

Searching for Short Distance Forces with the Mossbauer Effect

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The Johns Hopkins University**

**With David E. Kaplan and Giorgio Gratta,
[arXiv:2010.03588](https://arxiv.org/abs/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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How do we find them?

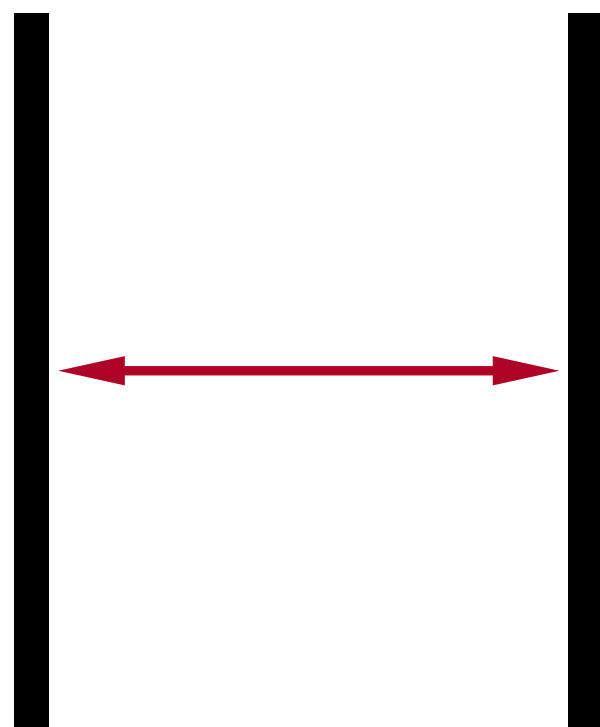
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Take two objects, measure anomalous forces between them



$$F = \alpha \frac{G m_p^2}{r^2} e^{-\frac{r}{\lambda}}$$

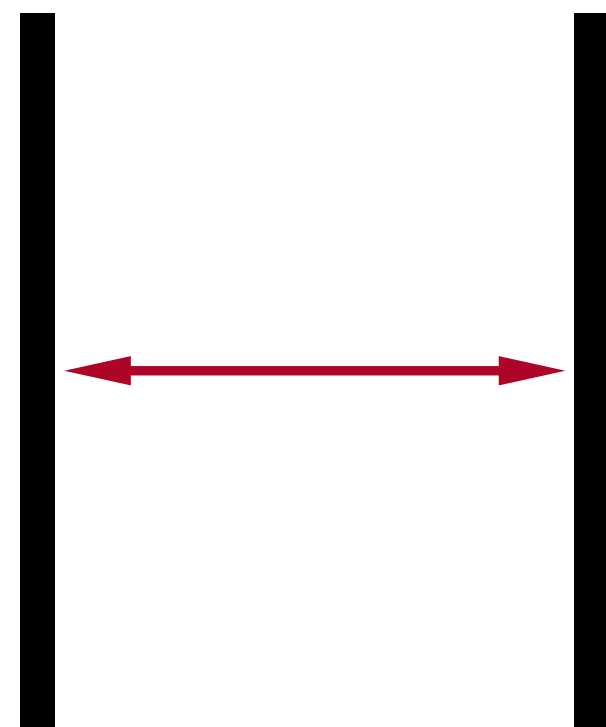
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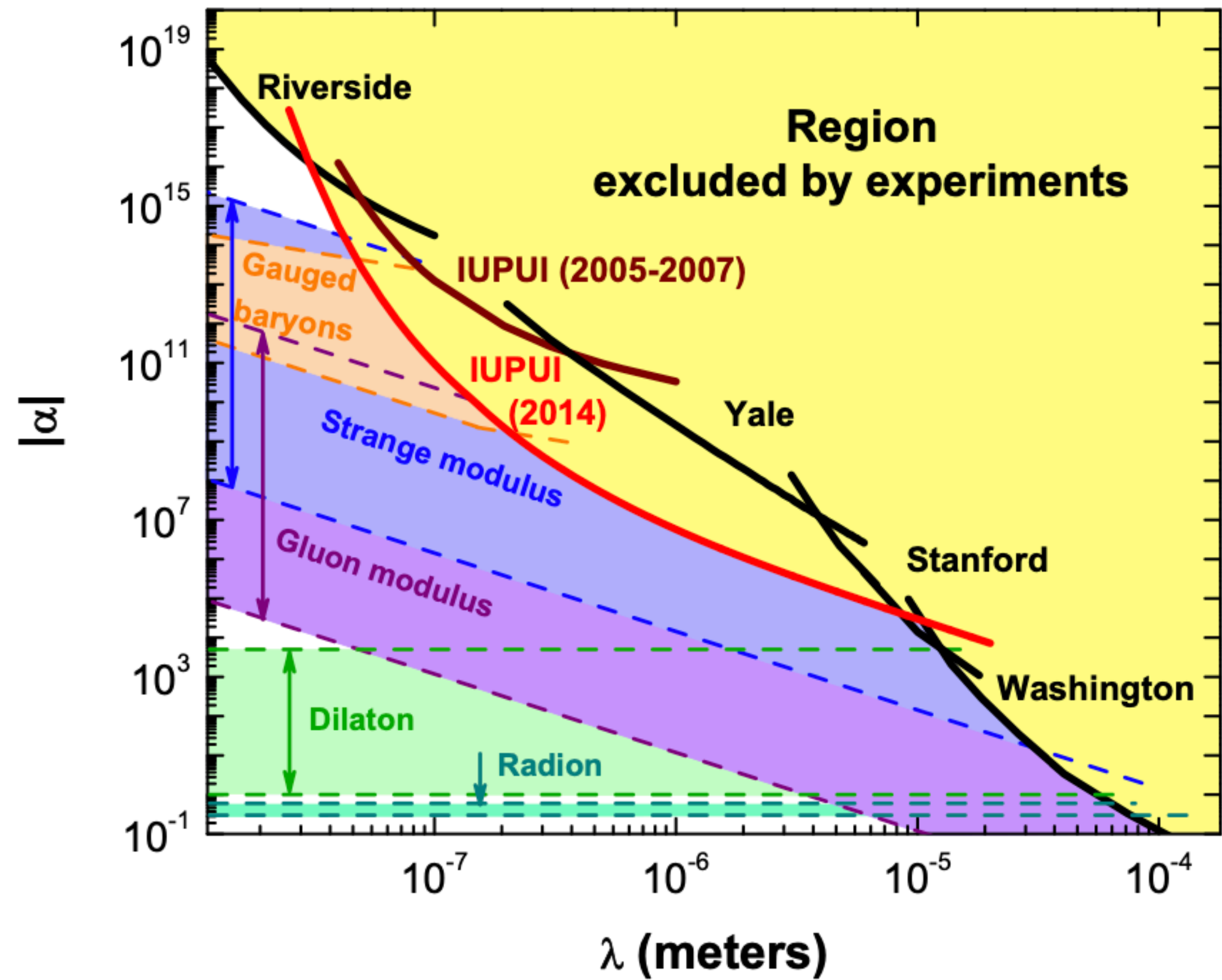
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Measure Relative Acceleration

Where are we?

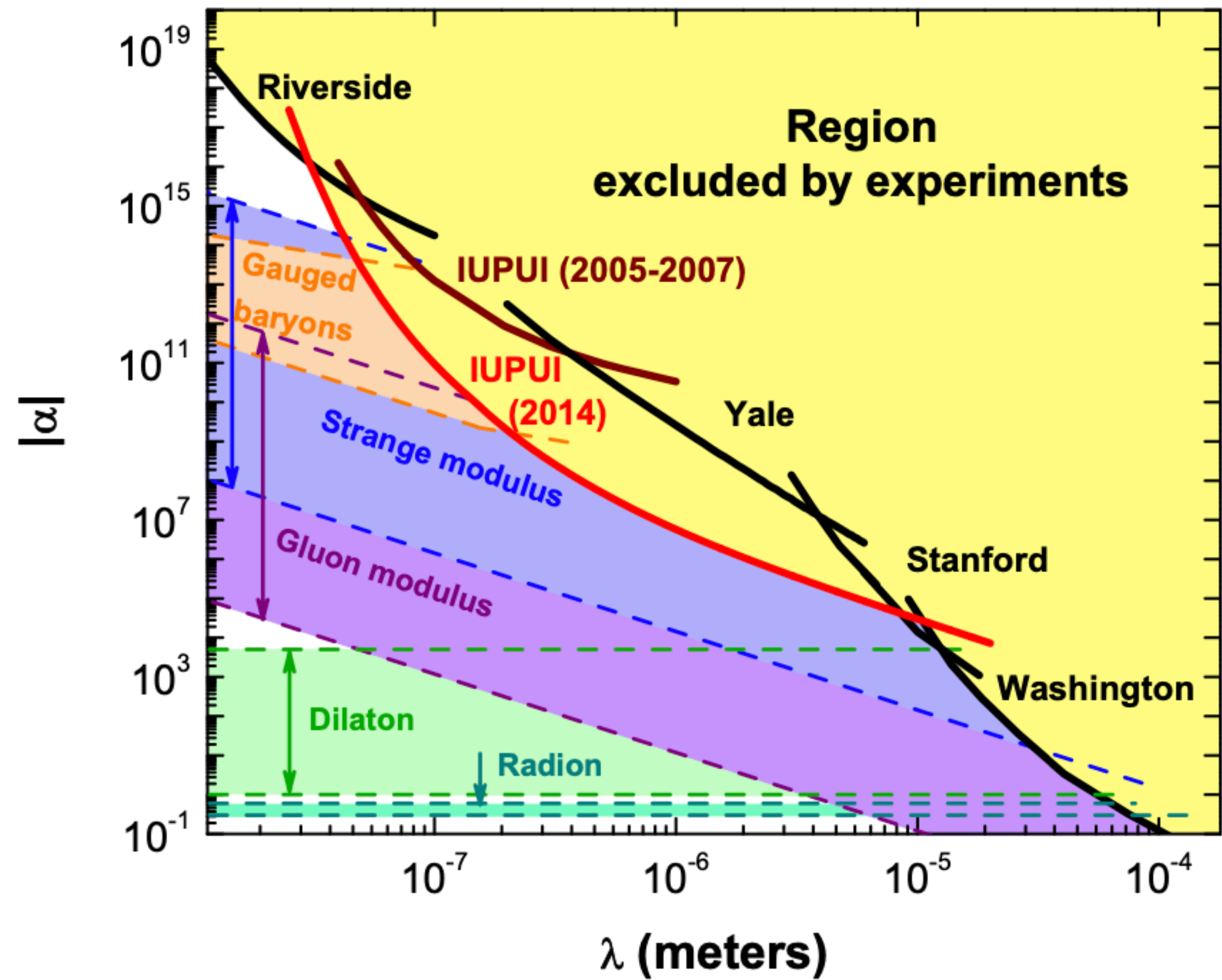


Very strong constraints at long ($> \mu\text{m}$) distances

Sensitivity rapidly drops at short ($< \mu\text{m}$) distances

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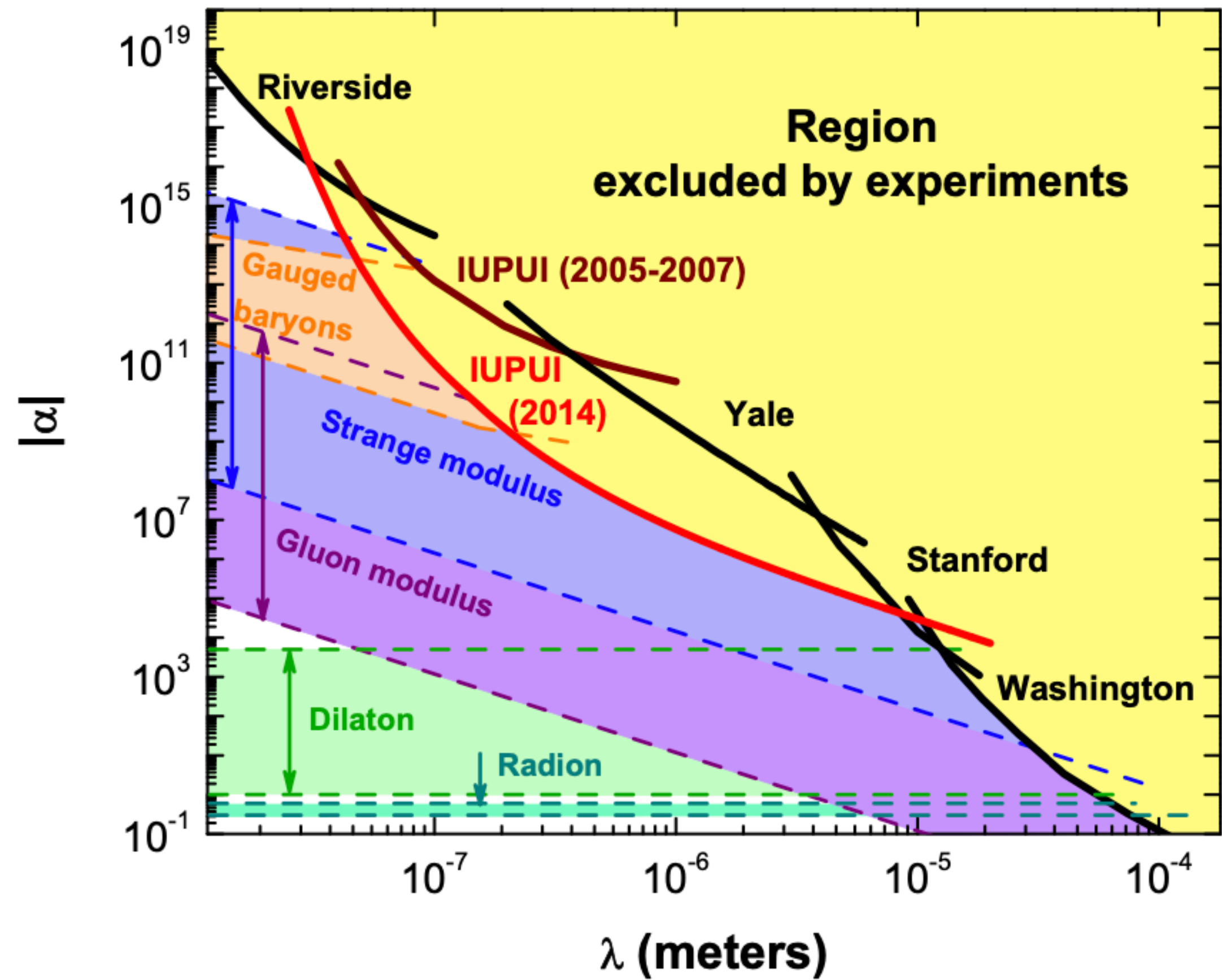


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Why?

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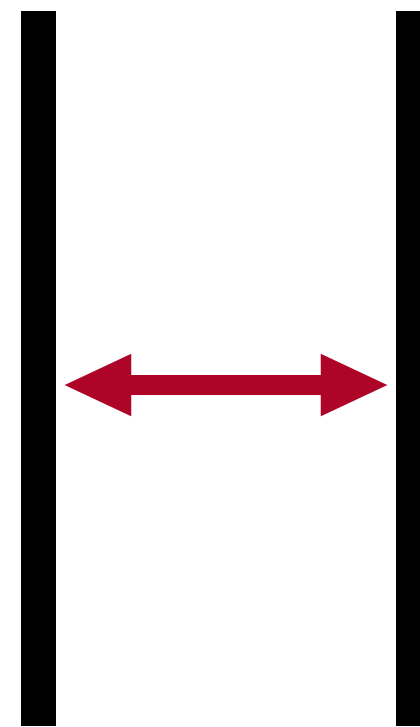
Why?

Short Range \Rightarrow Objects need to be close
Electromagnetism \gg New Physics

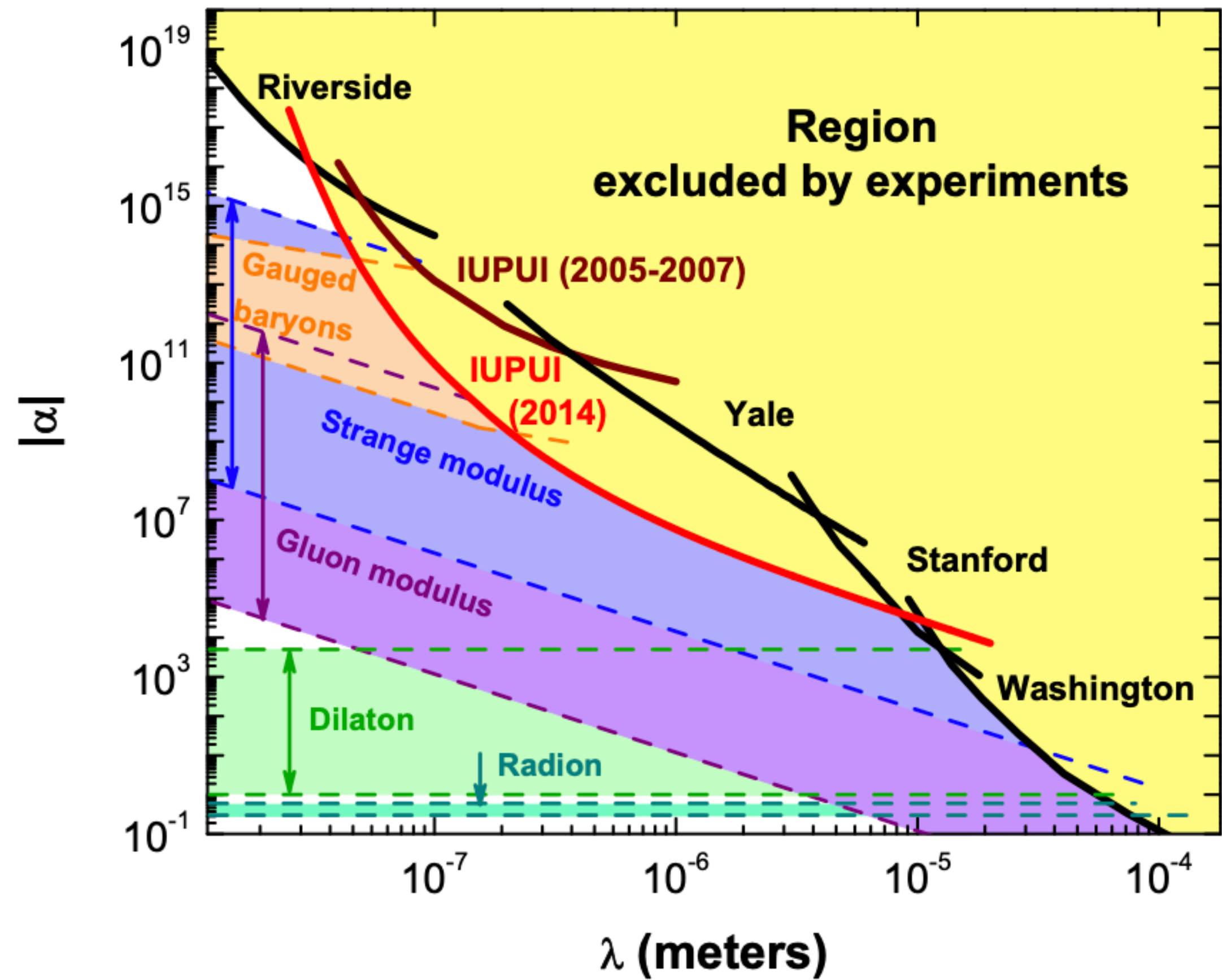
Short Range \Rightarrow Only material within λ affected

Need to deal with thin objects with high precision

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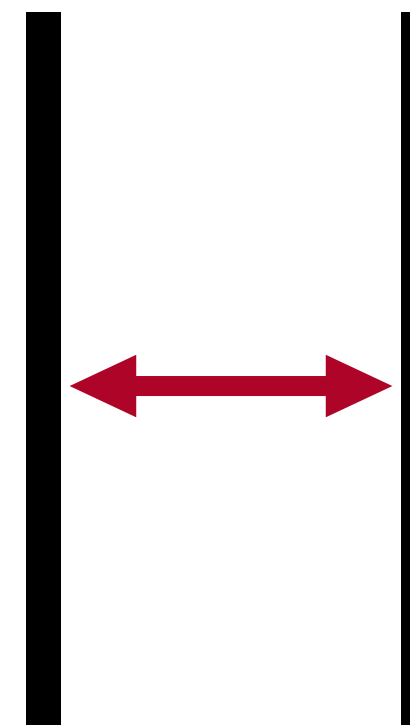
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Progress?

Outline

1. Mossbauer Effect

2. Setup

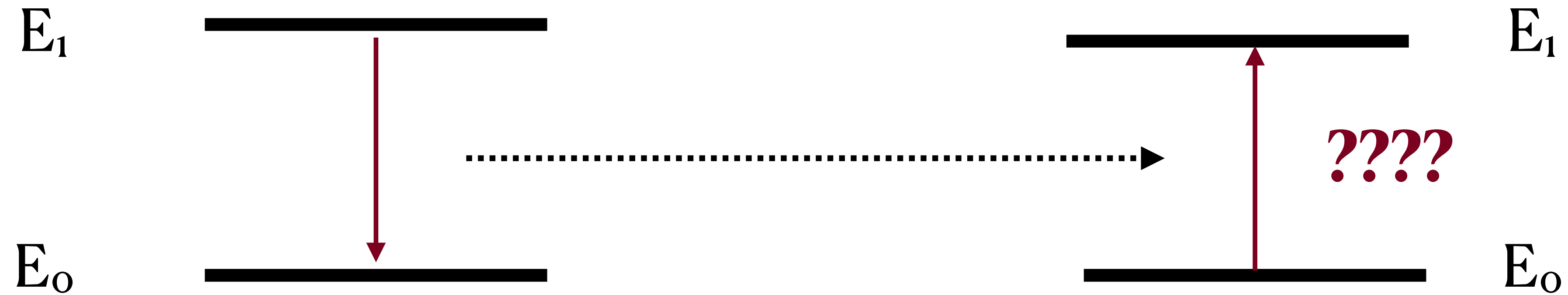
3. Backgrounds

4. Sensitivity

5. Synchrotron Light Sources?

6. Conclusions

Mossbauer Effect



Excited nuclear state decays via γ emission

Can the γ be reabsorbed?

Mossbauer Effect



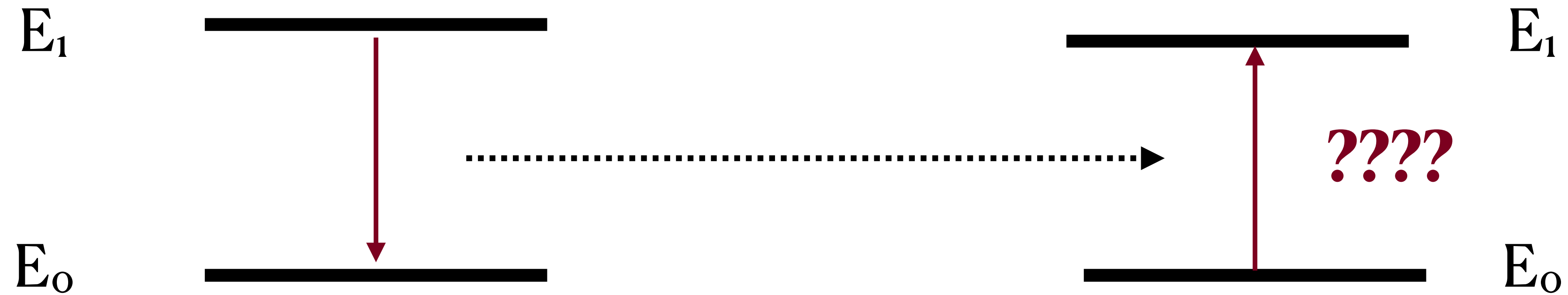
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Efficient reabsorption only possible on resonance

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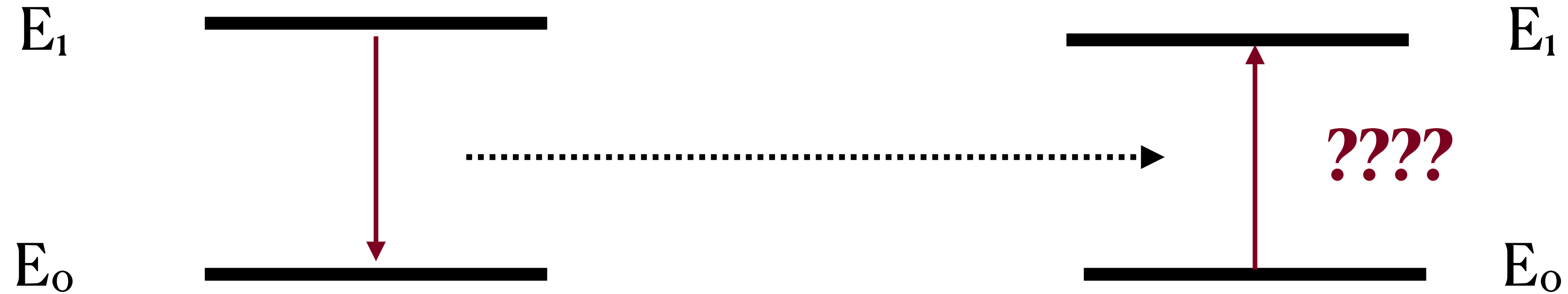
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No : Recoiling nucleus takes energy, γ outside narrow width

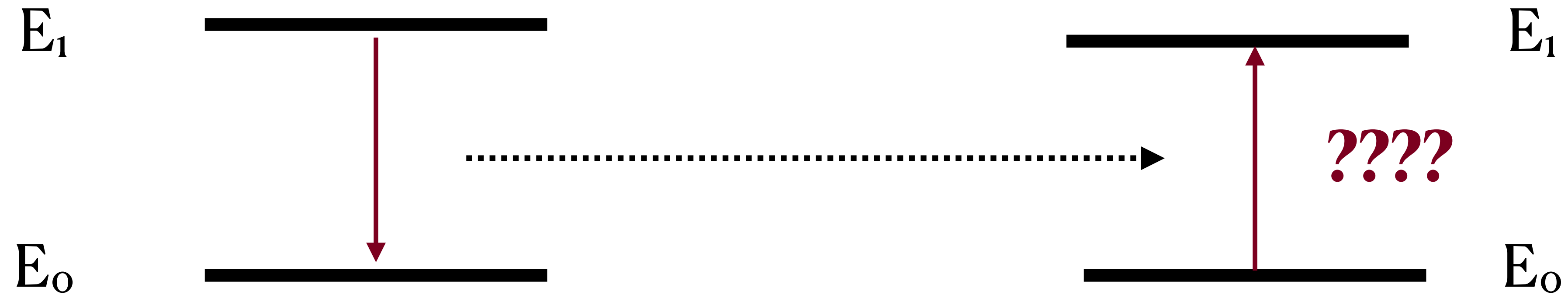
Mossbauer Effect



Small enough E_γ , entire lattice recoils!
Negligible lattice kinetic energy - monochromatic E_γ

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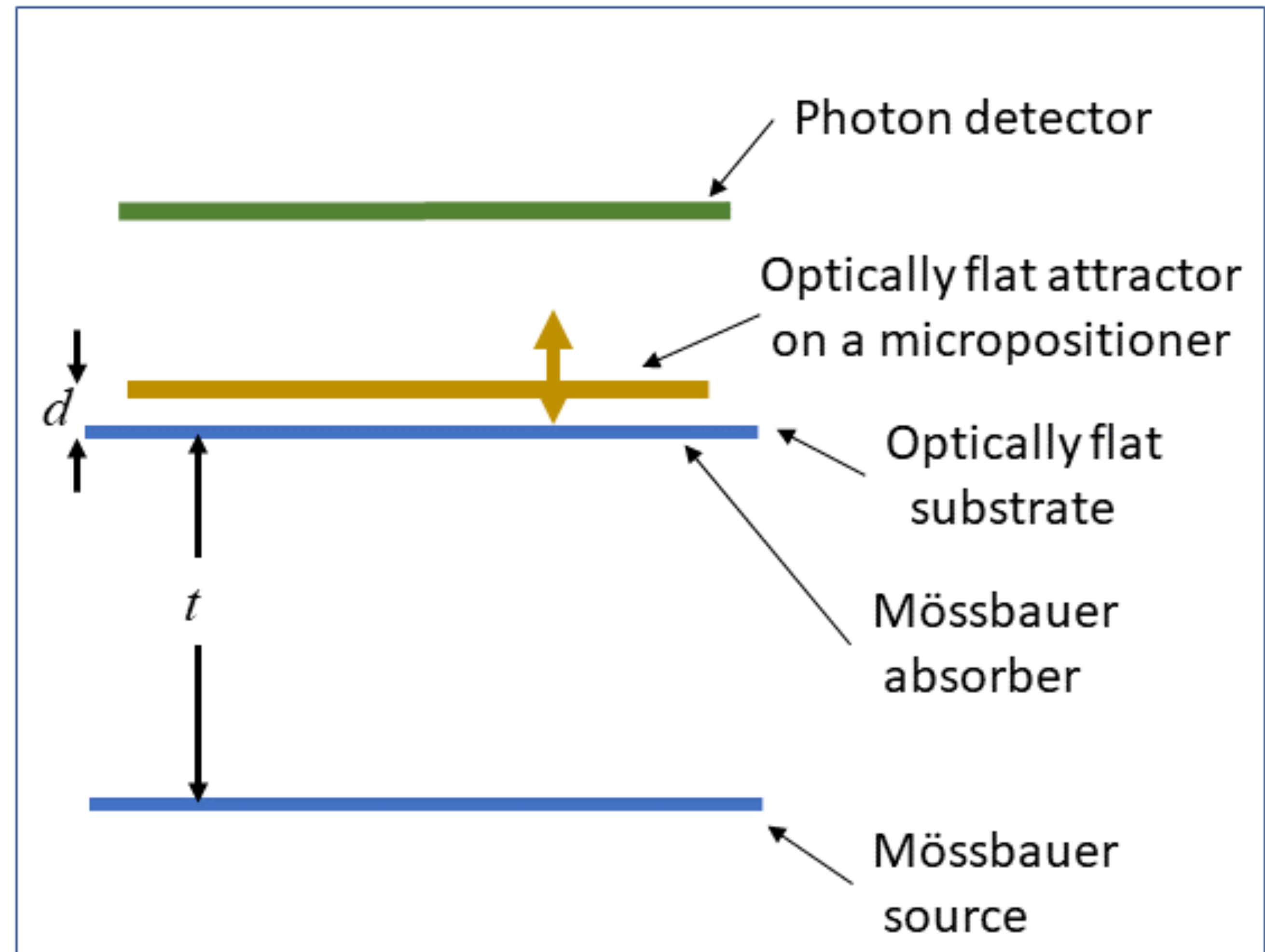
Resonant Reabsorption possible!

Narrow Nuclear Lines \Rightarrow High Sensitivity to energy shifts

Setup

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**New interaction
shifts nuclear energy**

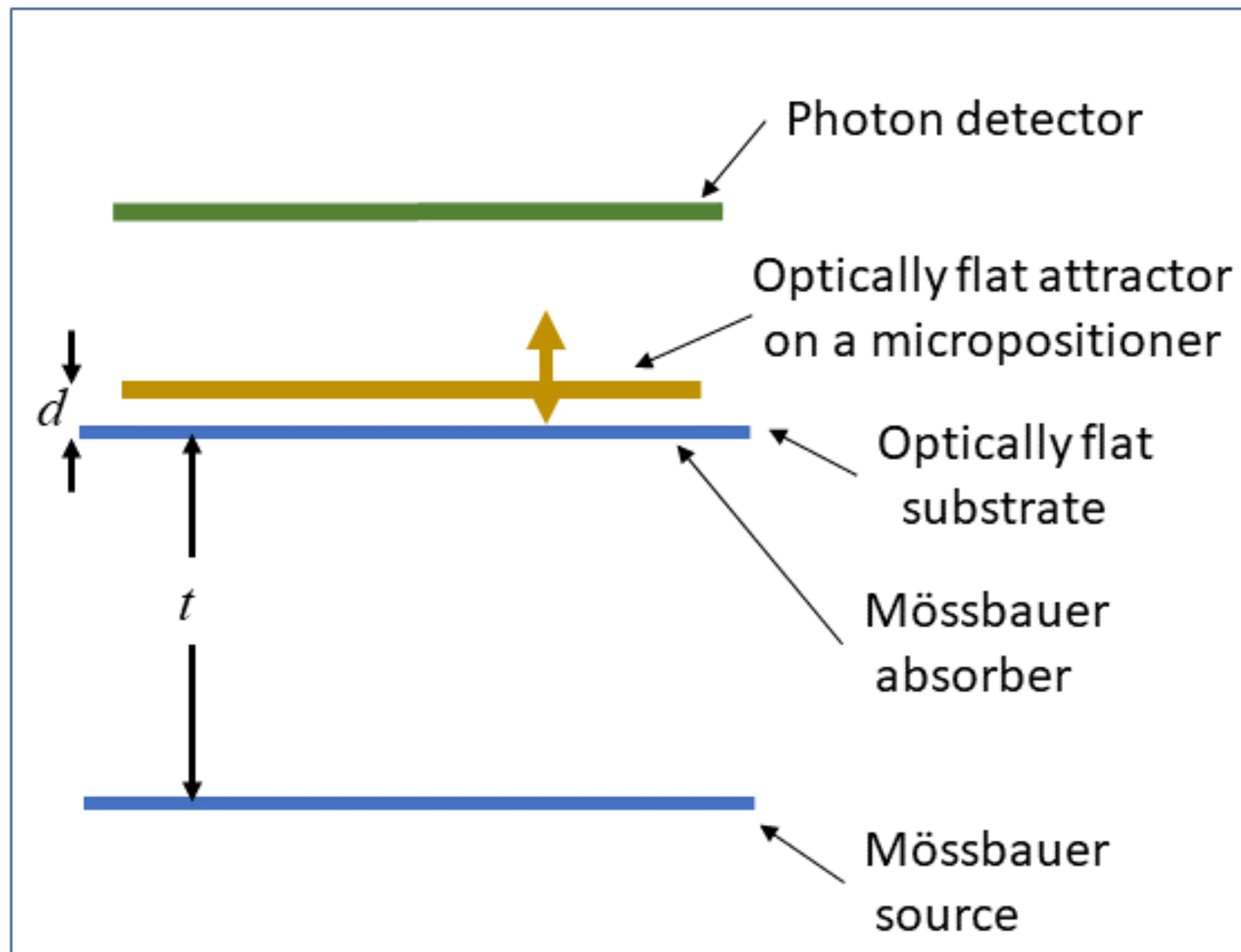


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**Resonant
Reabsorption as a
function of d**



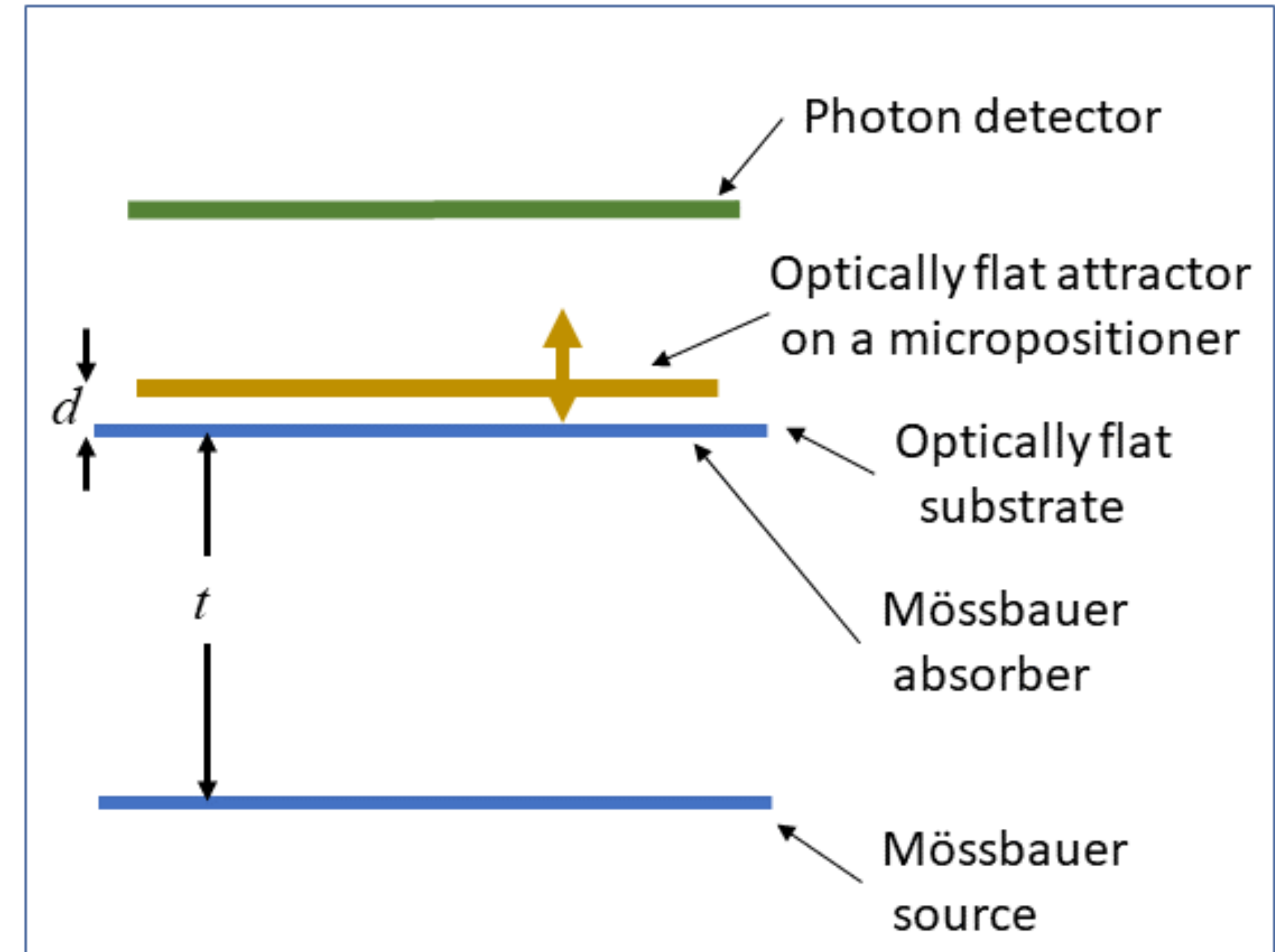
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Electromagnetism?

Needs to change nuclear transition energies

Suppressed by small nuclear moments,
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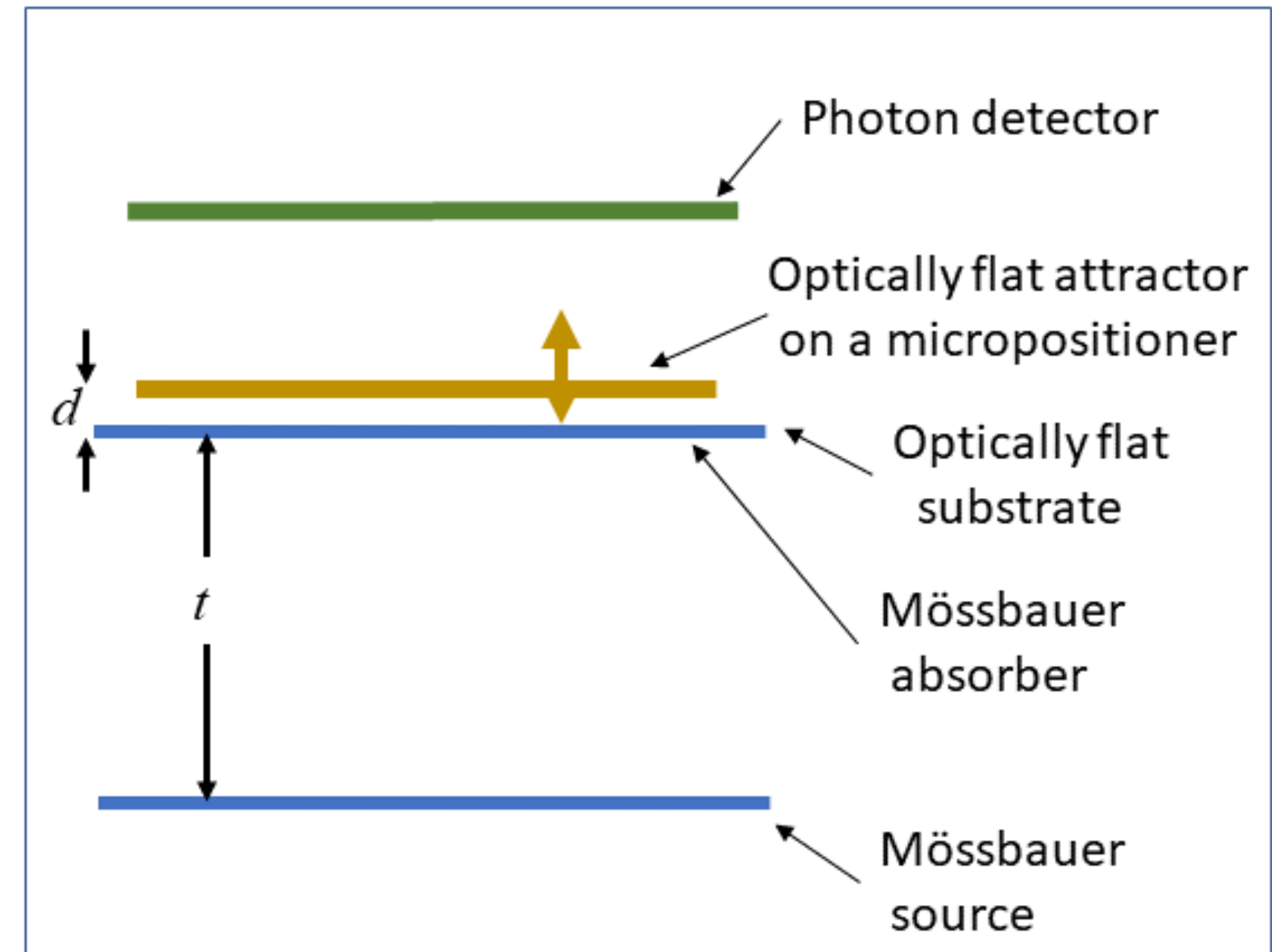
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Unpolarized nuclear spin \Rightarrow effects average
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Signal from new scalar and tensor
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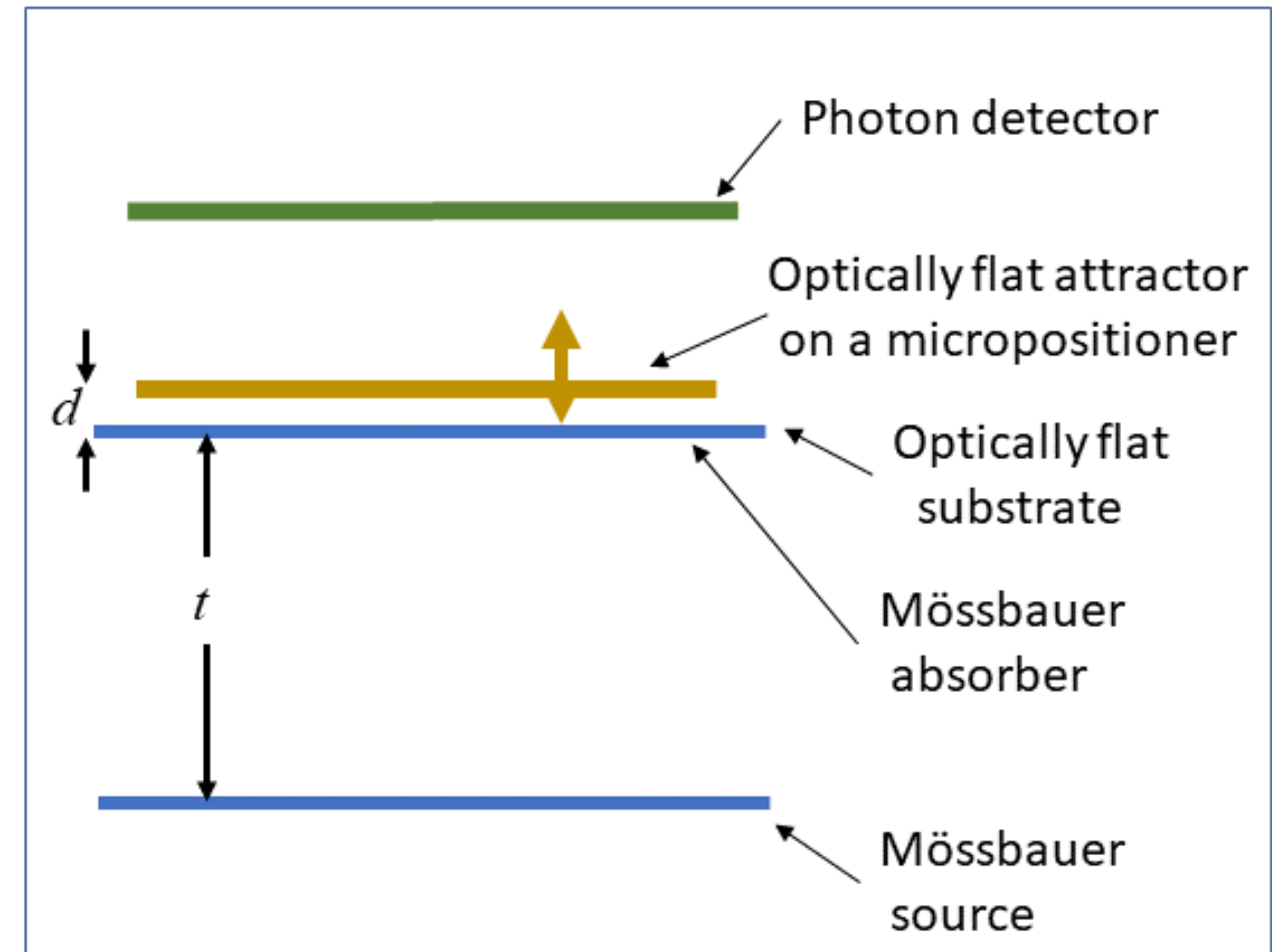
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First order effects irrelevant

Leading Background: Chemical Shift from Casimir

Sensitivity

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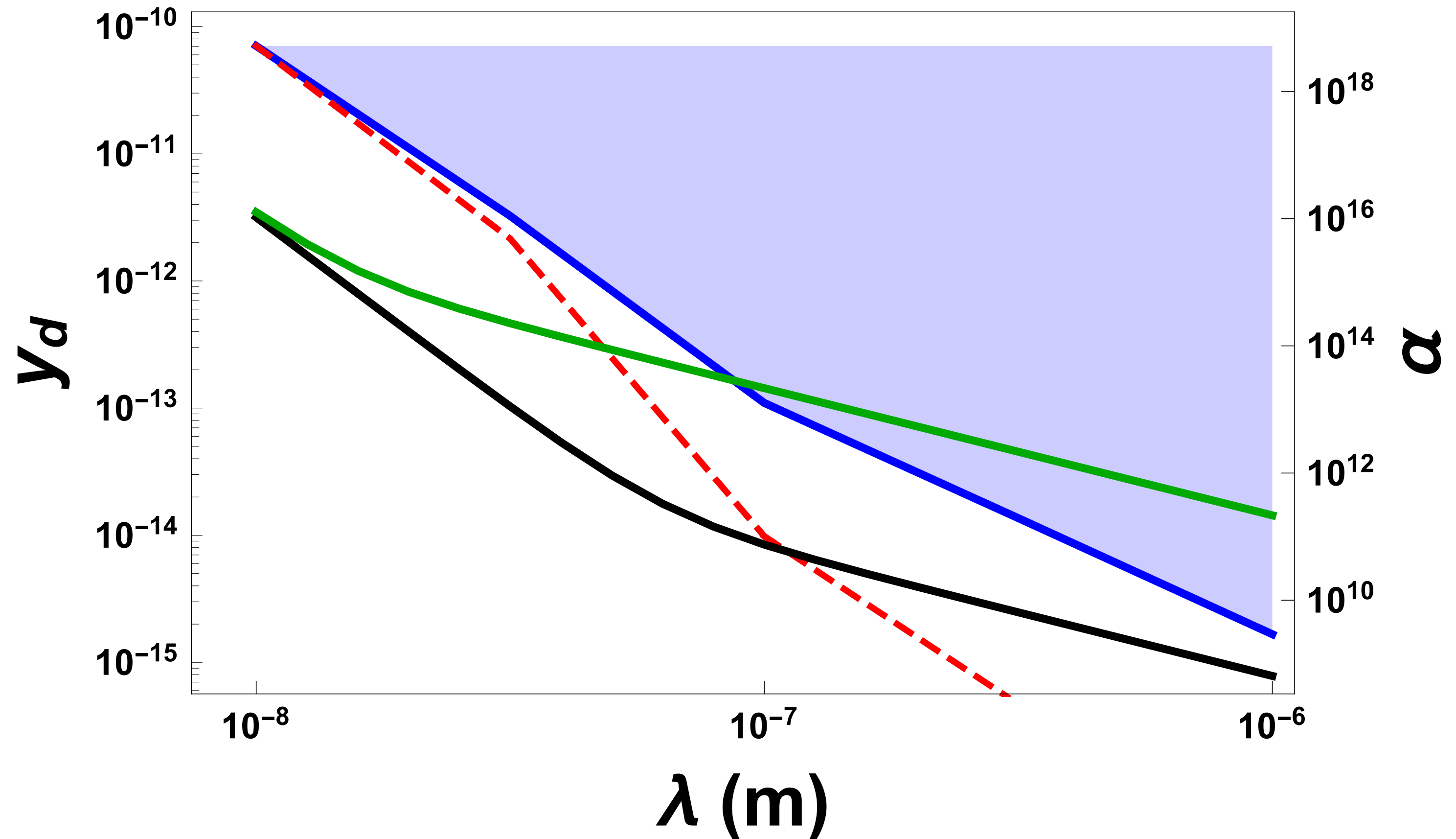
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$$^{57}\text{Fe} \quad \Delta E = 10^{-15} \text{ eV}$$

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



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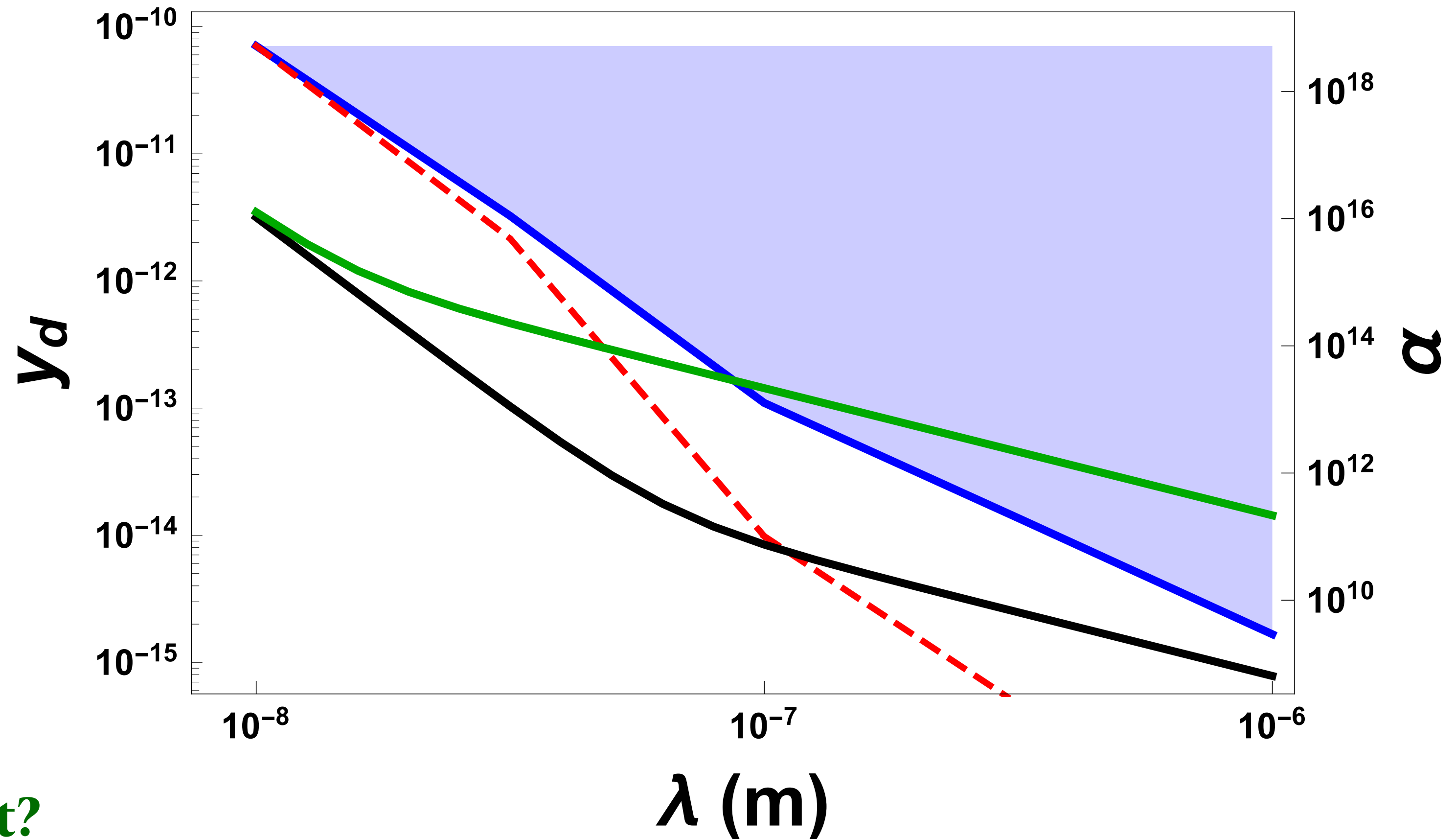
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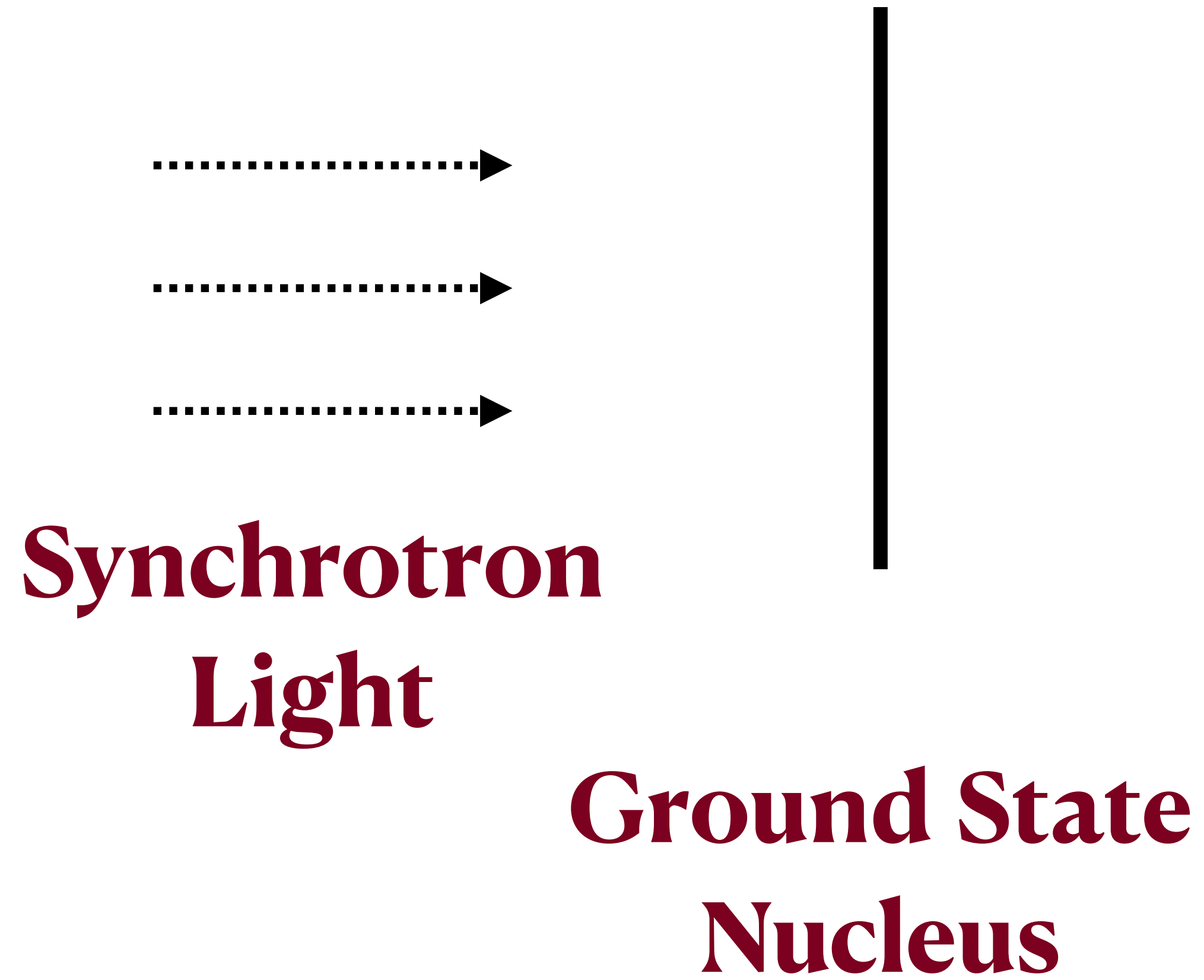
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Second Order Casimir Background at shortest distances

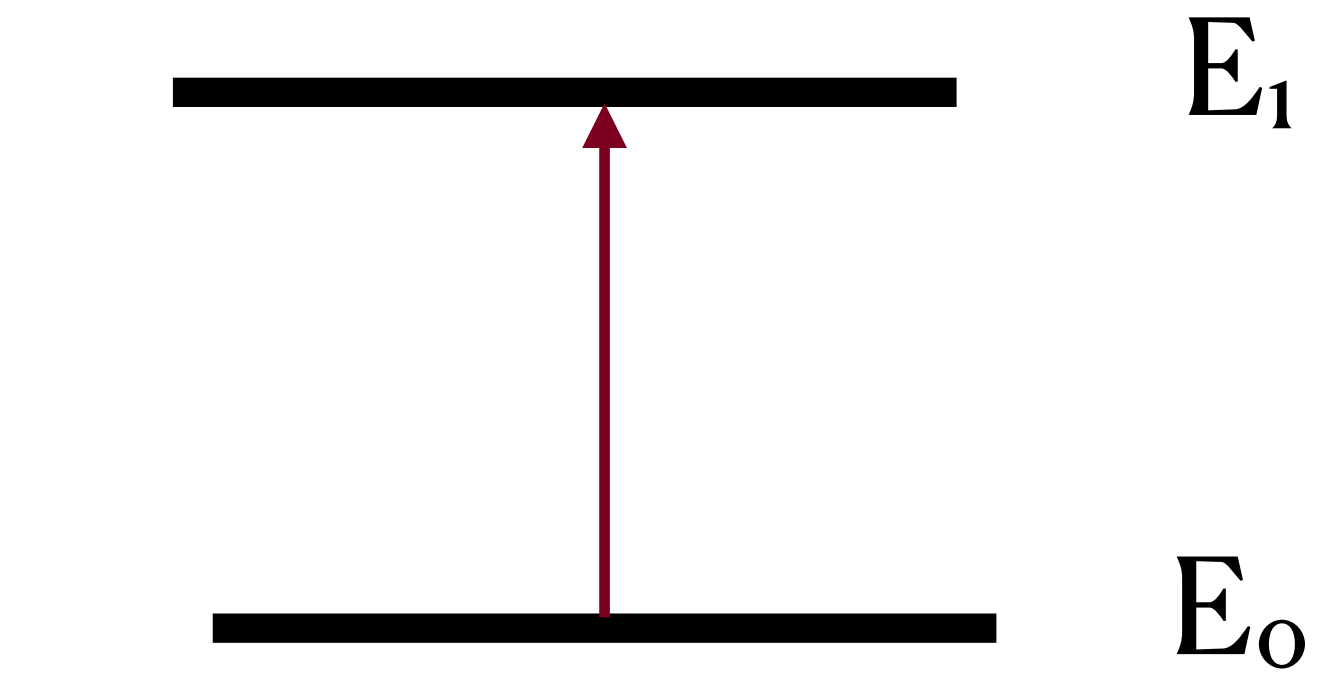
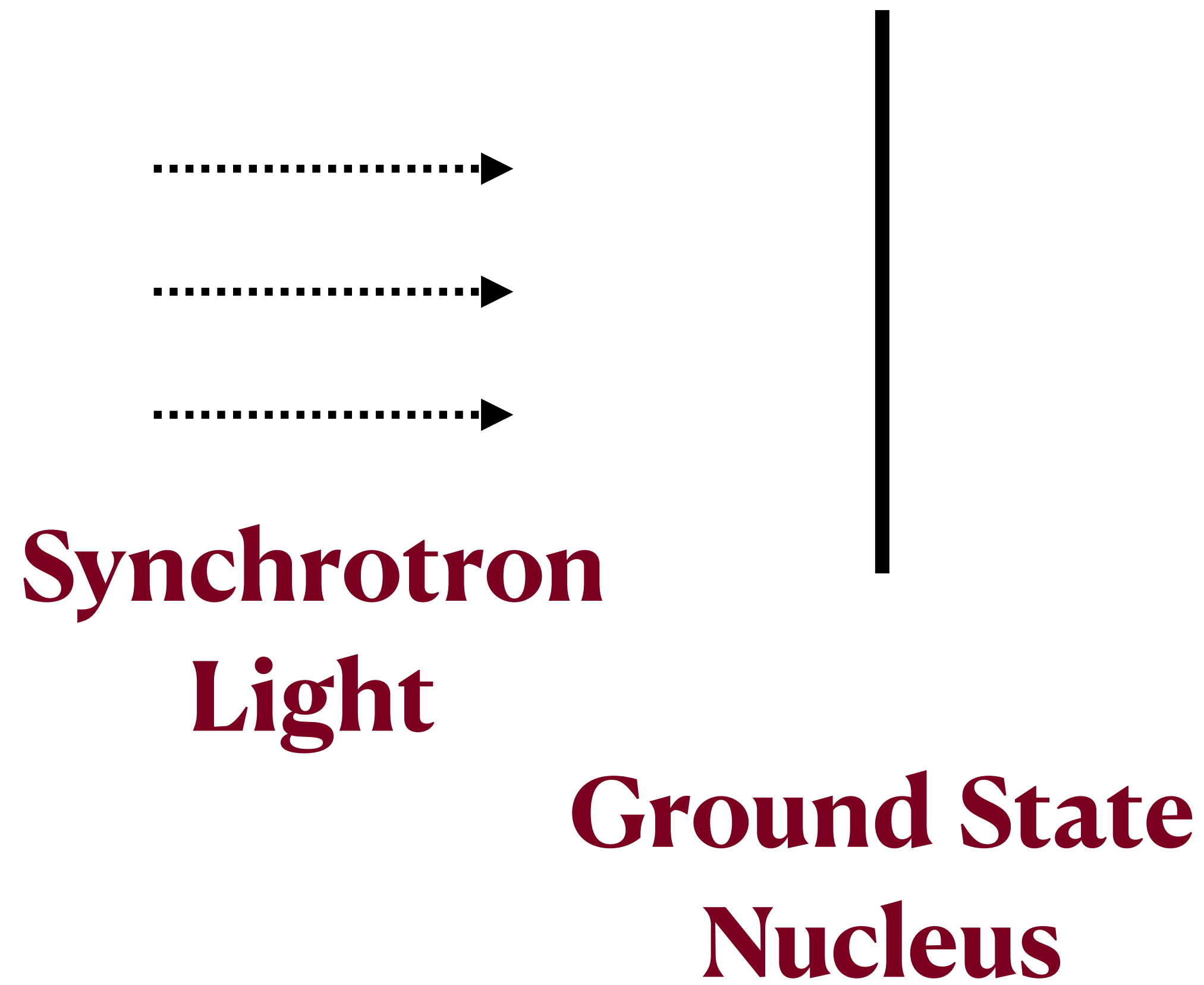


Mitigate using differential measurement?

Mossbauer at Synchrotron Source

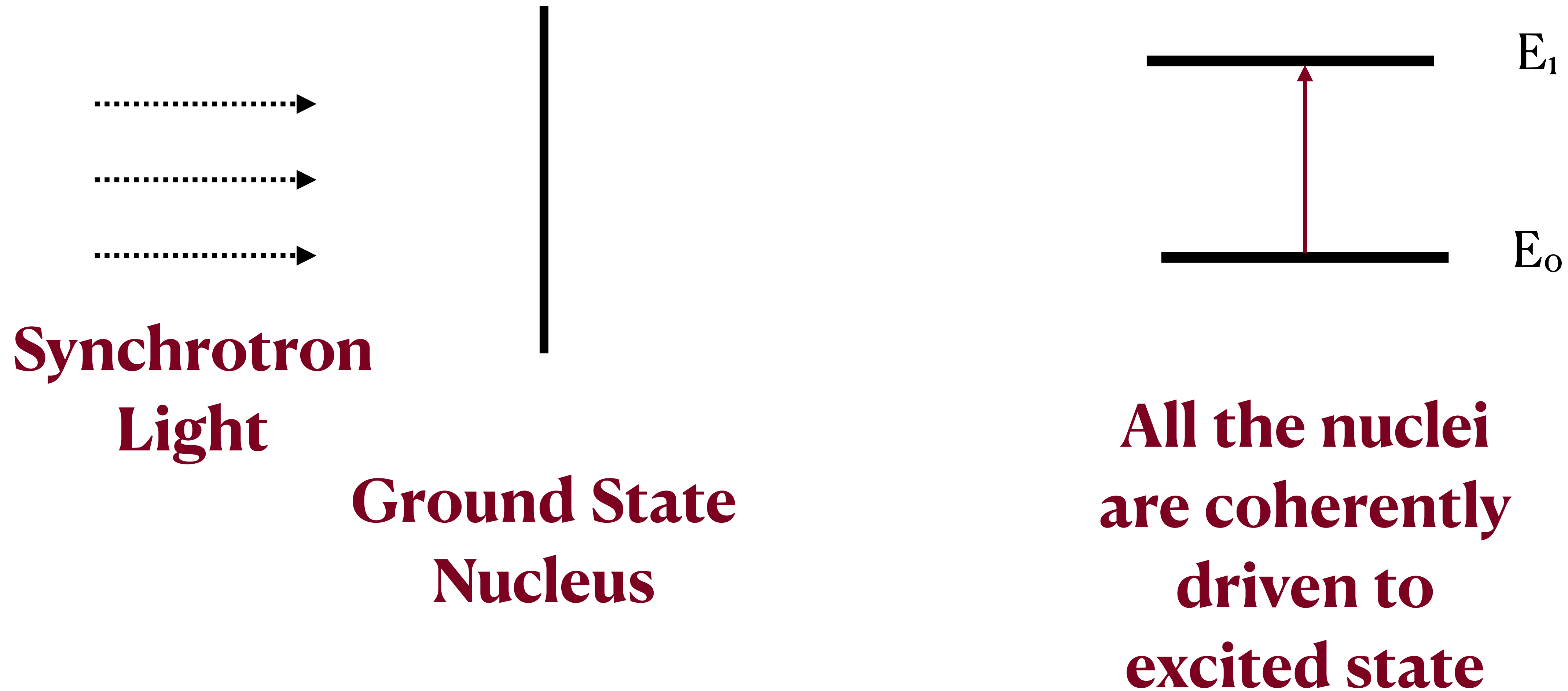


Mossbauer at Synchrotron Source



**All the nuclei
are coherently
driven to
excited state**

Mossbauer at Synchrotron Source



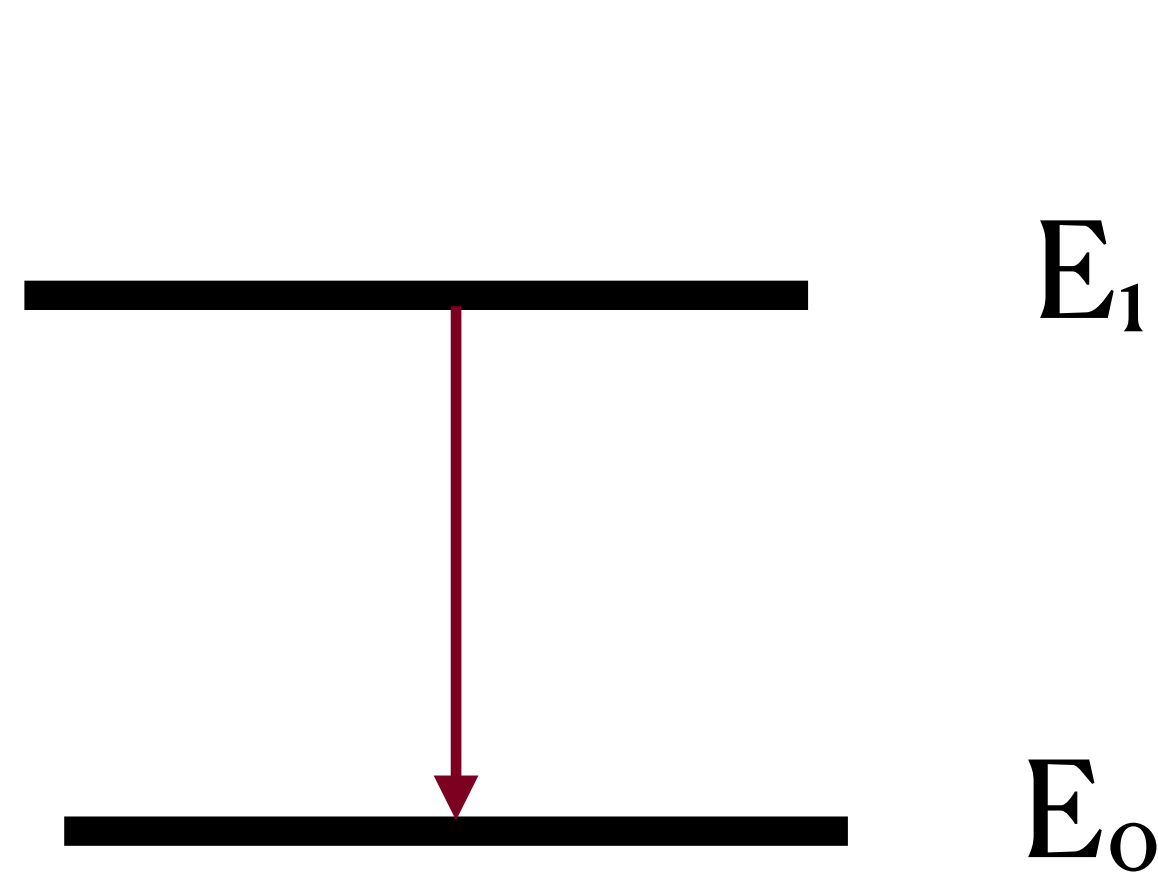
Short Pulse \ll Lifetime of State

Mossbauer at Synchrotron Source

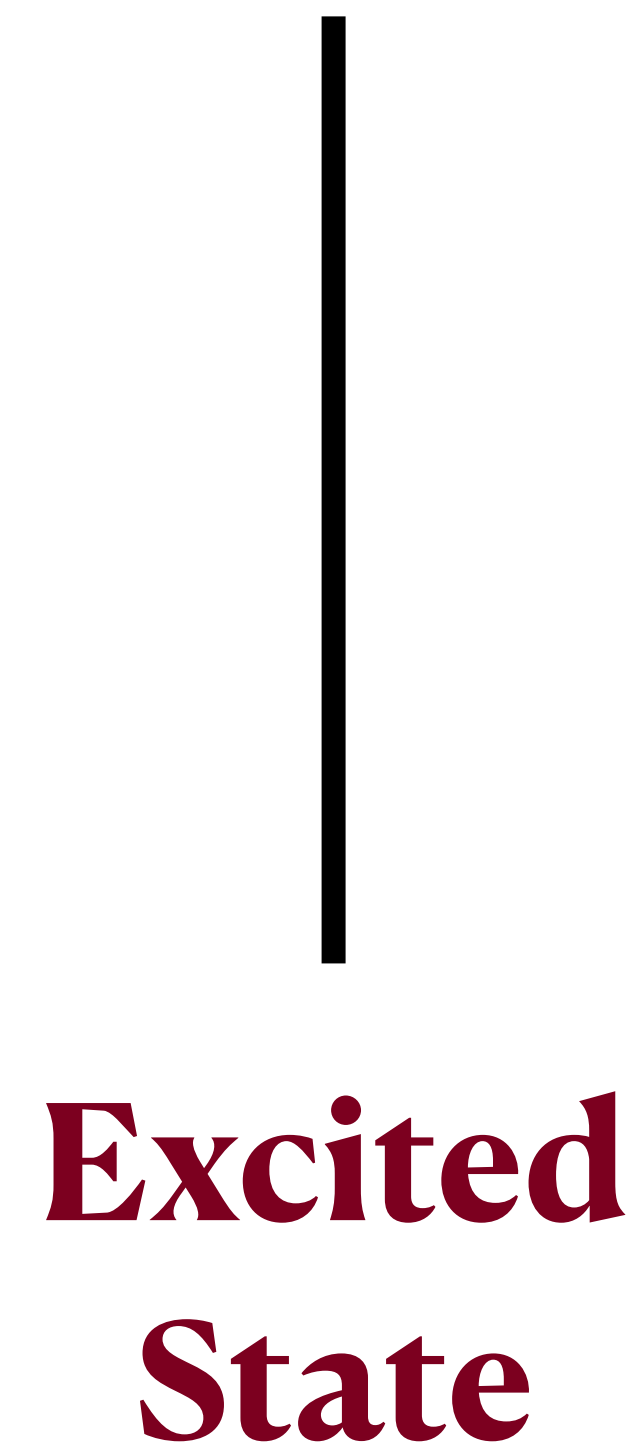
Well after pulse, state starts to decay

Coherent initial excitation => decays in phase

Decay along forward direction amplified by in phase addition



In phase decay

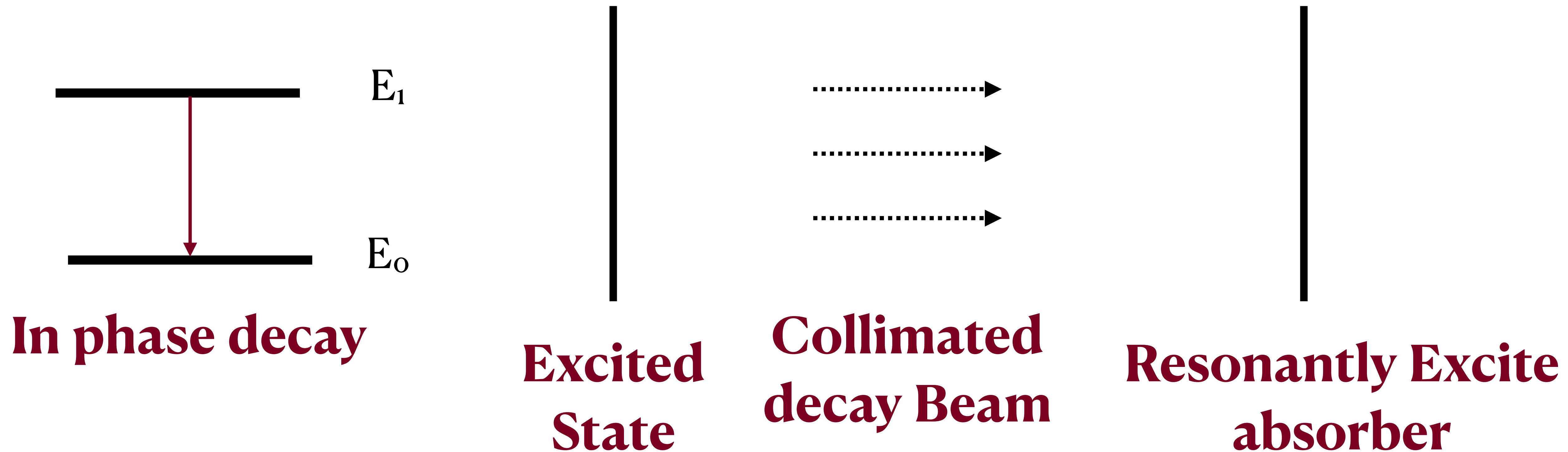


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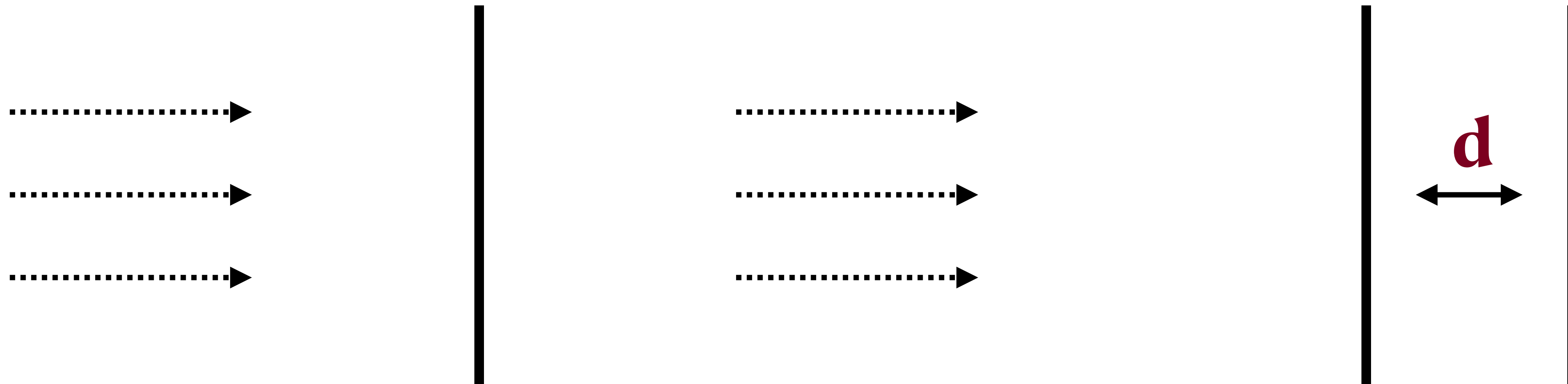
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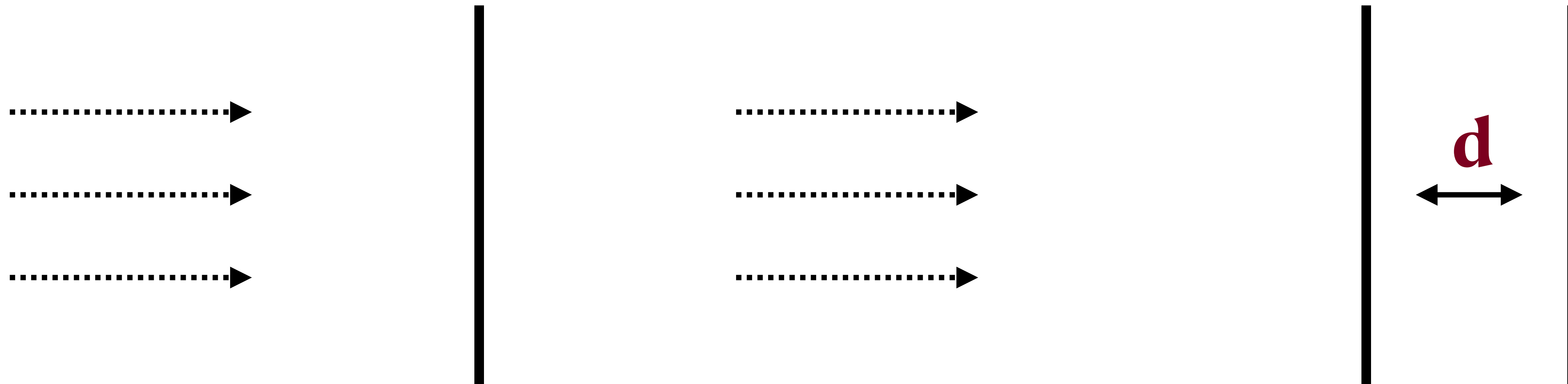


Send Synchrotron Pulse

Well after pulse, collimated emission

Measure resonant reabsorption as a function of d

Mossbauer at Synchrotron Source



Send Synchrotron Pulse

Well after pulse, collimated emission

Measure resonant reabsorption as a function of d

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**