

Bootstrap Methods in Modern Physics

Building Nature from the Bottom-Up!

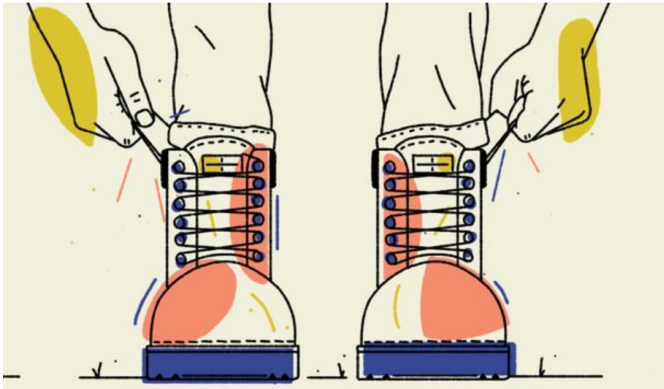
Francesco Sciotti

IFAE, Alex Pomarol

Cross-Collserola 2023

Bootstrap:

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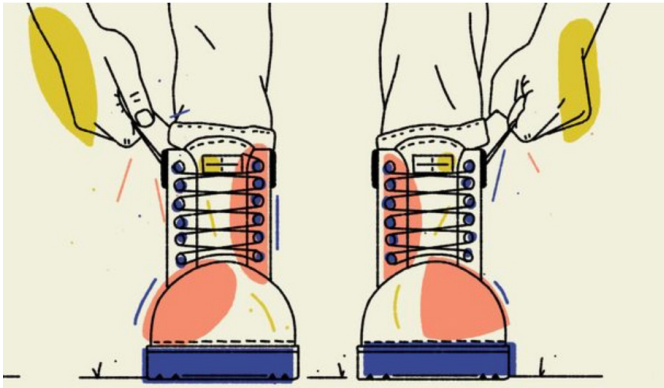


"Pull yourself up from your Bootstraps"



Use your own resources

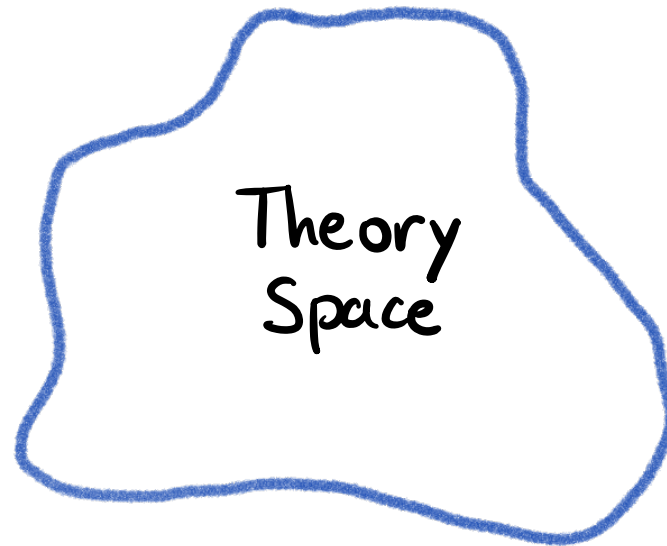
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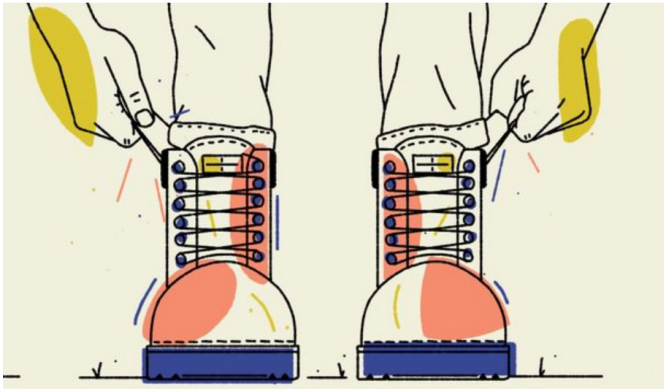
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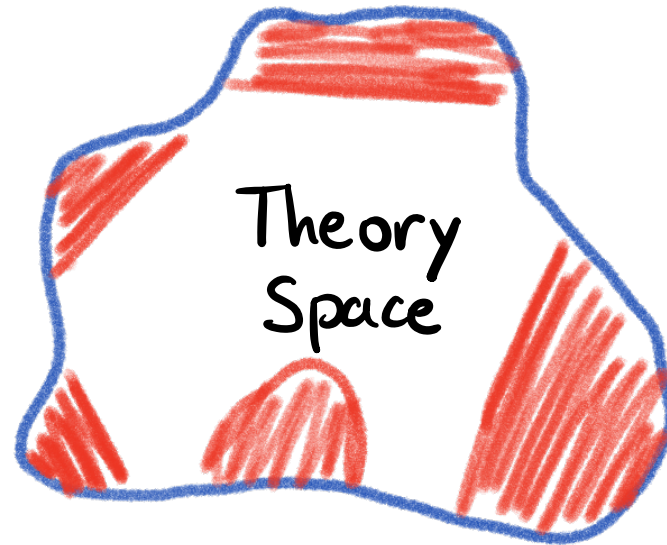
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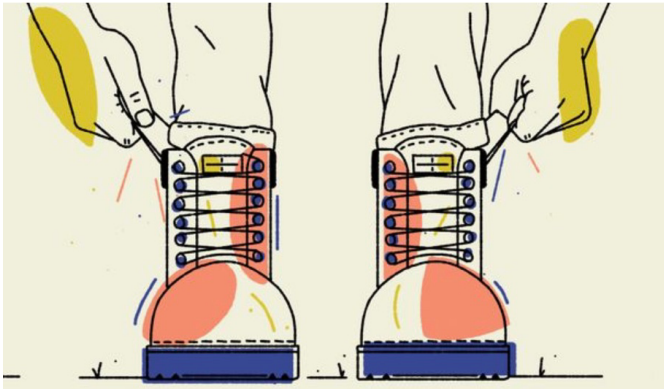
Use your own resources



"Carving Out"

according to
some principles

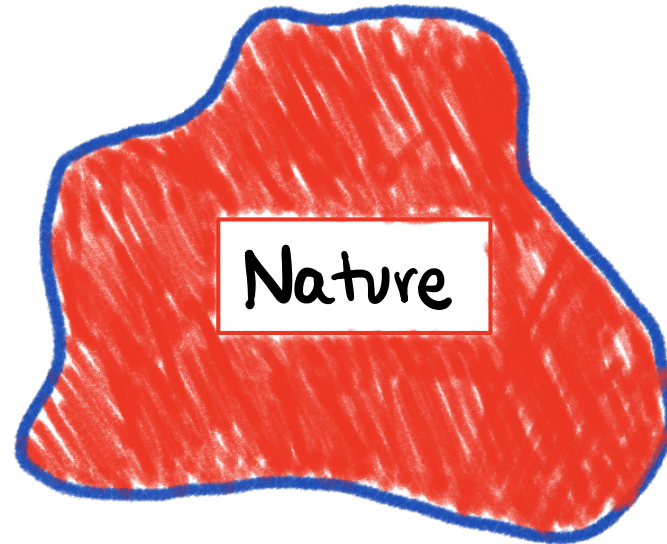
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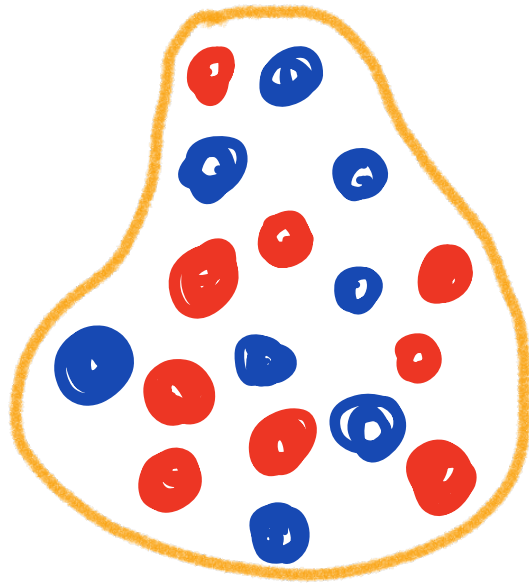
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"Carving Out"

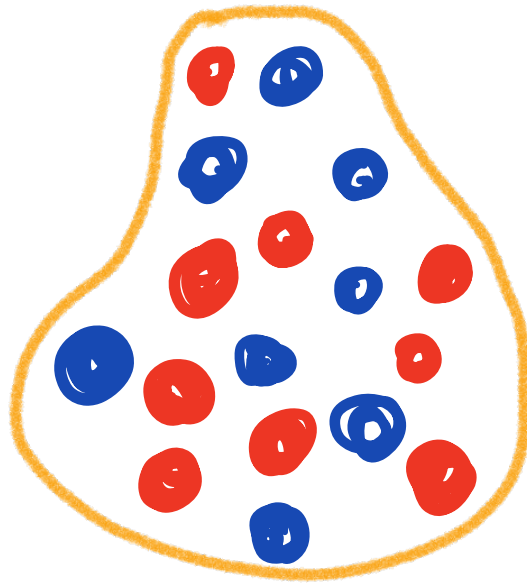
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What does "Bottom-Up" Mean?



Distribution of charge

What does "Bottom-Up" Mean?

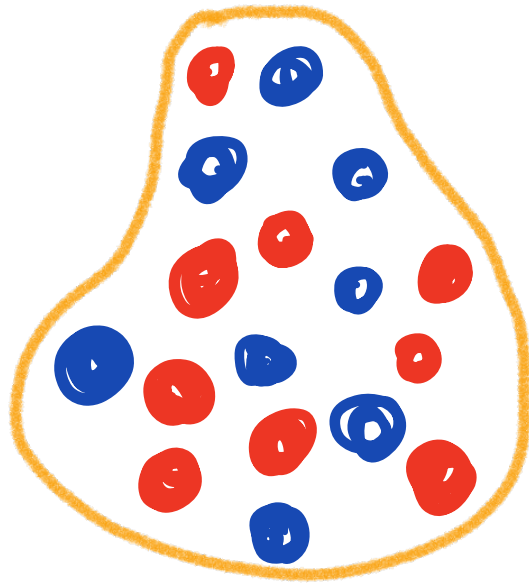


Distribution of charge



What is the $\phi(R)$?

What does "Bottom-Up" Mean?

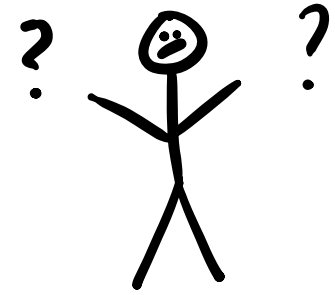


Distribution of charge

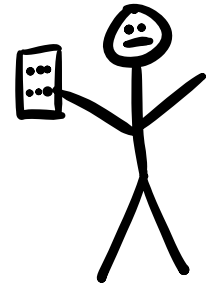


What is the $\phi(R)$? $\Rightarrow \rho(R)$

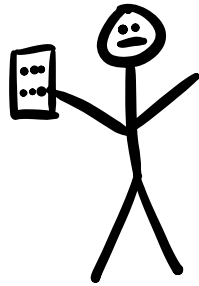
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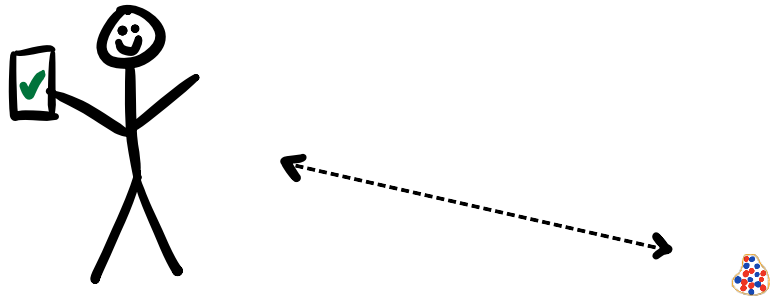
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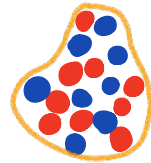
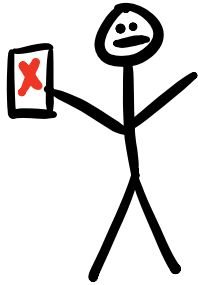


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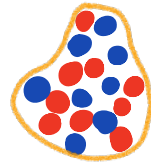
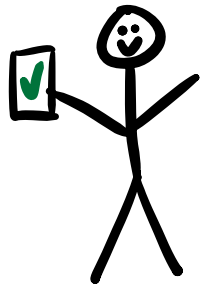
$$\phi(R) = \frac{Q^{\circ}}{R}$$

What does "Bottom-Up" Mean?



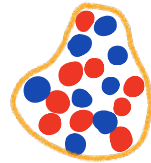
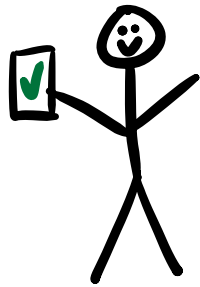
$$\phi(R) \neq \frac{Q^{\circ}}{R}$$

What does "Bottom-Up" Mean?



$$\phi(R) = \frac{Q^0}{R} + \frac{Q^i R^i}{R^3} + \frac{Q^{ij} R^i R^j}{R^5} + \dots$$

What does "Bottom-Up" Mean?

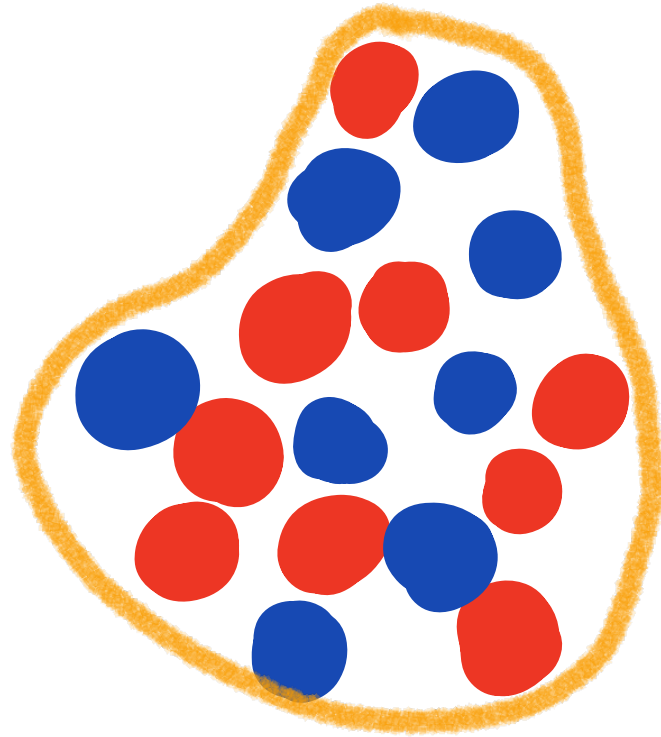


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$1/R$ a/R^2 a^2/R^3

↳ "Effective Description"

What does "Bottom-Up" Mean?



$$\phi(R) = \frac{Q^0}{R} + \frac{Q^1 R^1}{R^3} + \frac{Q^2 R^1 R^1}{R^5} + \dots$$

The equation is annotated with red text above the terms: $1/R$ above the first term, a/R^2 above the second term, and a^2/R^3 above the third term. The entire equation is crossed out with a large, red, wavy scribble.

↳ "~~Effective Description~~" → $\rho(R)$

What does "Bottom-Up" Mean?

IR

UV

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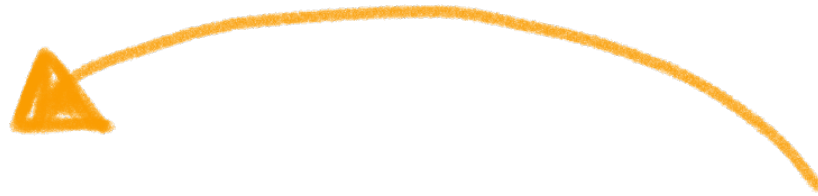
$\rho(R)$

What does "Bottom-Up" Mean?

IR

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EASY



$$\phi(R) = \frac{Q^0}{R} + \frac{Q^i R^i}{R^3} + \frac{Q^{ij} R^i R^j}{R^5} + \dots$$

$P(R)$

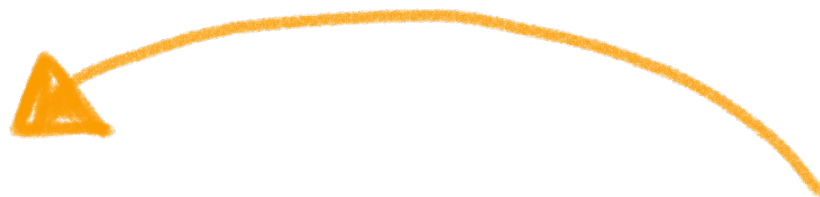
UV theory DEFINES your $\{Q^0, Q^i, Q^{ij}, \dots\}$

What does "Bottom-Up" Mean?

IR

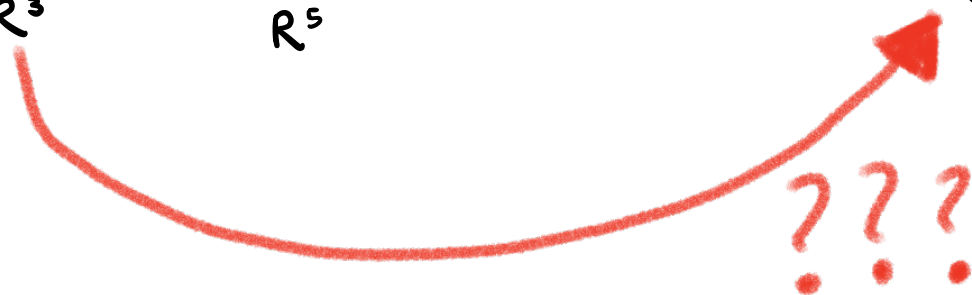
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$P(R)$



UV theory DEFINES your $\{Q^0, Q^i, Q^{ij}, \dots\}$

What can

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- Make some assumptions
about the UV

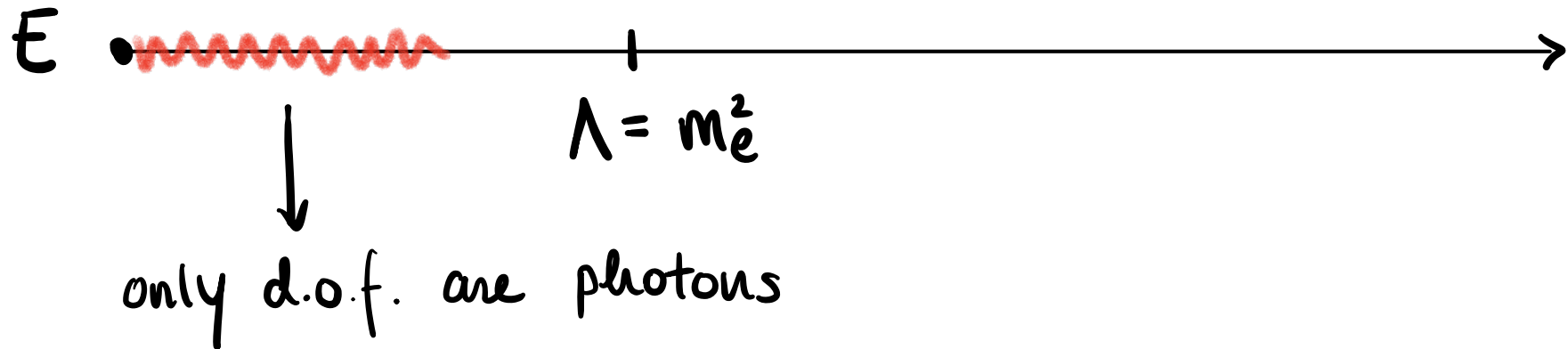
What can I do?

- Make some assumptions about the UV
- Check that IR is consistent with these assumptions

Effective Field Theories

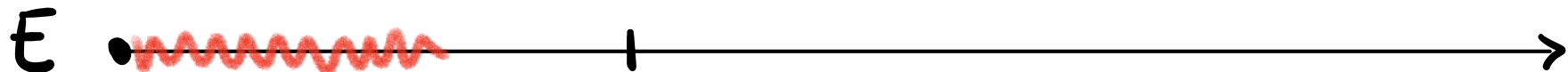
Effective Field Theories

QED:



Effective Field Theories

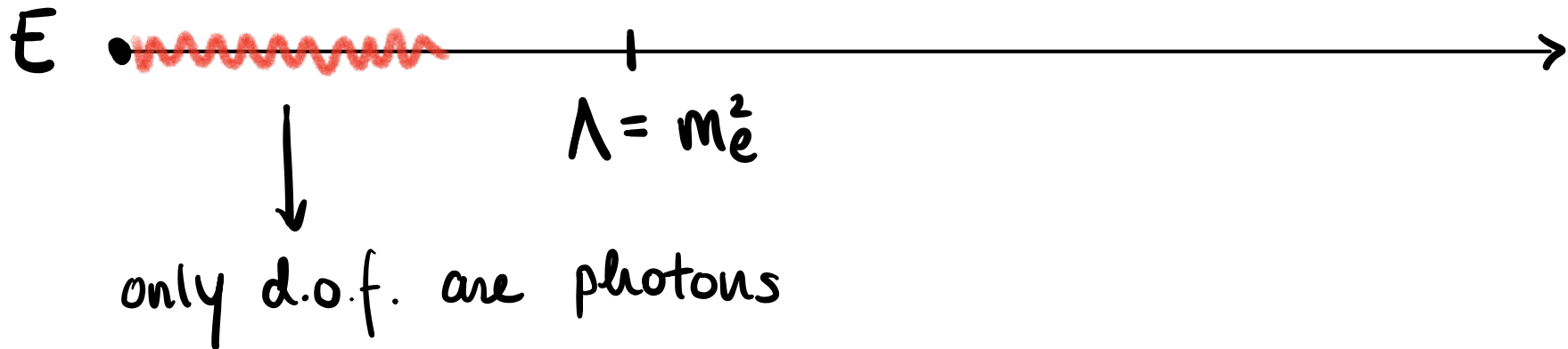
QED:



$$\mathcal{L} = -\frac{1}{4} F^2$$

Effective Field Theories

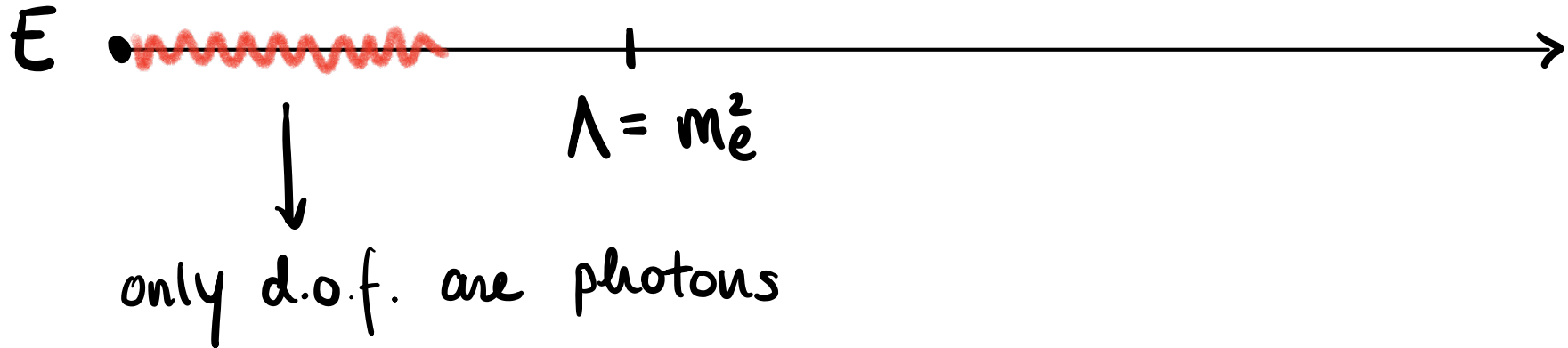
QED:



$$\mathcal{L}^{\text{EFT}} = -\frac{1}{4} F^2 + \frac{\alpha^2}{\Lambda^2} \left(c_1 F^4 + c_2 (F\tilde{F})^2 \right) + \dots$$

Effective Field Theories

QED:



$$\mathcal{L}^{\text{EFT}} = -\frac{1}{4} F^2 + \frac{\alpha^2}{\Lambda^2} \left(c_1 F^4 + c_2 (F\tilde{F})^2 \right) + \dots$$

$$Z \sim \int D_H D_L e^{-iS} = \int D_L e^{-iS^{\text{EFT}}}$$

Effective Field Theories

Wilson Coefficients

$$\mathcal{L}^{\text{EFT}} = -\frac{1}{4} F^2 + \frac{\alpha^2}{\Lambda^2} \left(c_1 F^4 + c_2 (F\tilde{F})^2 \right) + \dots$$

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Effective Field Theories

UV information is encoded in these c_i 's...

Wilson Coefficients

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"Building" ?

"Building"?

IR \longrightarrow UV

Q: What Wilson Coefficients (IR)
give me a UV theory which is:

"Building"?

IR \longrightarrow UV

Q: What Wilson Coefficients (IR)
give me a UV theory which is:

- UNITARY
- CAUSAL

"Building"?

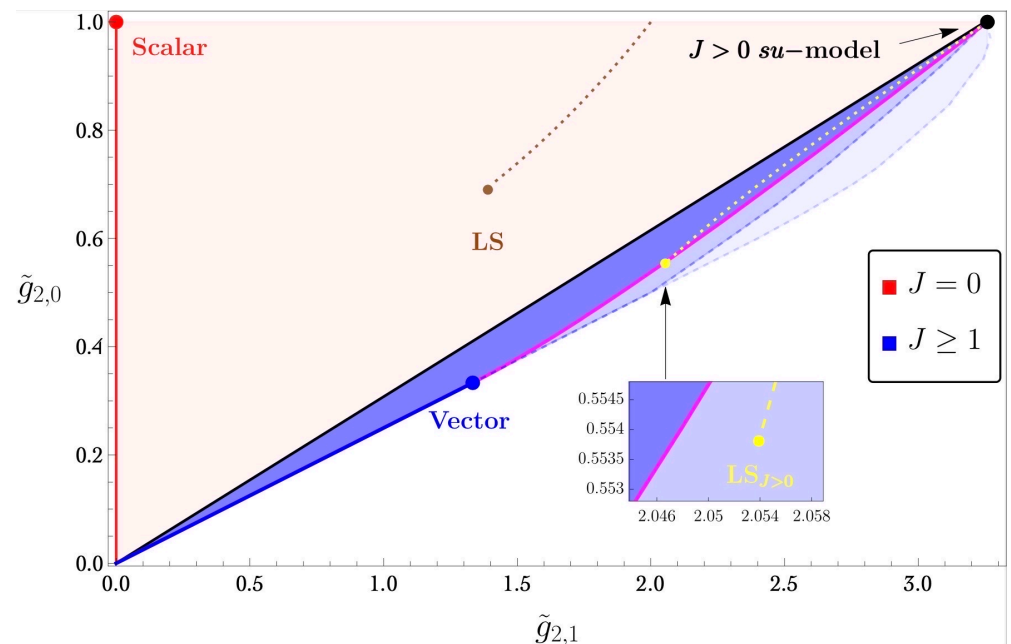
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"Building"?

IR \longrightarrow UV

Q: What Wilson Coefficients (IR)
give me a "consistent" UV theory

★ CFT's \longrightarrow most precise measurement
of Ising Model

★ SWAMPLAND

★ QUANTUM MECHANICS

⋮

Thanks!