Searching for Short Distance Forces with the Mossbauer Effect

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arXiv:2010.03588

Short Distance Forces

Light bosonic particles motivated by BSM Physics
(e.g. radions, moduli, relaxions)

$$\mathcal{L} \supset y_q \phi \bar{q} q + \frac{\phi}{f_\gamma} F_{\mu\nu}^2 + \frac{\phi}{f_g} G_{\mu\nu}^2 + \frac{\tilde{h}_{\mu\nu}}{f_T} F^{\mu}{}_{\sigma} F^{\nu\sigma} + g\phi h^2 + \frac{m_\phi^2}{2}\phi^2$$

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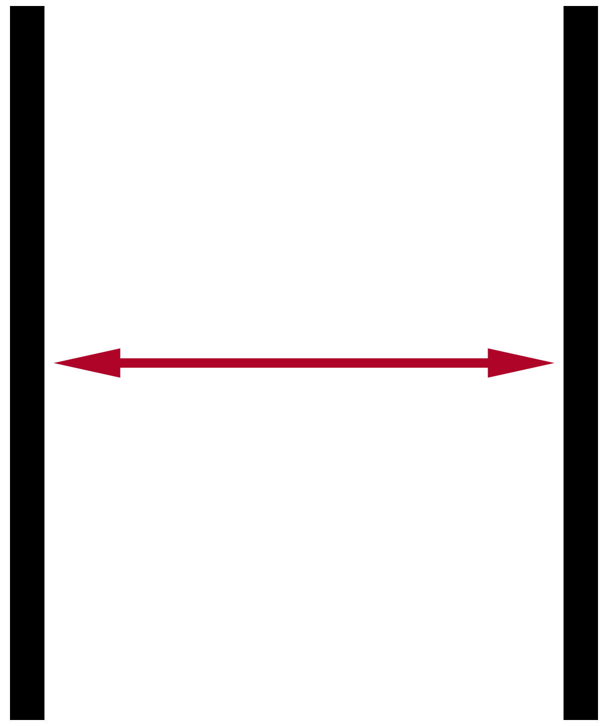
Take two objects, measure anomalous forces between them



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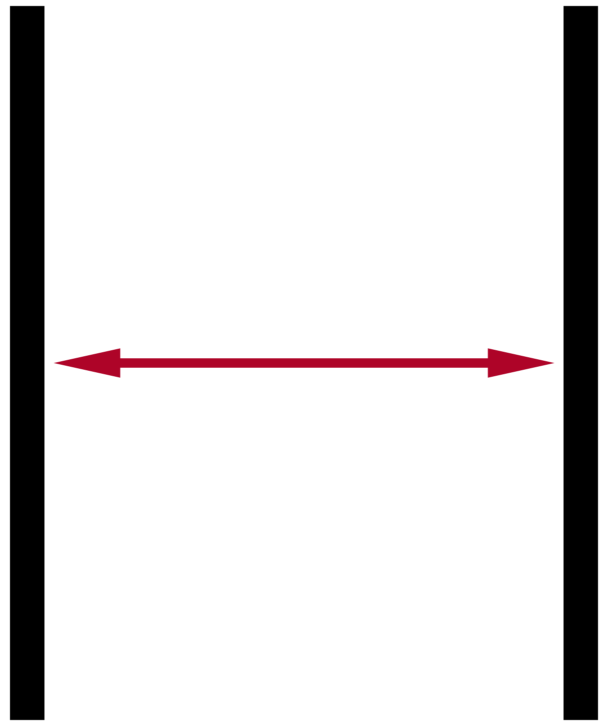

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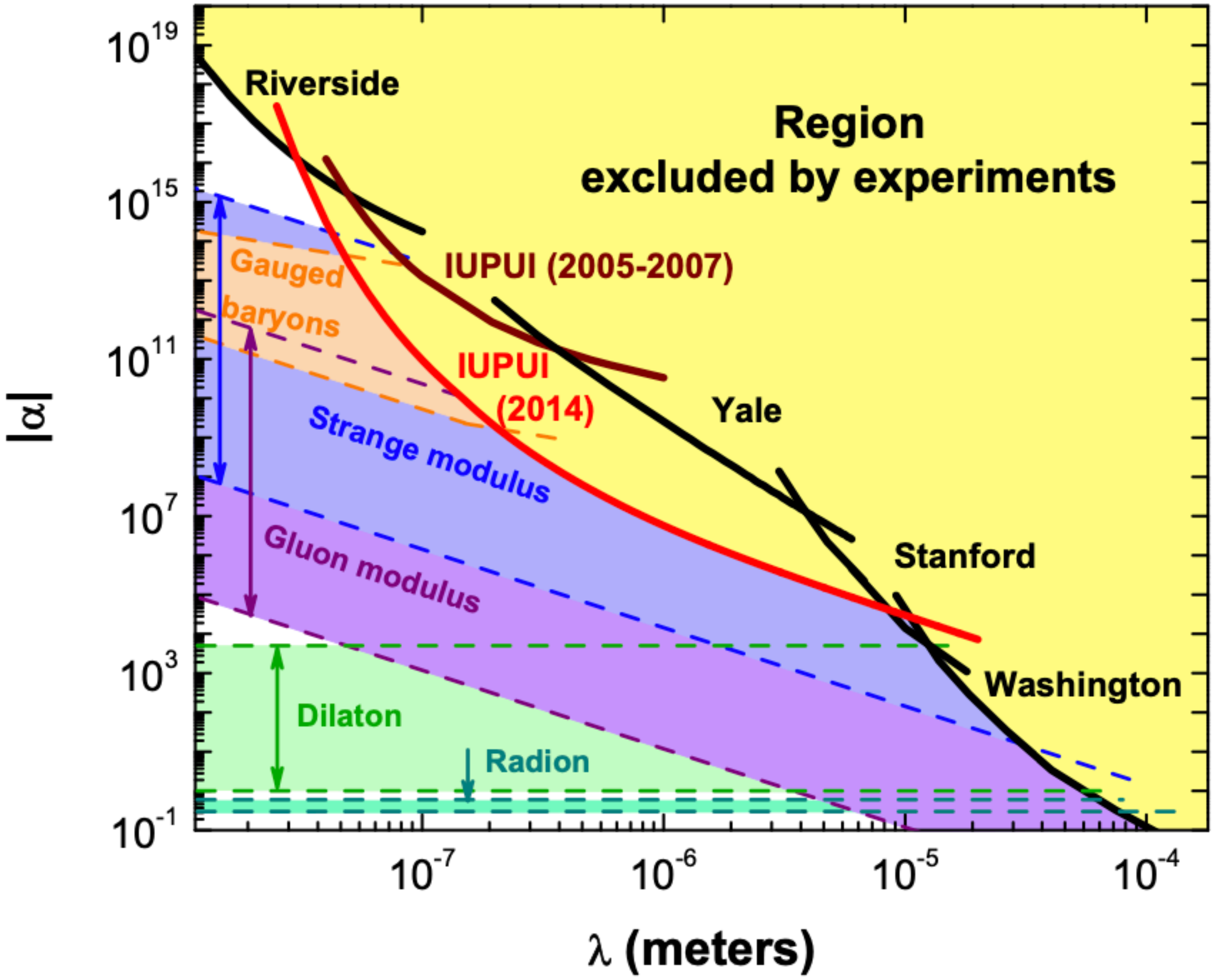
Measure Relative Acceleration

Where are we?



Very strong constraints at long (> μm) distances

Sensitivity rapidly drops at short (< μm) distances

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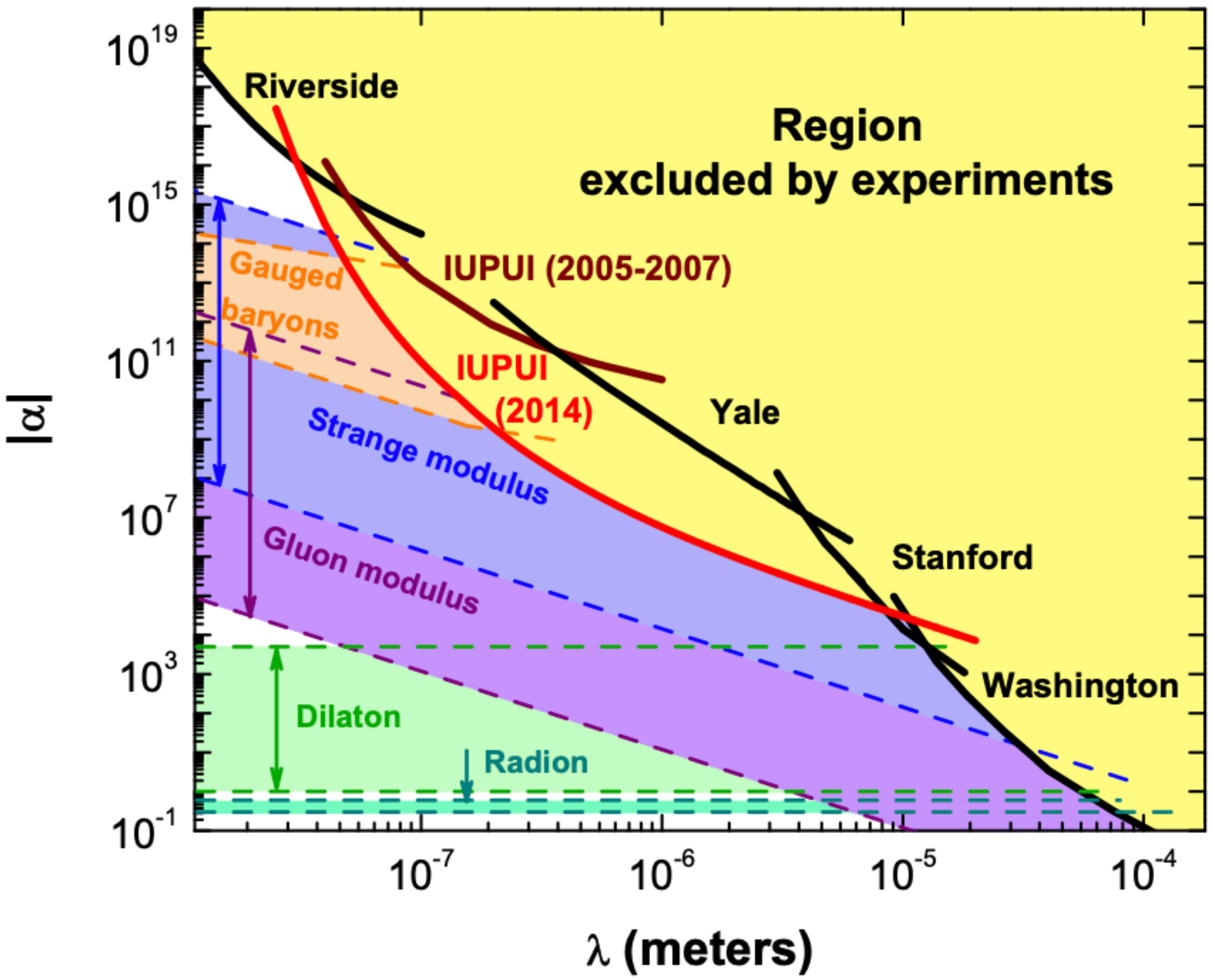

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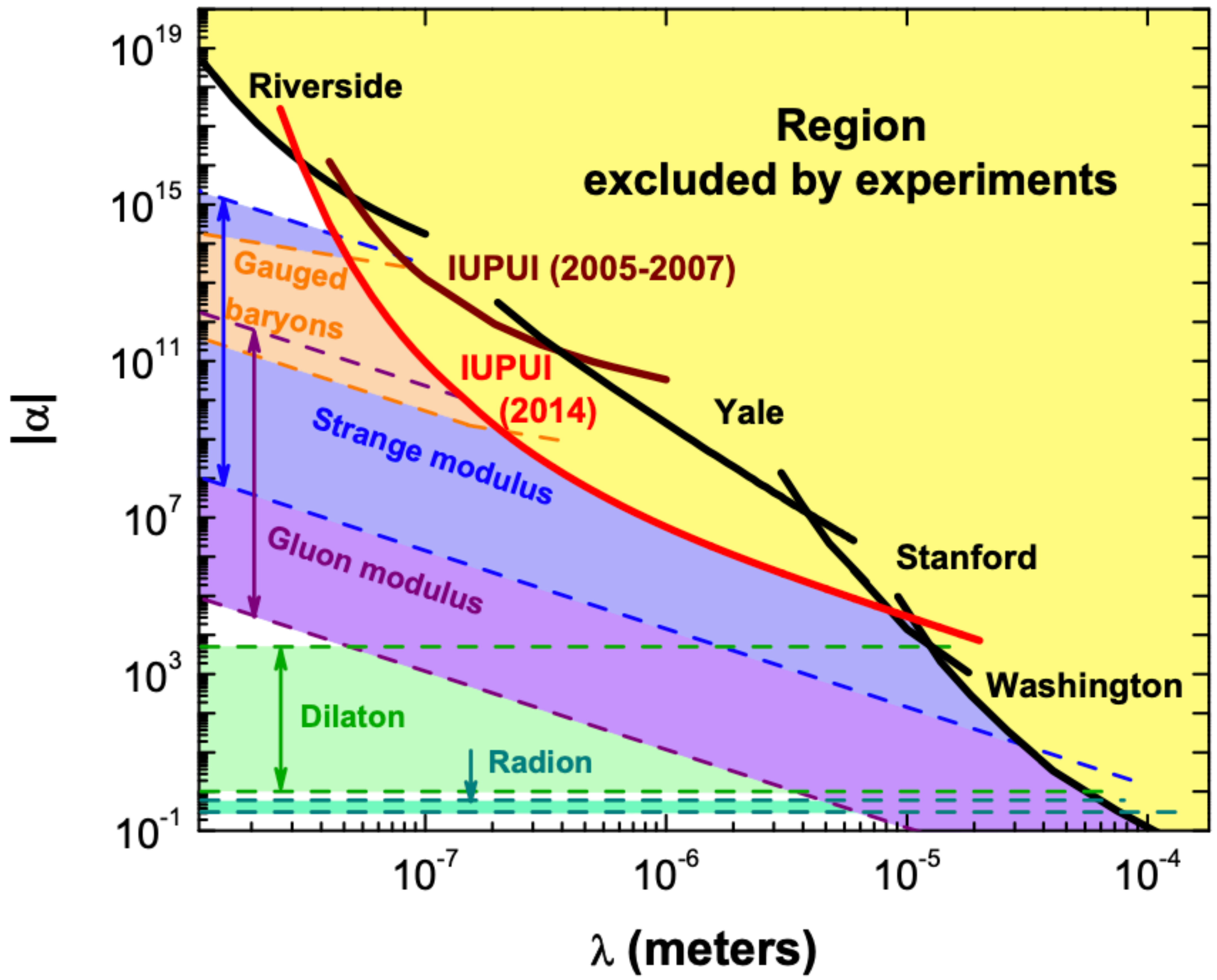

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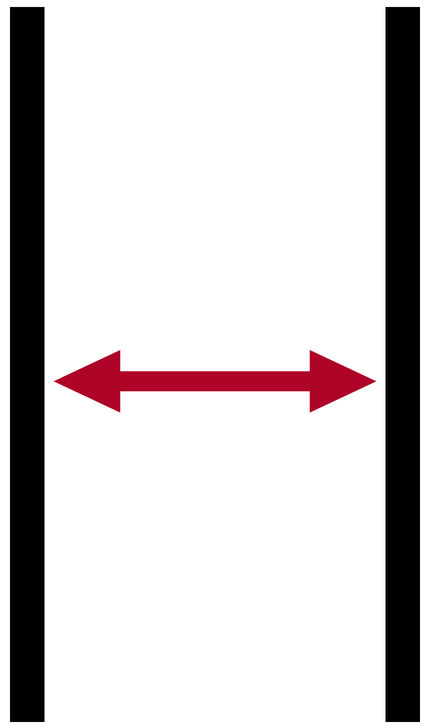

Short Range => Objects need to be close

Electromagnetism >> New Physics

Short Range => Only material within λ affected

Need to deal with thin objects with high precision

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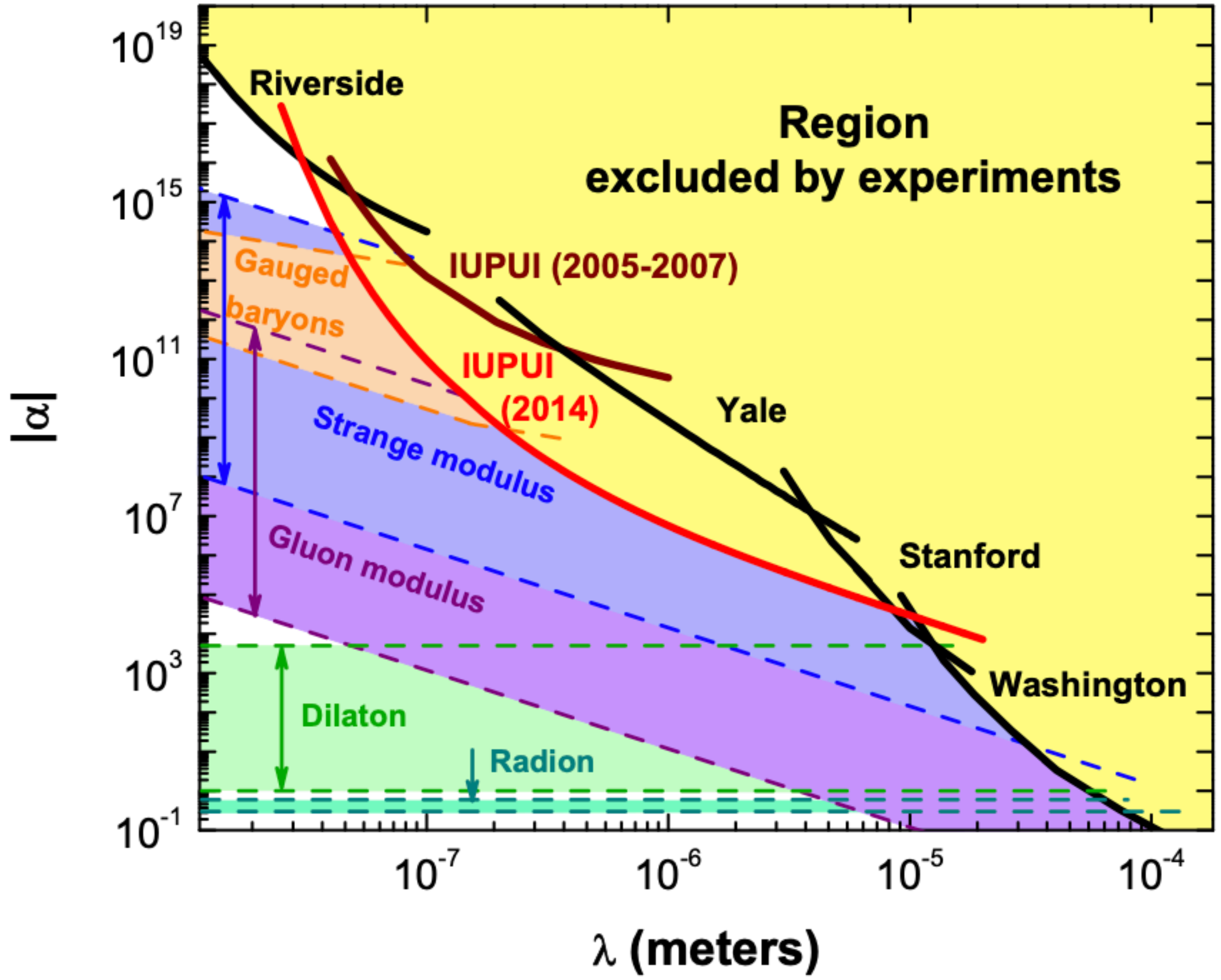

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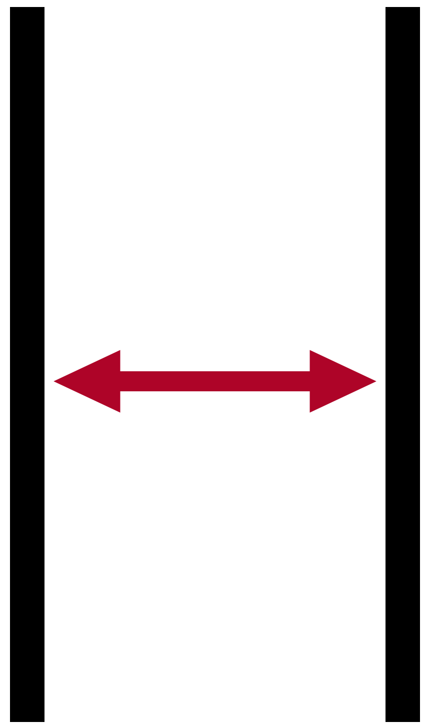

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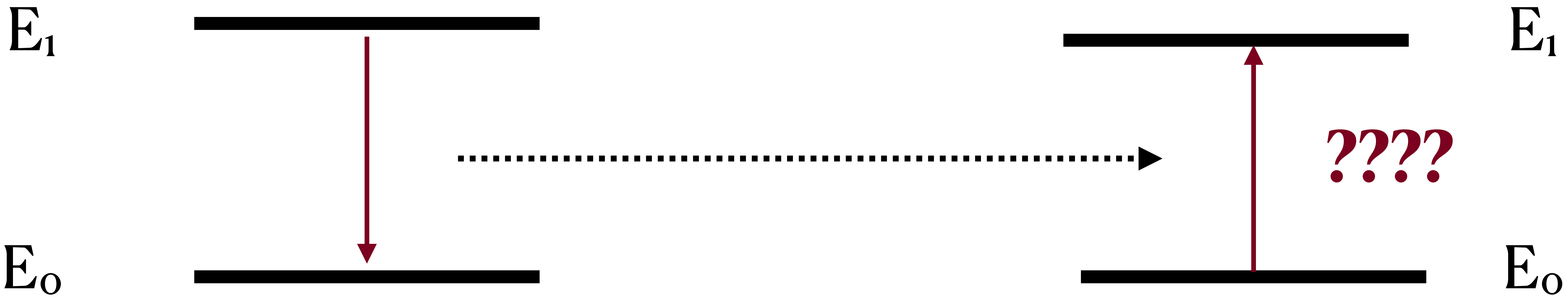
Progress?

Outline

1. Mossbauer Effect
2. Setup
3. Backgrounds
4. Sensitivity
5. Synchrotron Light Sources?
6. Conclusions

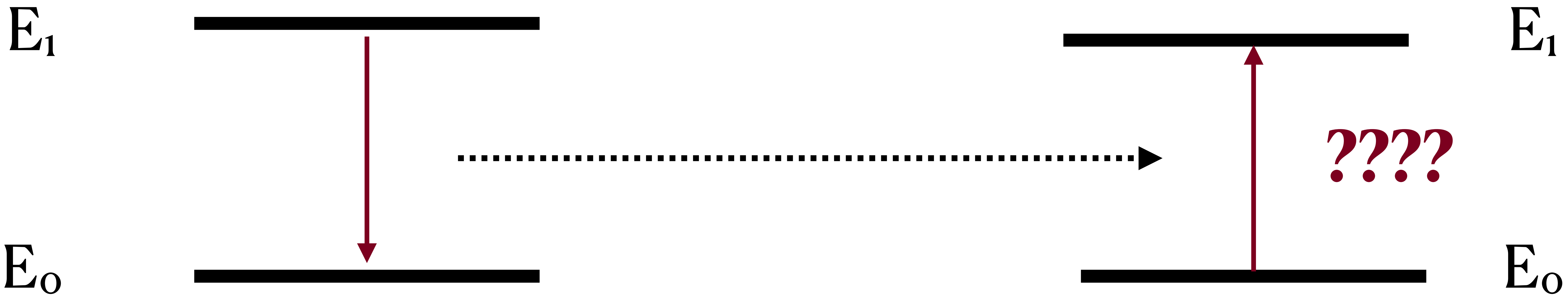
Mossbauer Effect



Excited nuclear state decays via γ emission

Can the γ be reabsorbed?

Mossbauer Effect



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Efficient reabsorption only possible on resonance

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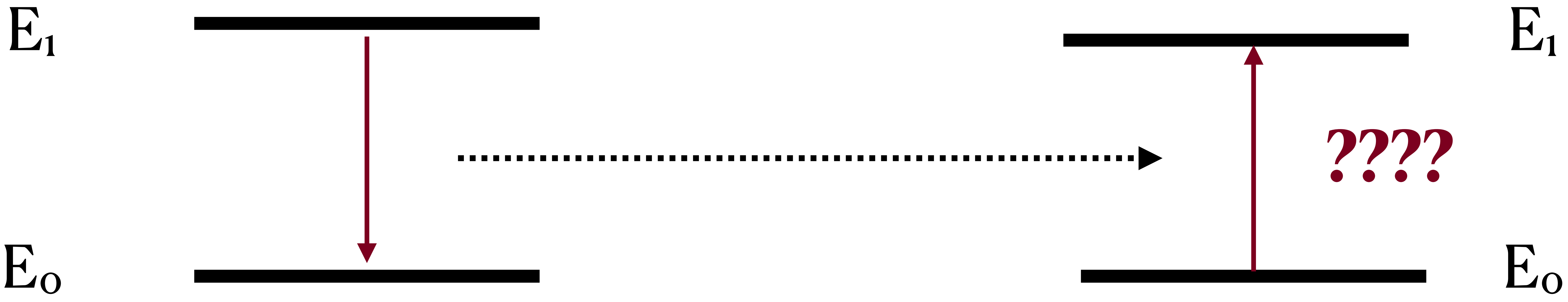

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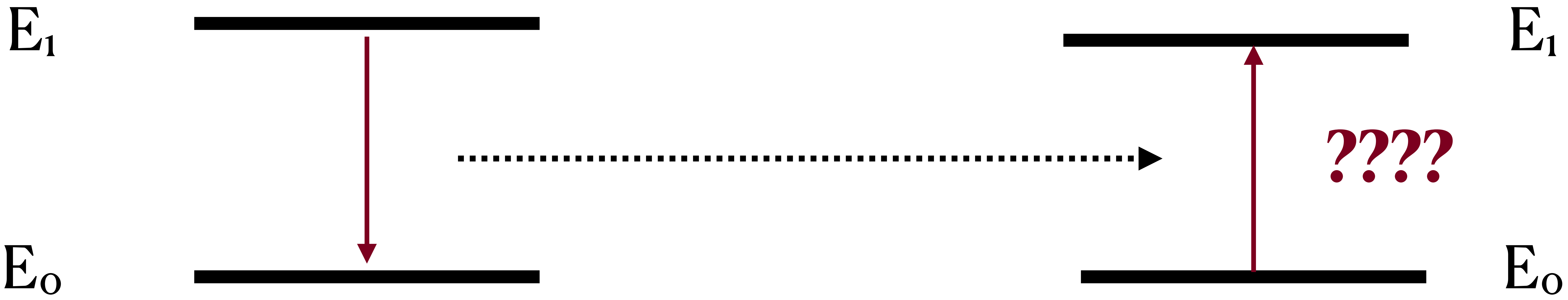

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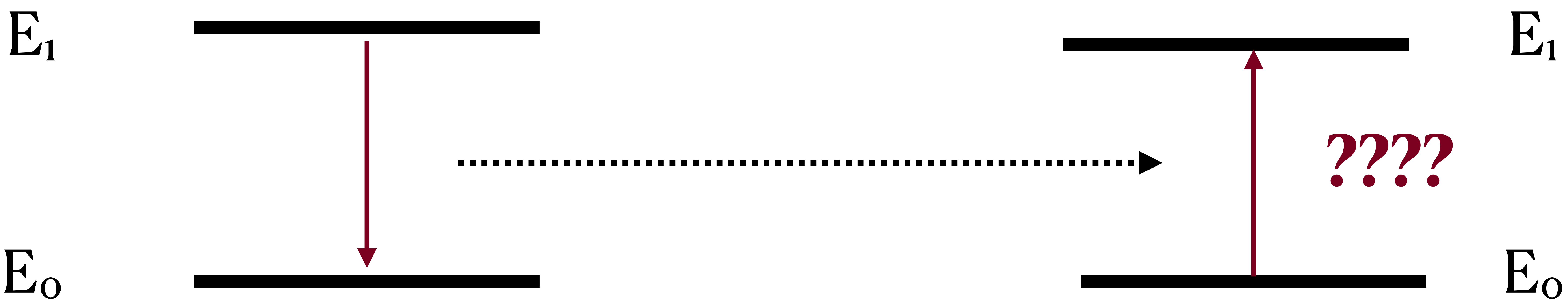
No : Recoiling nucleus takes energy, γ outside narrow width

Mossbauer Effect



E_1

E_0

????

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Small enough E_γ, entire lattice recoils!

Negligible lattice kinetic energy - monochromatic E_γ

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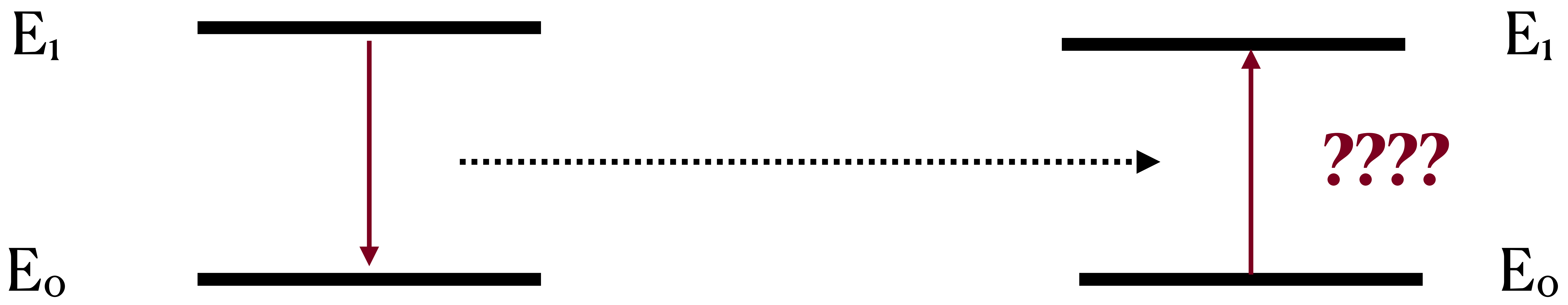

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Narrow Nuclear Lines => High Sensitivity to energy shifts

Setup

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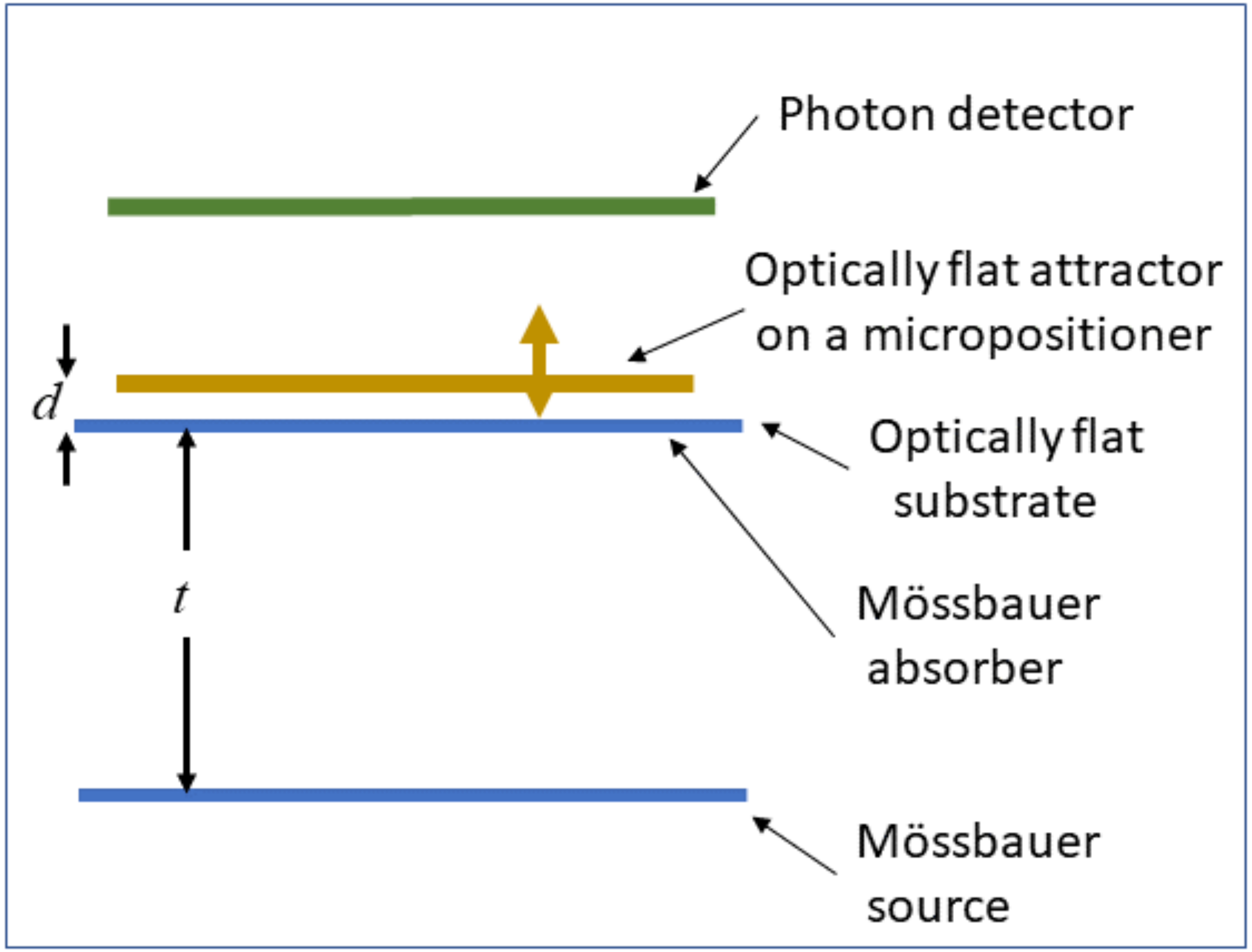

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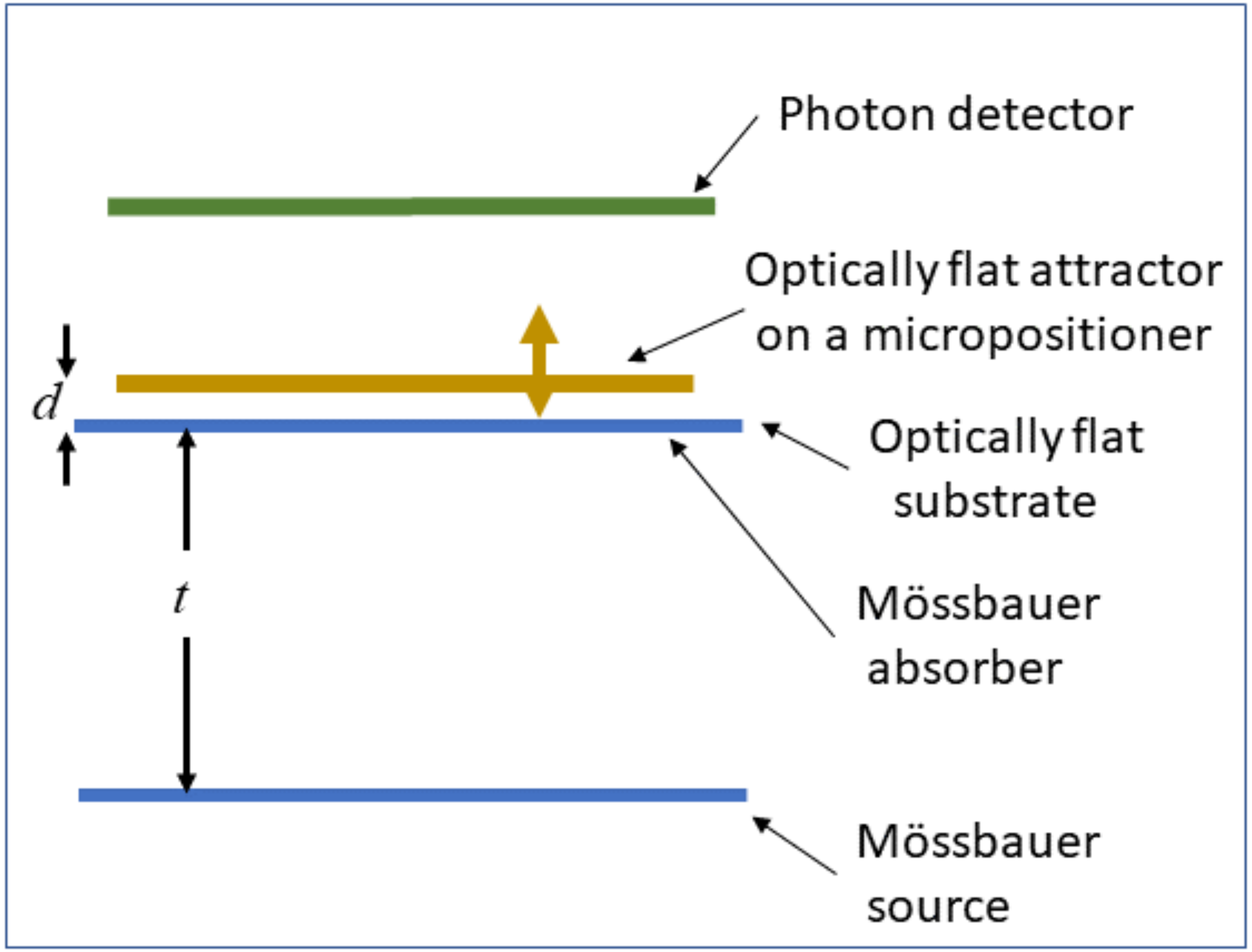

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Resonant Reabsorption as a function of d

Backgrounds

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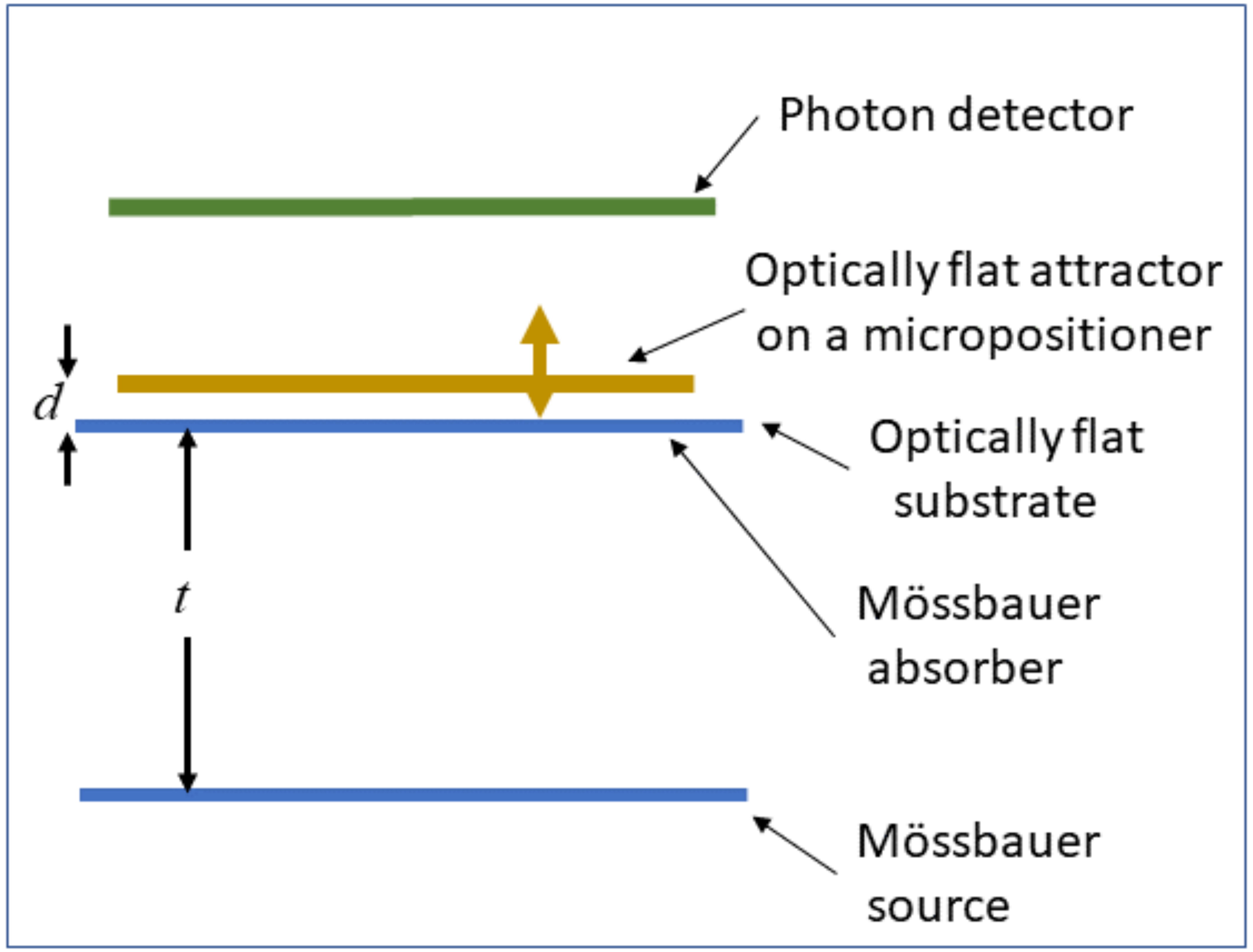
Electromagnetism?

Needs to change nuclear transition energies

Suppressed by small nuclear moments, electron shielding



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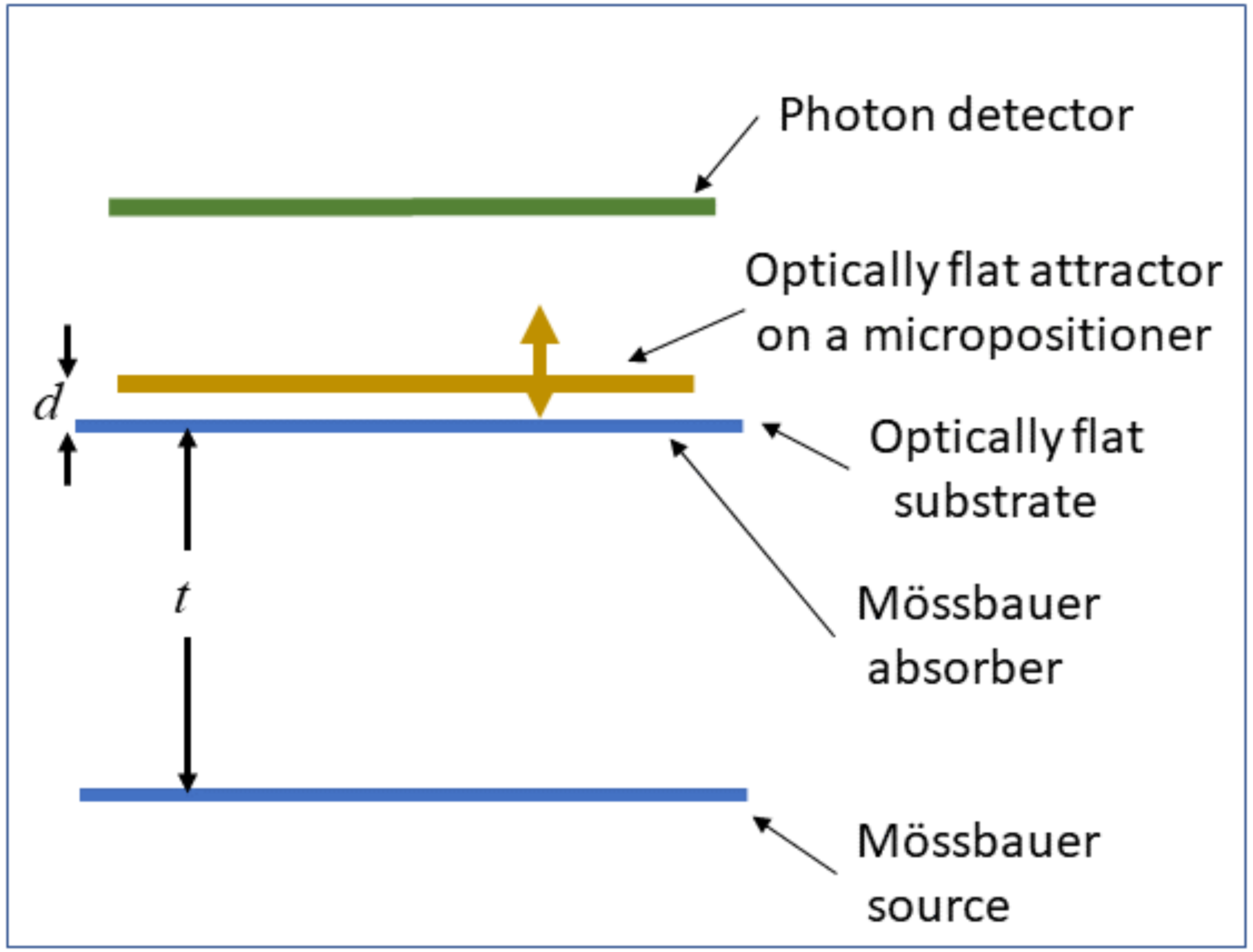

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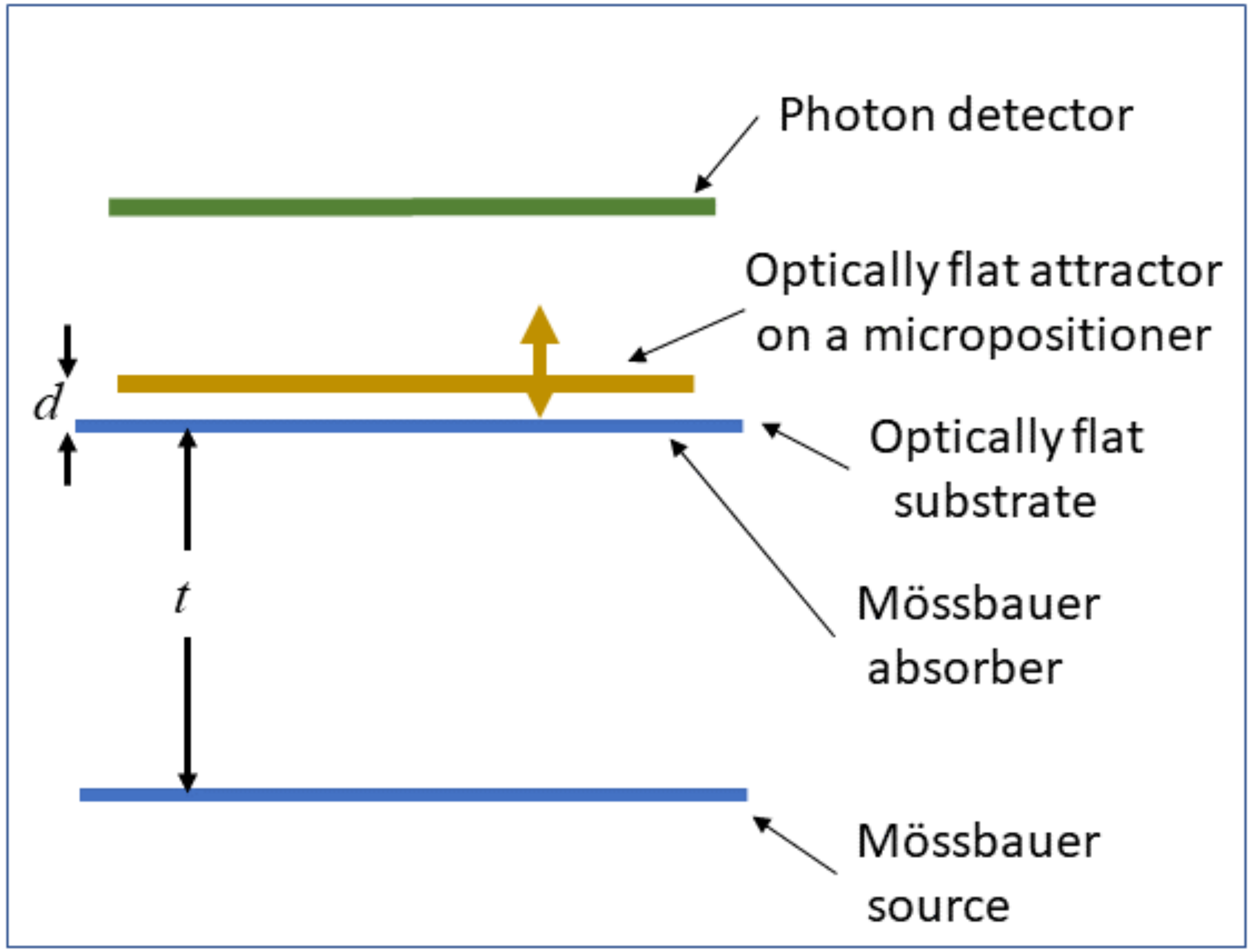

First order effects irrelevant

Leading Background: Chemical Shift from Casimir

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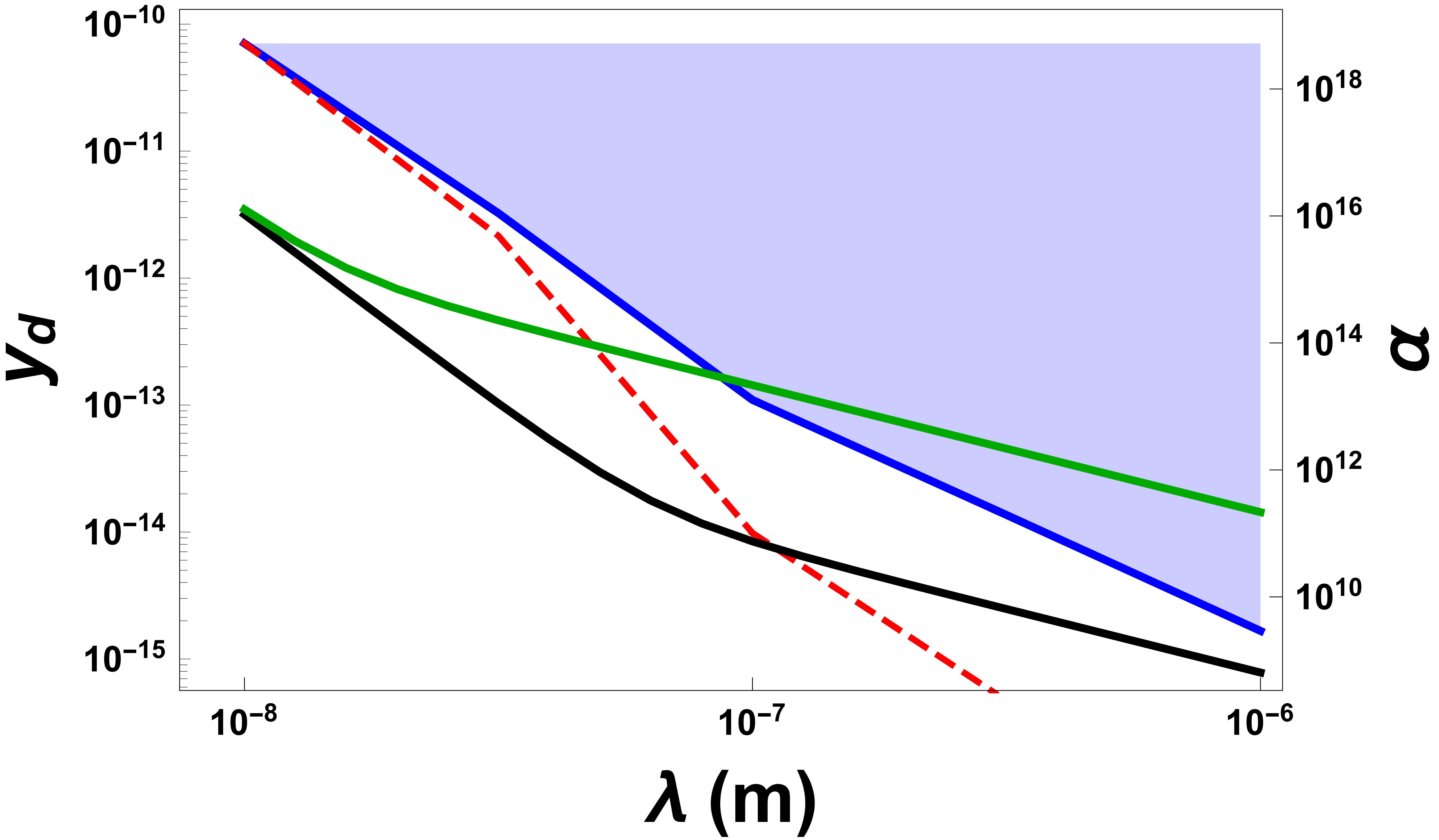
$$N_\gamma = 3 \times 10^{14}$$



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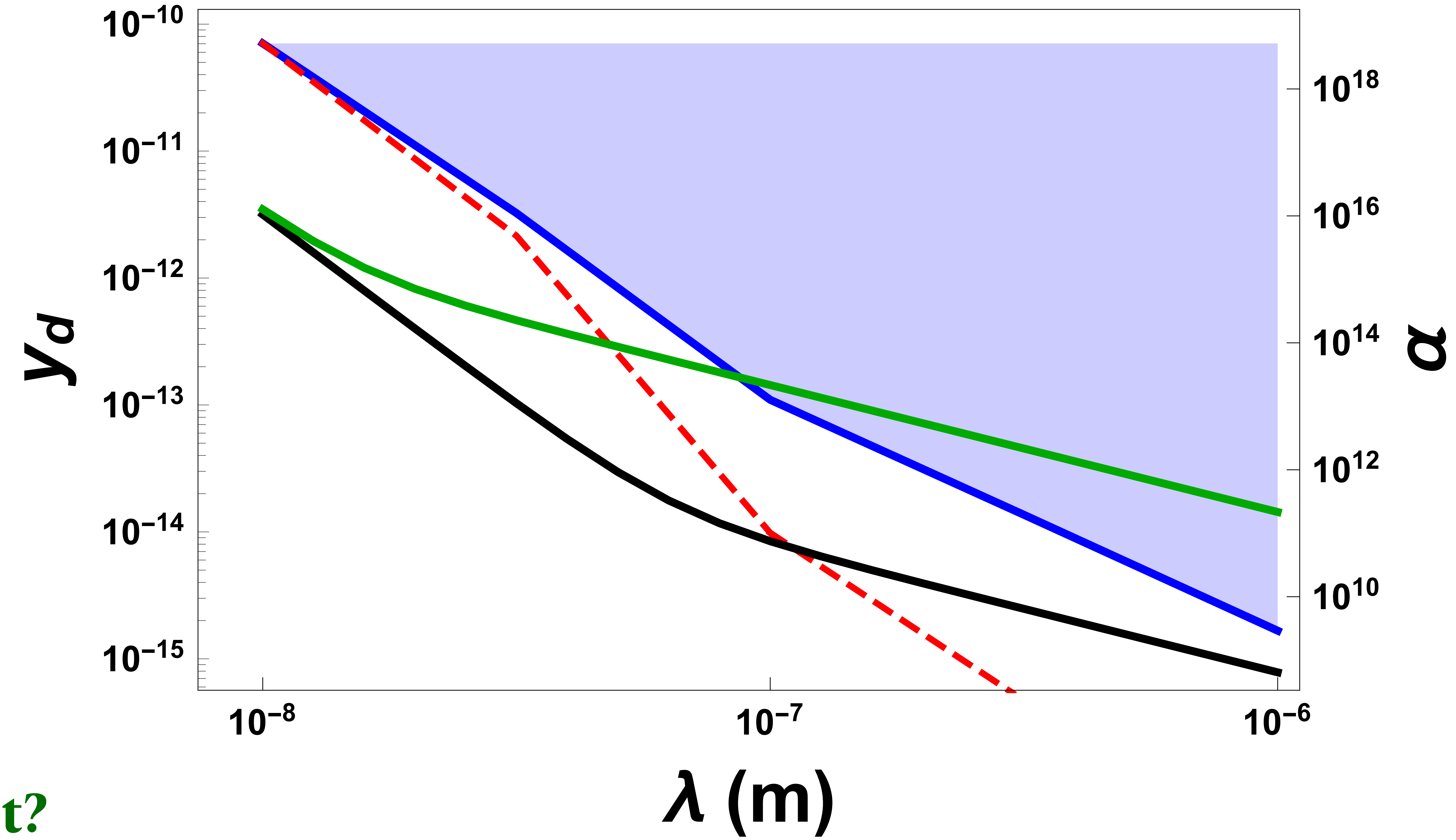
Second Order Casimir Background at shortest distances



Mitigate using differential measurement?

Mossbauer at Synchrotron Source

Synchrotron Light

Ground State Nucleus

Mossbauer at Synchrotron Source

Synchrotron Light

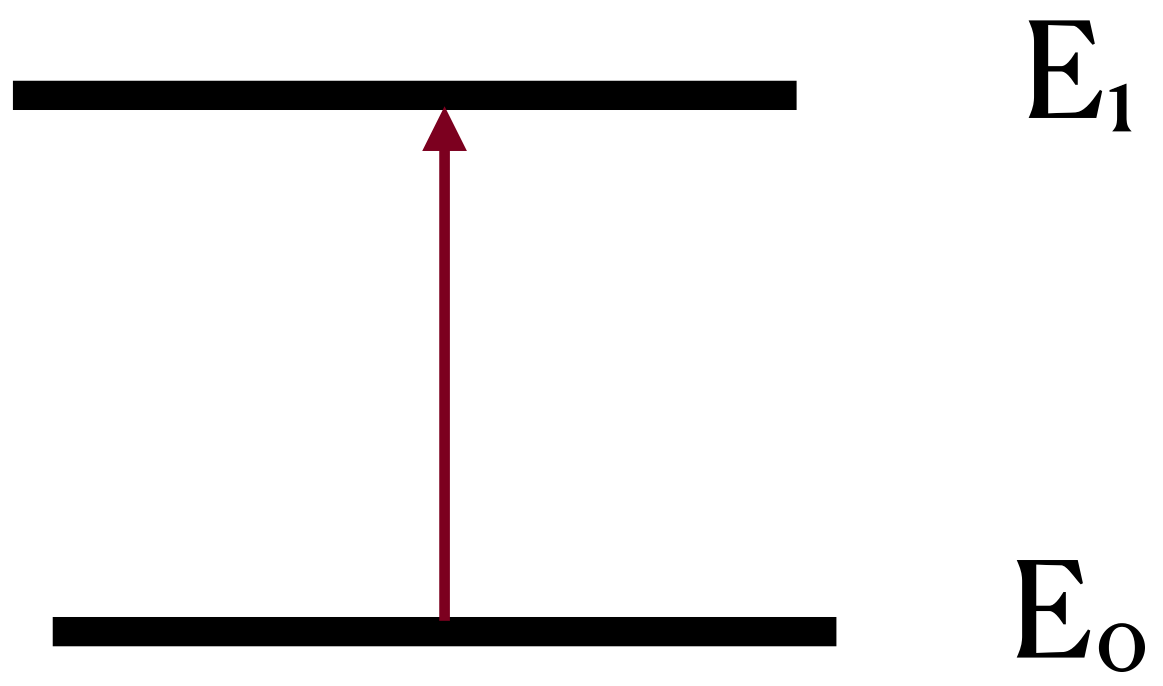
Ground State Nucleus

All the nuclei are coherently driven to excited state

Mossbauer at Synchrotron Source

Synchrotron
Light

Ground State
Nucleus



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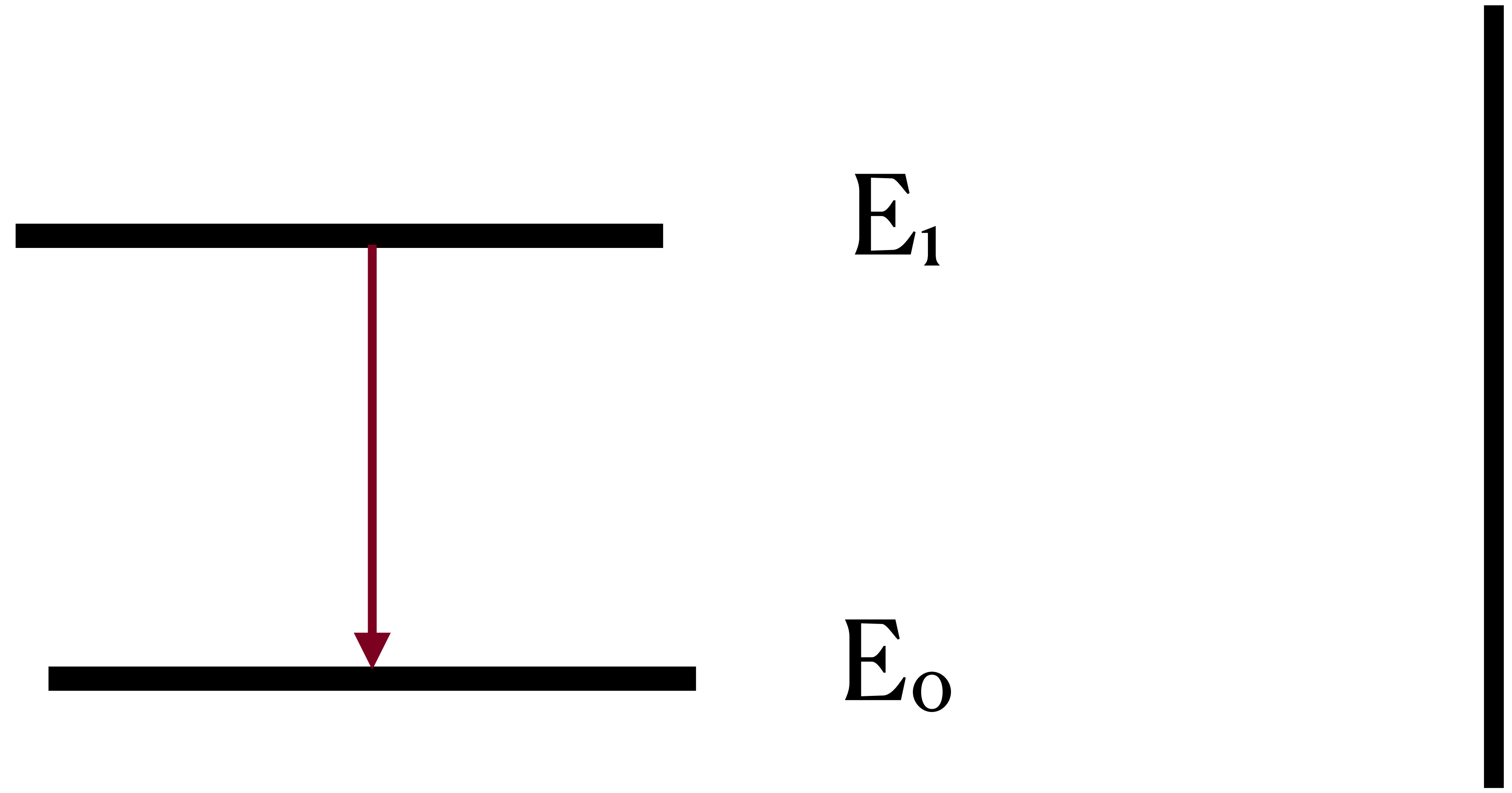
Short Pulse << Lifetime of State

Mossbauer at Synchrotron Source

Well after pulse, state starts to decay

Coherent initial excitation => decays in phase

Decay along forward direction amplified by in phase addition



In phase decay

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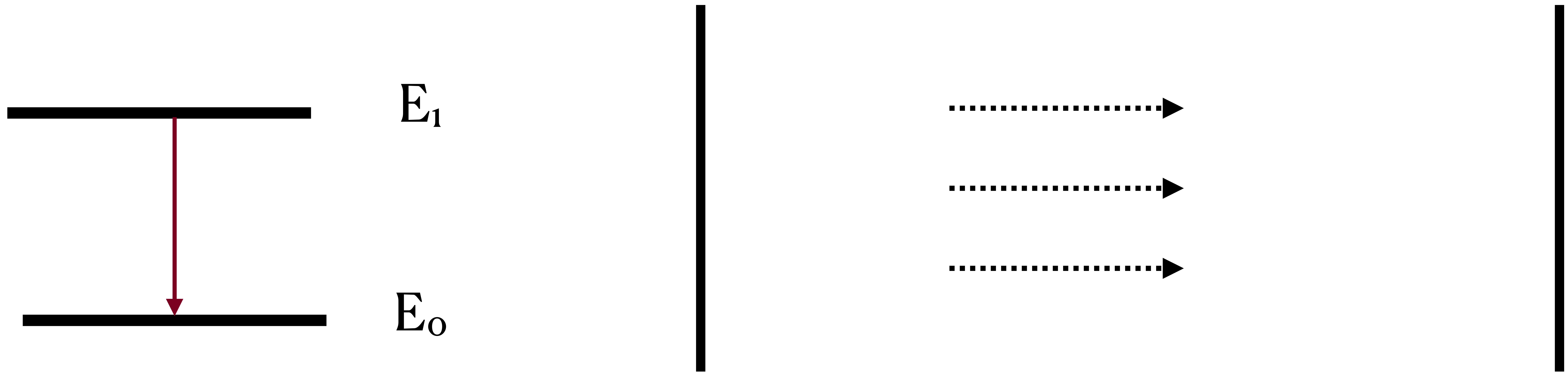


In phase decay

Excited State

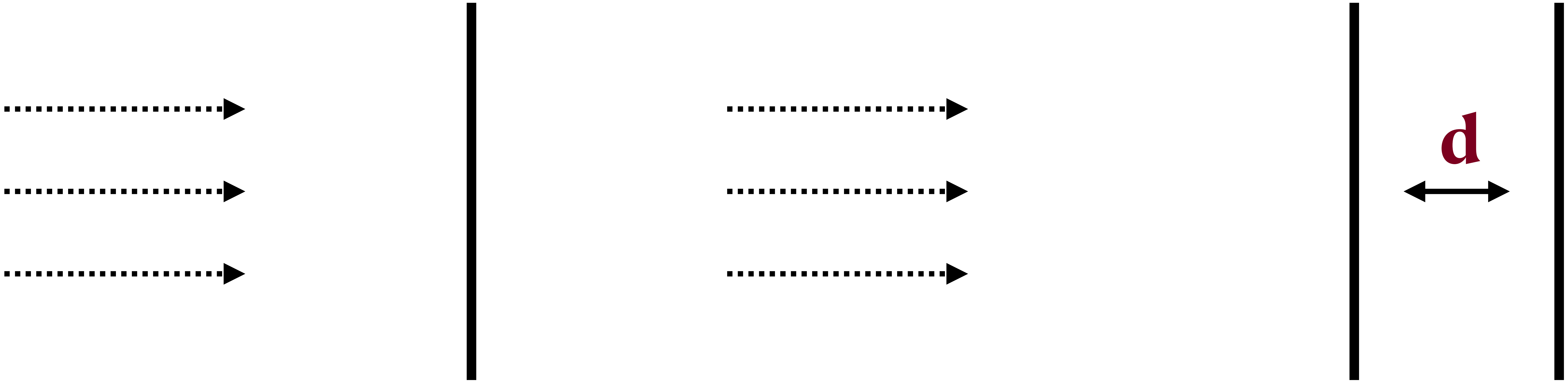
Collimated decay Beam

Resonantly Excite absorber

Mossbauer at Synchrotron Source

Send Synchrotron Pulse

Mossbauer at Synchrotron Source

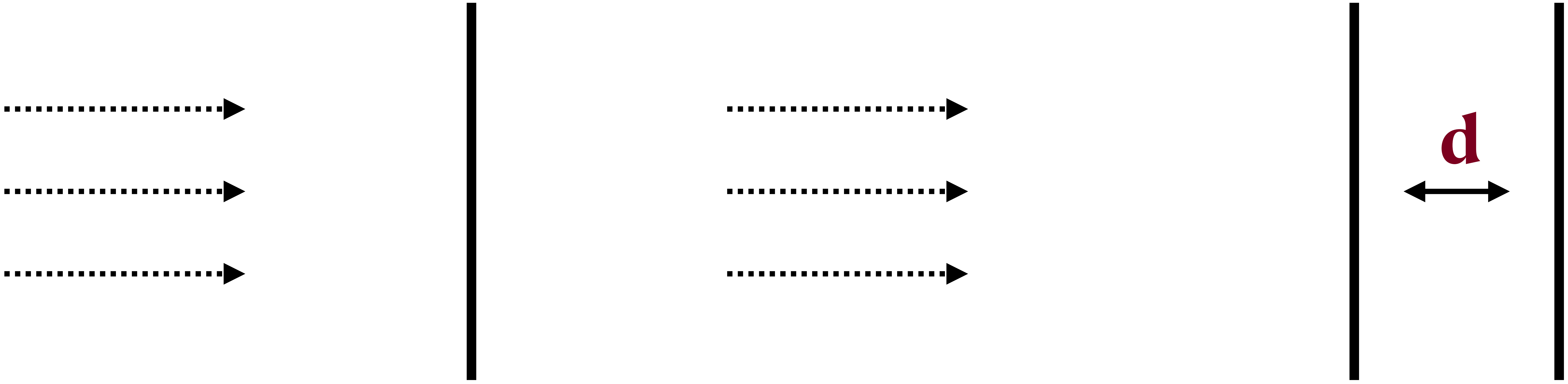


Send Synchrotron Pulse

Well after pulse, collimated emission

Measure resonant reabsorption as a function of d

Mossbauer at Synchrotron Source



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Why?

Clean excitation unlike radioactive decay

May enable new class of ultra narrow Mossbauer

Conclusions

1. Mossbauer Effect seems well suited to probe short distance forces

2. Natural electromagnetic background suppression

3. Ideal for scalar and tensor forces

4. Synchrotron light sources may enable new Mossbauer sources