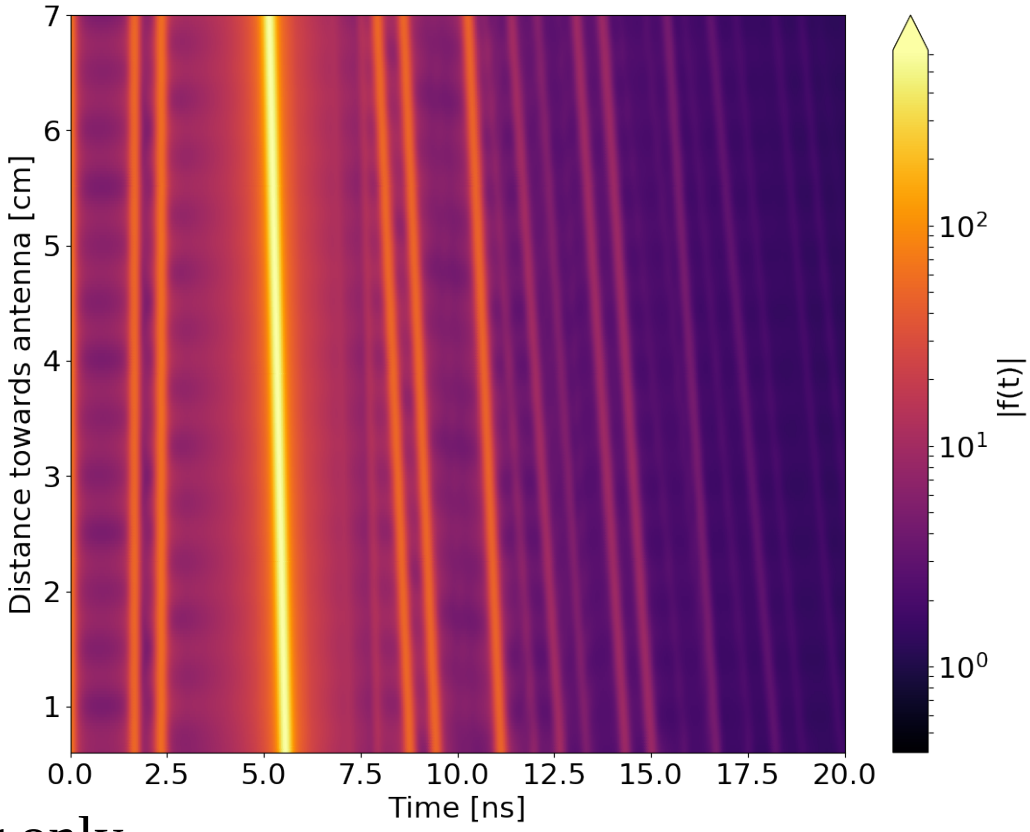
Reflections

Idea: Include reflections in simulation

Measurement

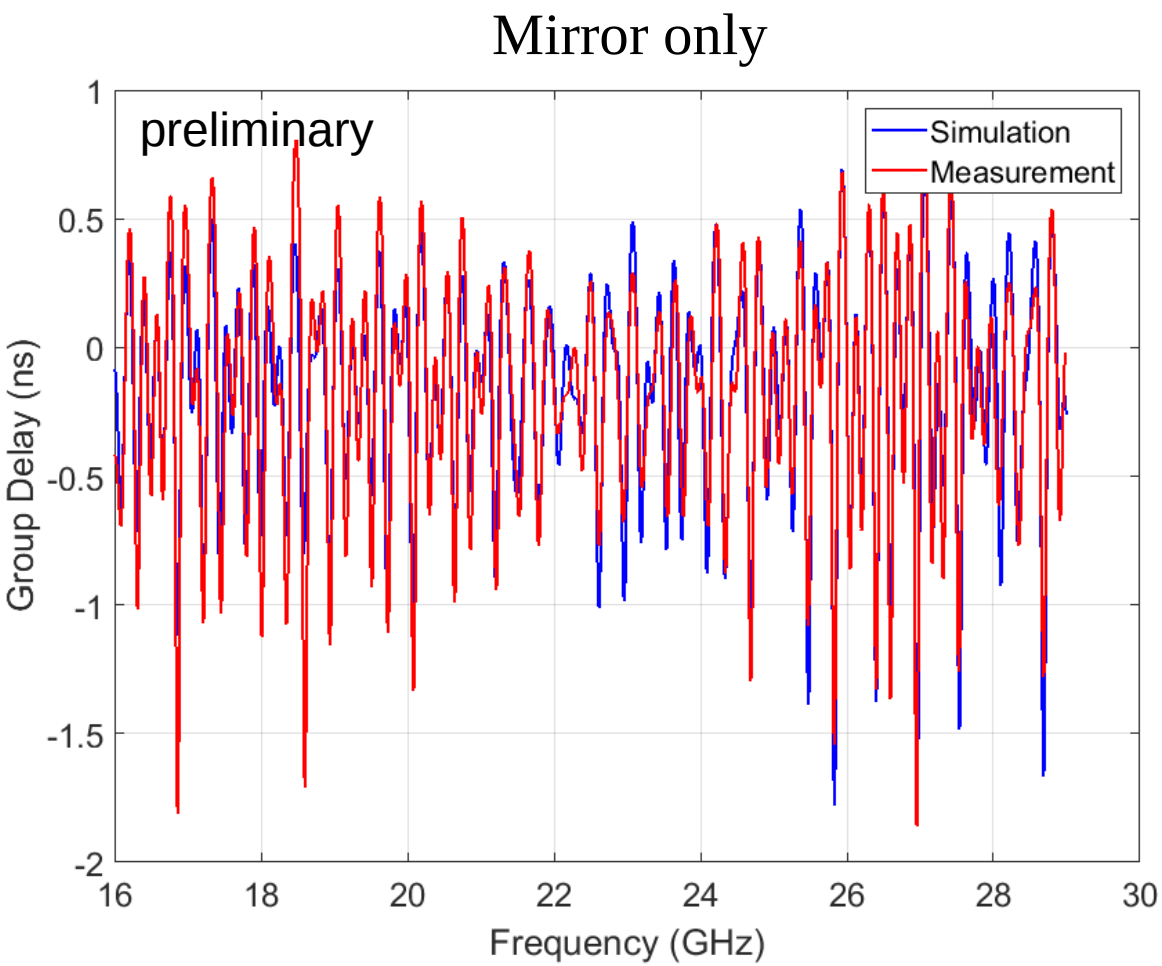


Simulation



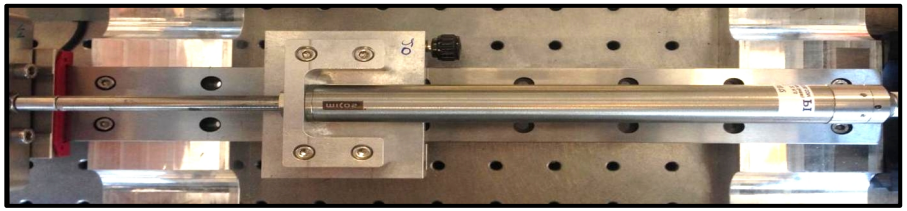
Mirror only

Reflections

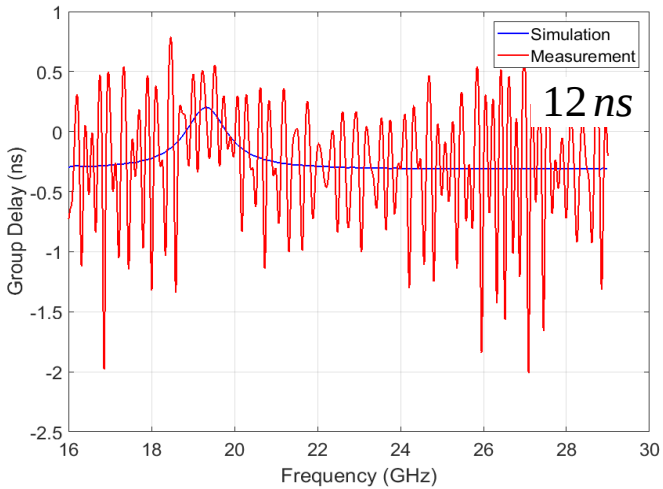


- Simulation reproduces group delay reasonably well
- Uncertain behavior for many discs

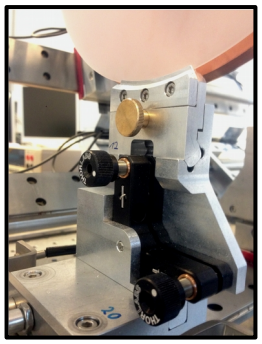
Conclusion and Outlook



- Mechanical precision of µm

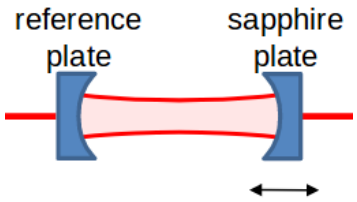


- Reflections cause problems



- Effect of disc tilts
  → Automatic tilting

- Losses



- Absolute positioning
  → Interferometer