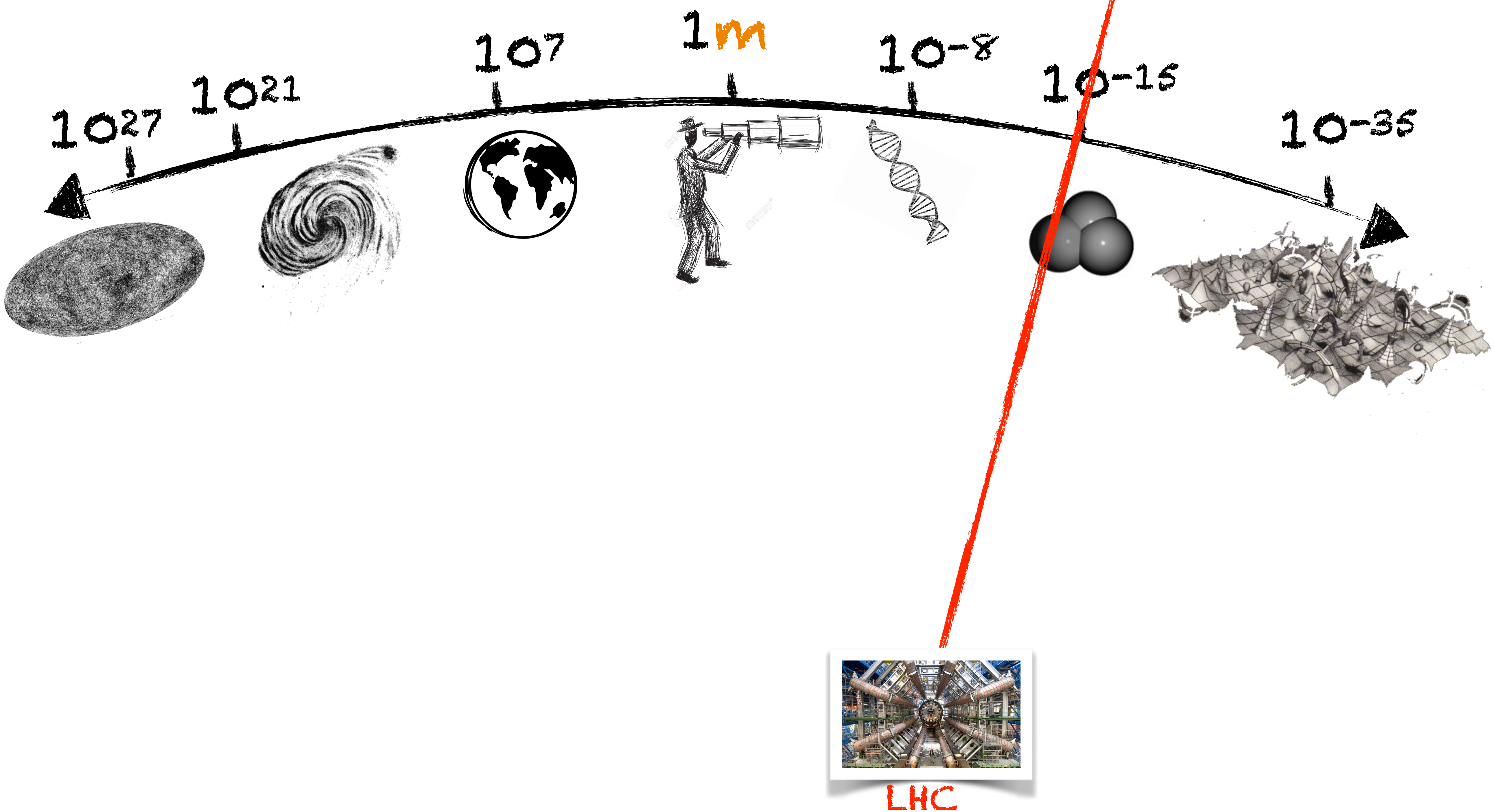
FCC and the size of the Higgs boson

Francesco Riva
(Geneva University)

High-Energy Particle Physics



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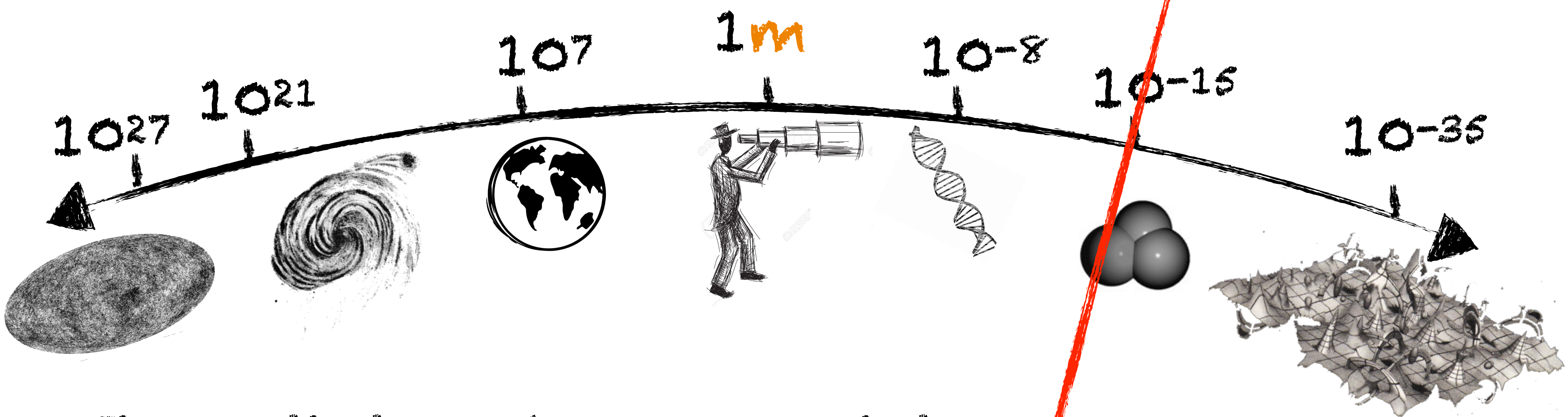

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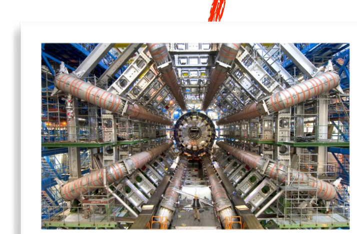

LHC

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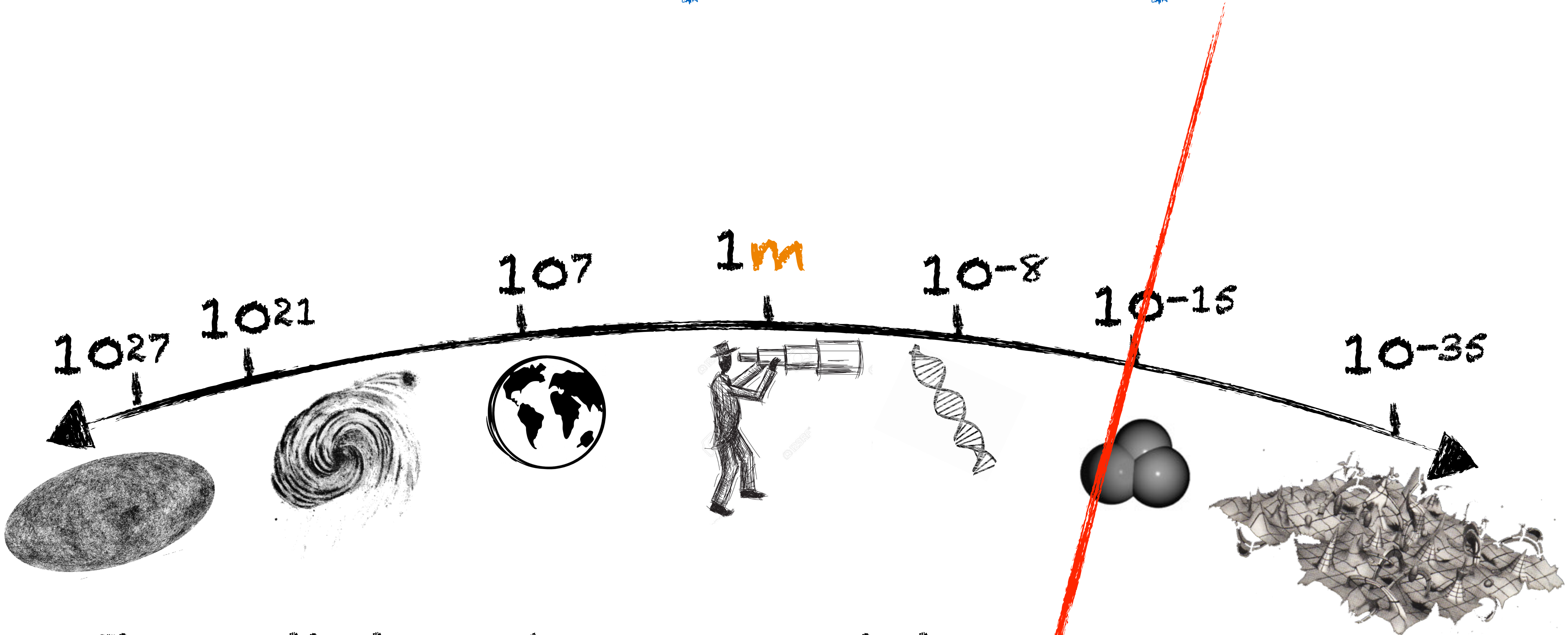

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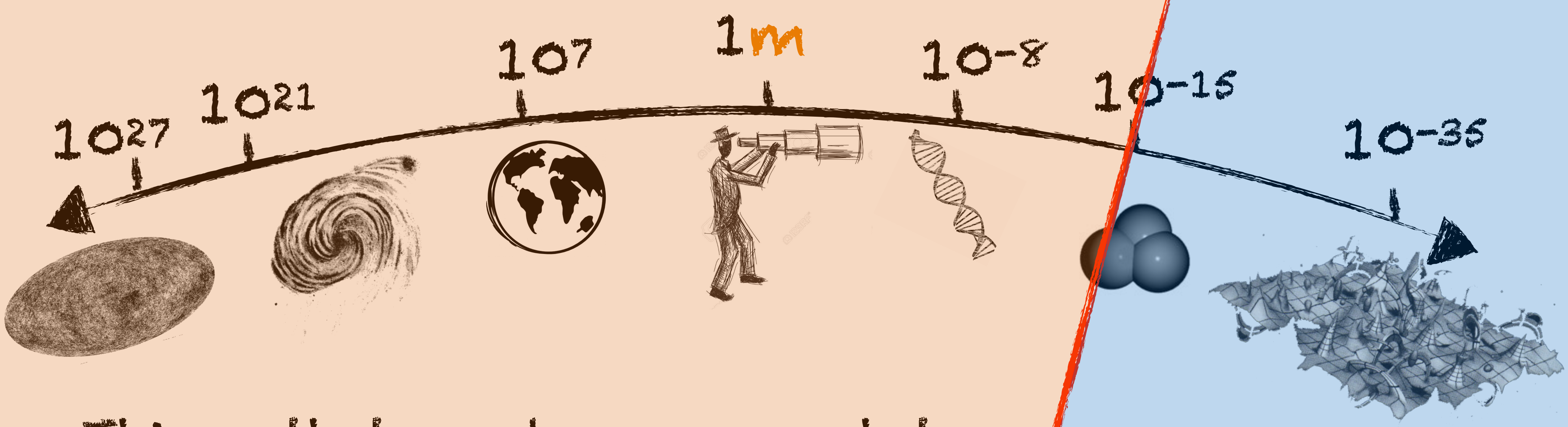

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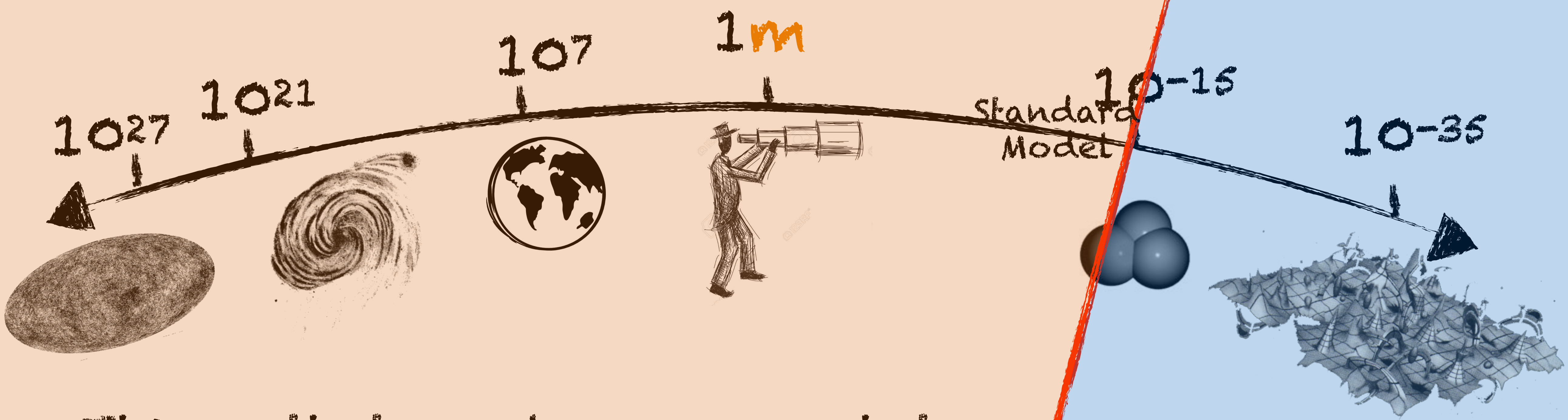

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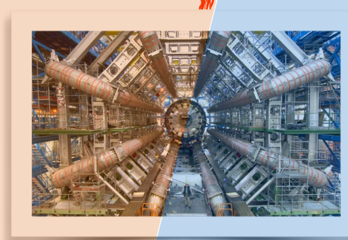

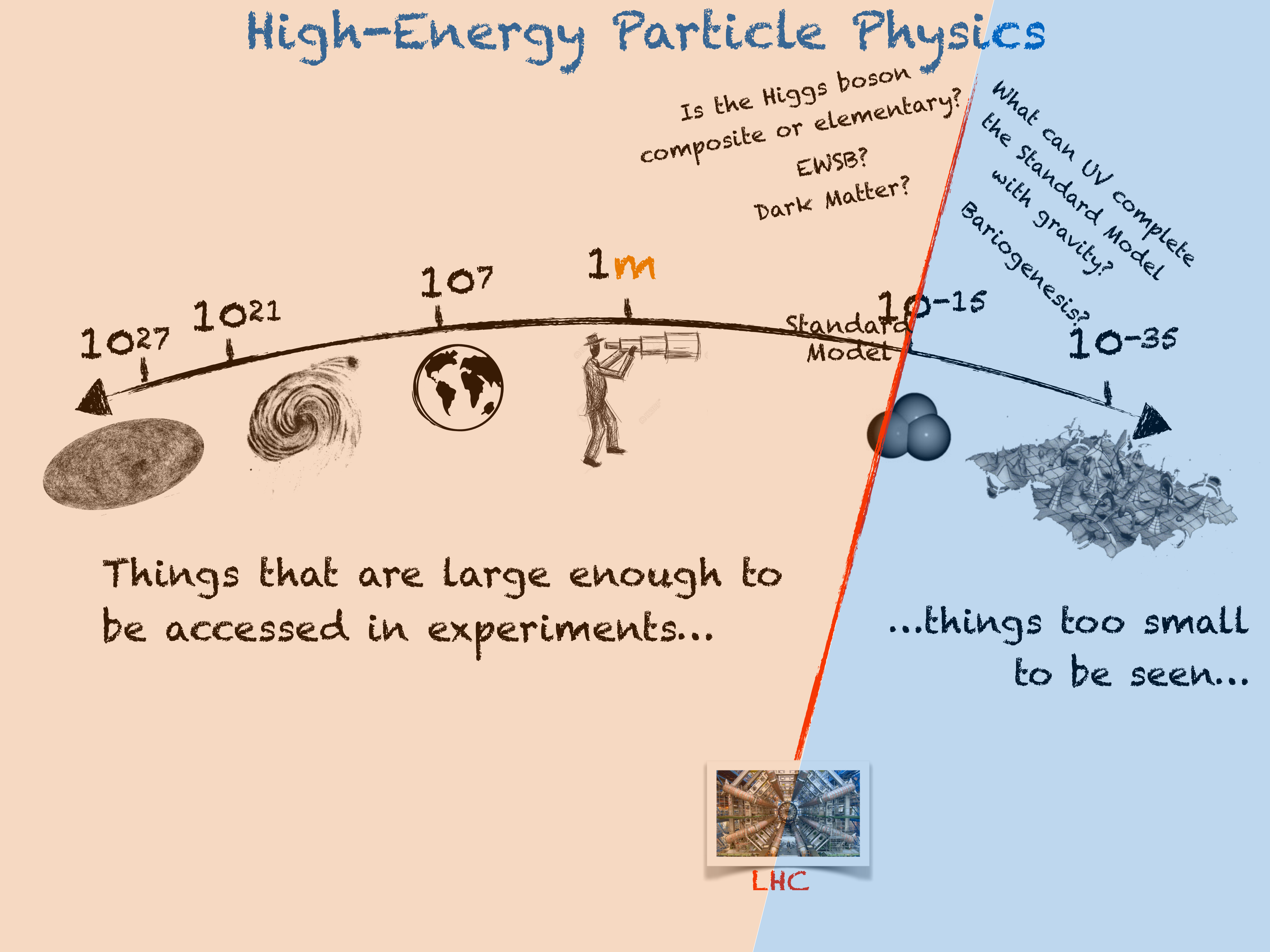
High-Energy Particle Physics
Is the Higgs boson composite or elementary?
EWSB?
Dark Matter?
What can UV complete the Standard Model with gravity?
Bariogenesis?
10^27
10^21
10^7
1m
10^-15
Standard Model
10^-35
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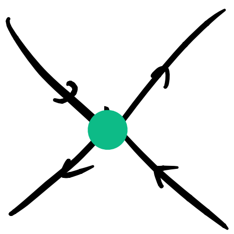
No Lose Theorems

HEP: a history of guaranteed discoveries



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$$\psi\psi \to \psi\psi$$

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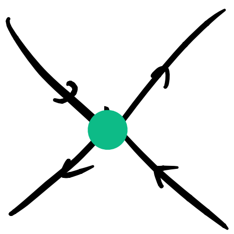

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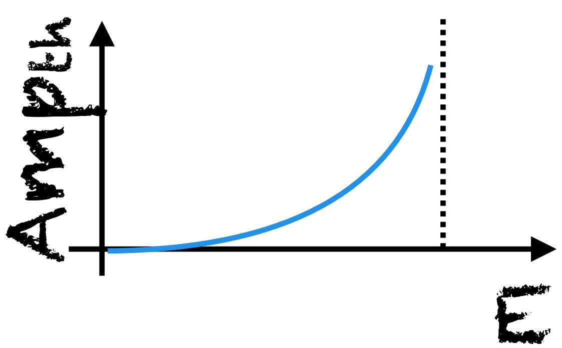

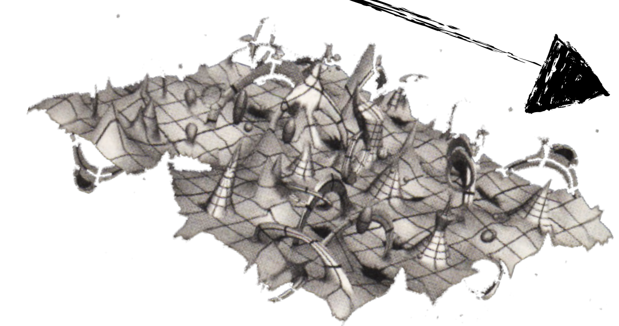

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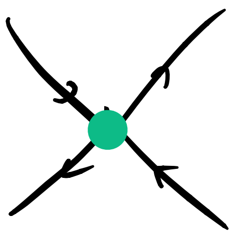

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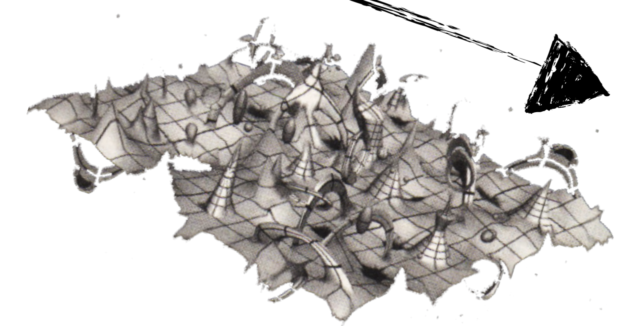

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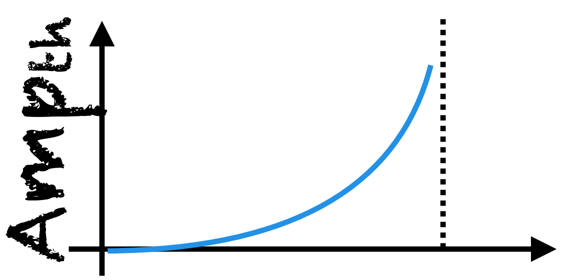

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$m_W \lesssim 3TeV$

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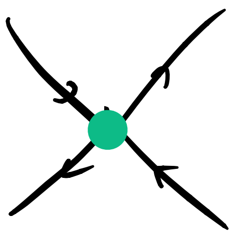

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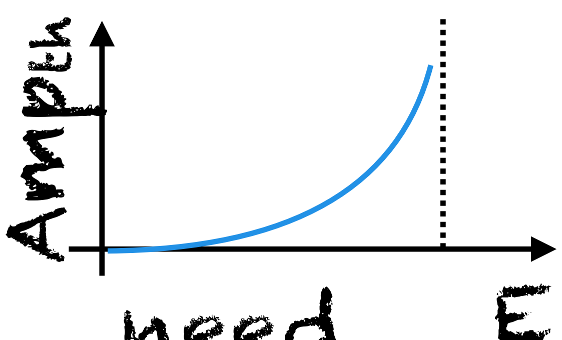

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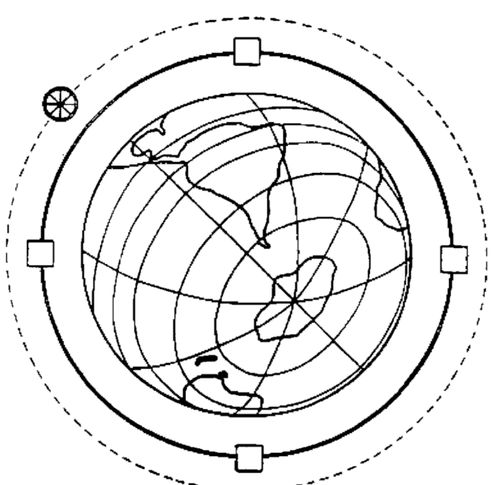

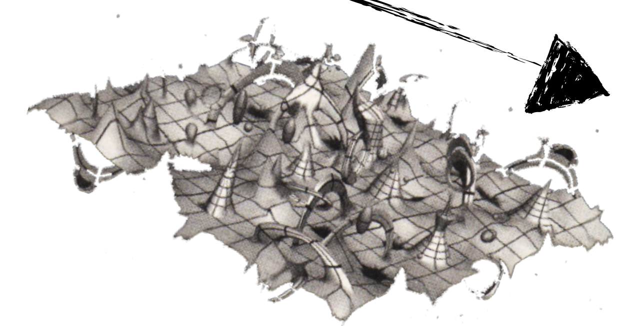

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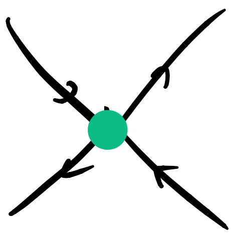

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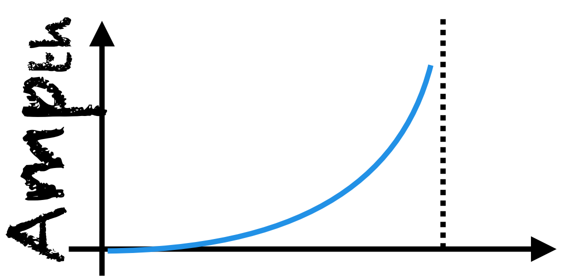

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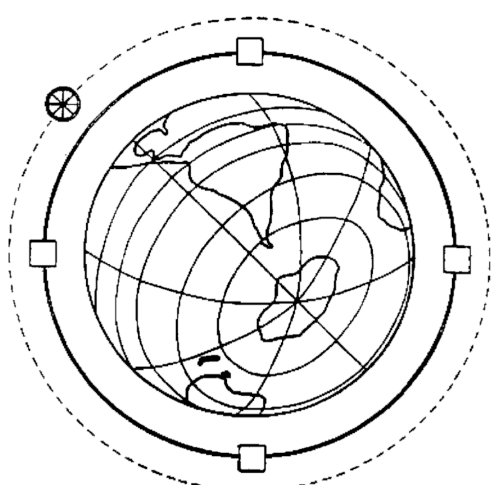

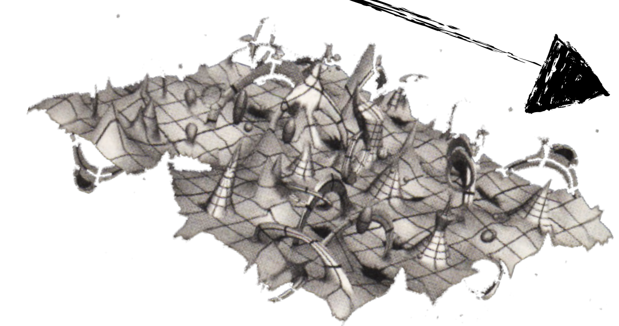

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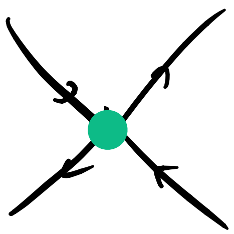

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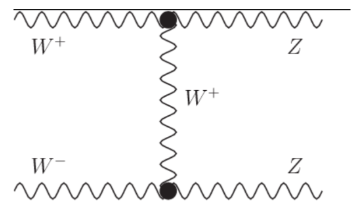

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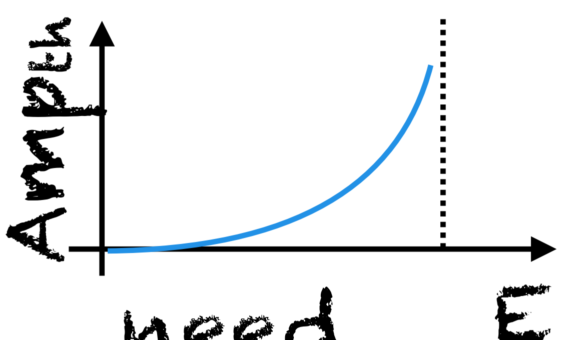

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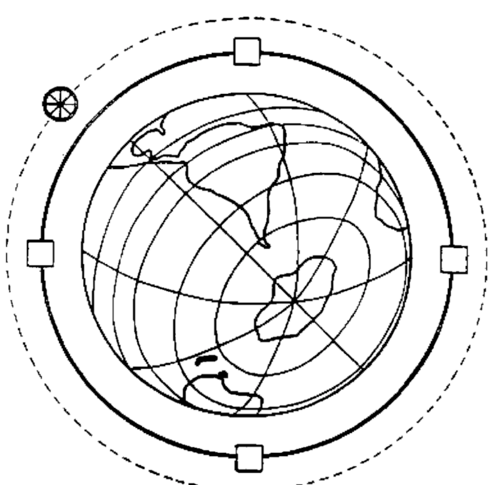

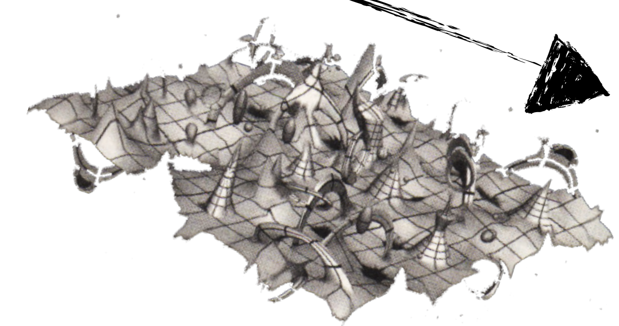

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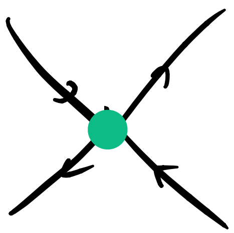

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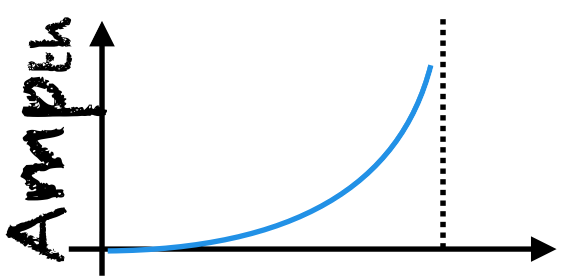

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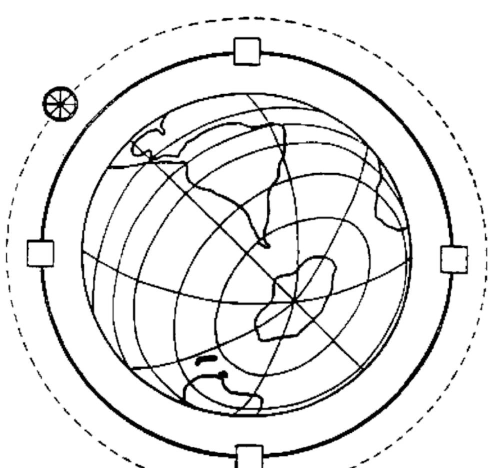

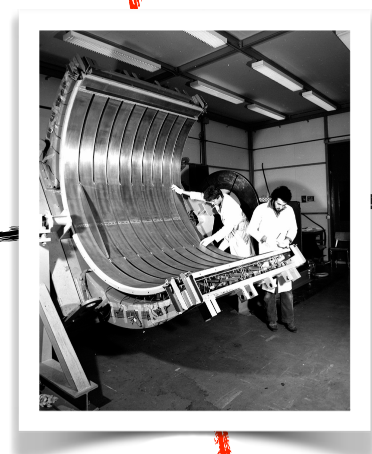

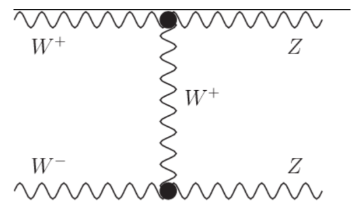

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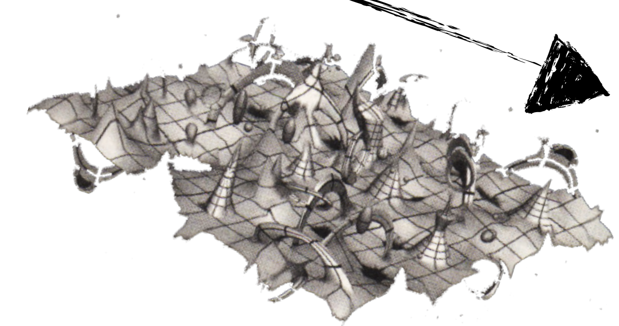

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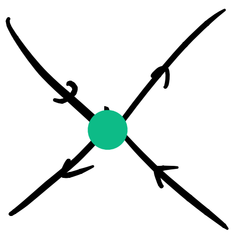

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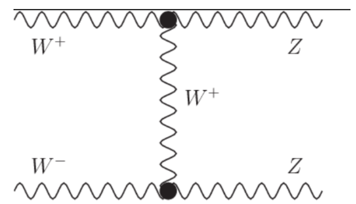

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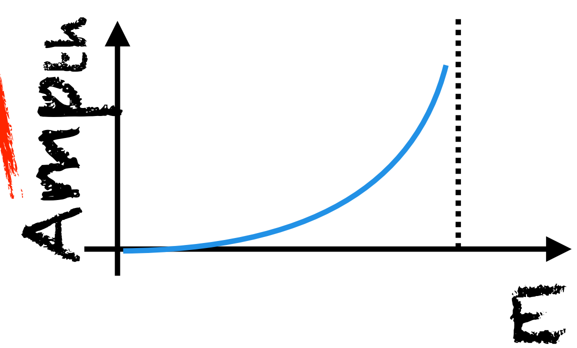

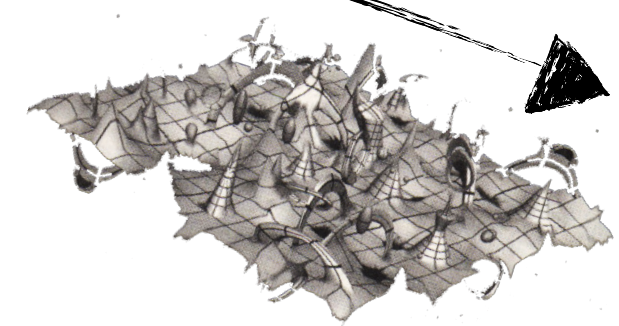

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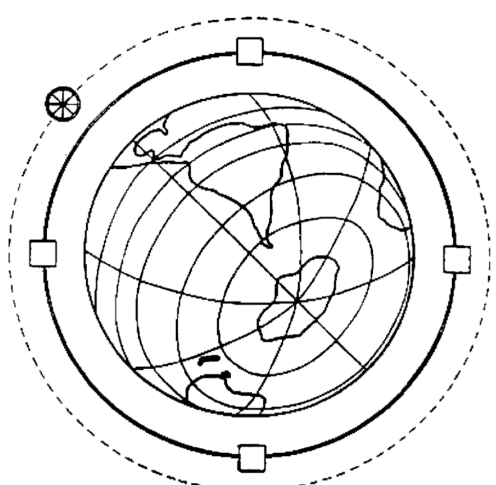

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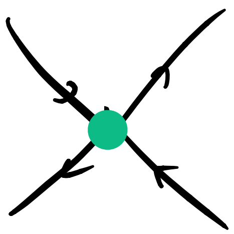

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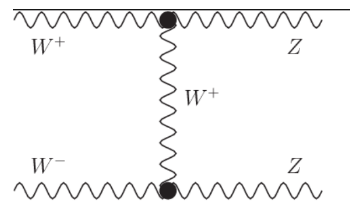

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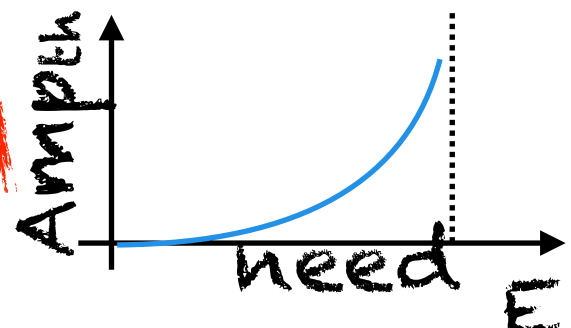

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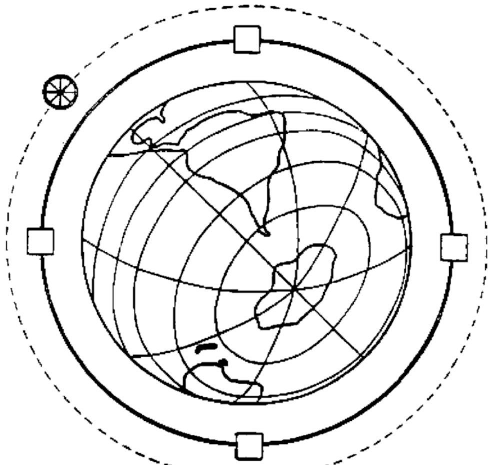

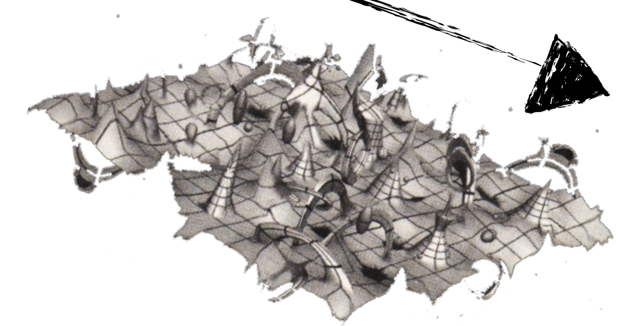

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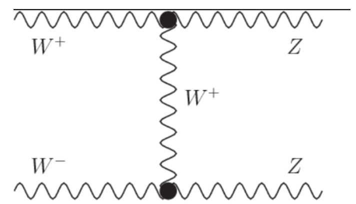

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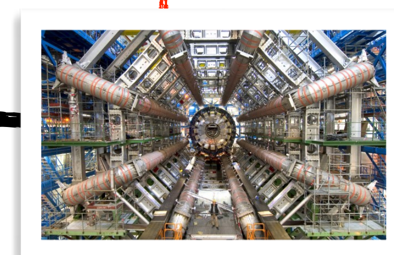

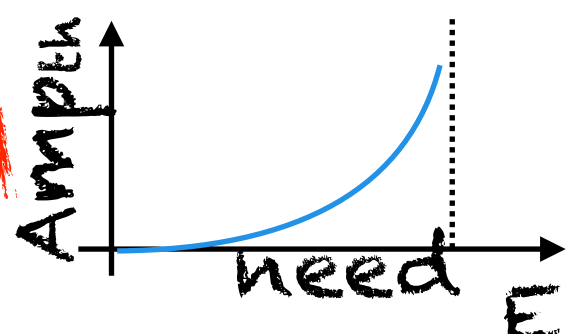

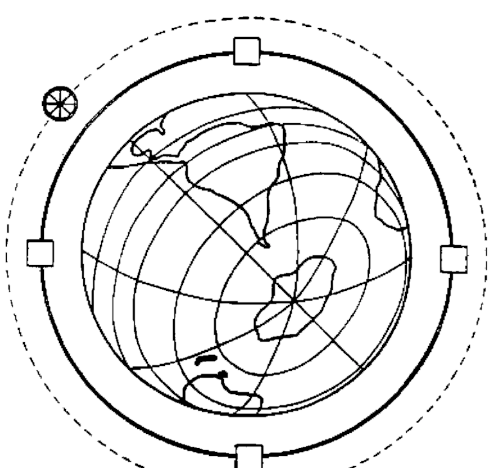

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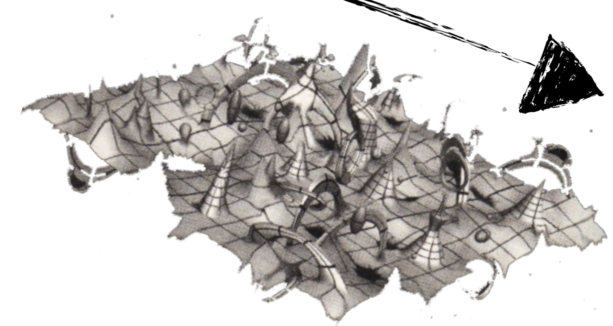

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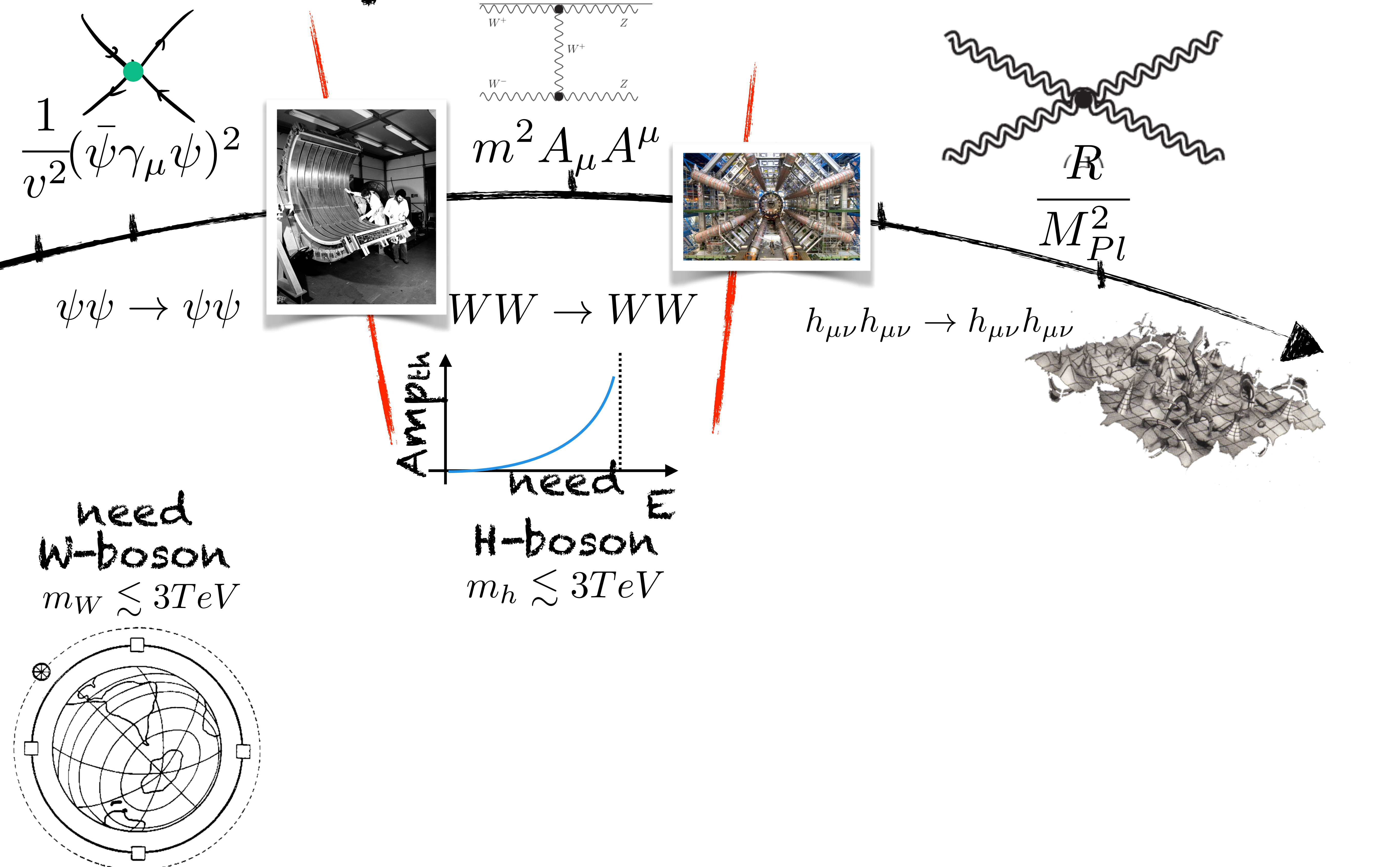

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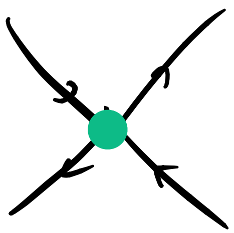

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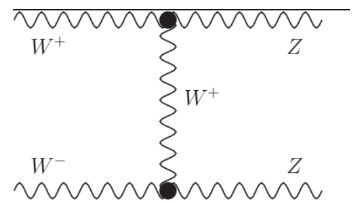

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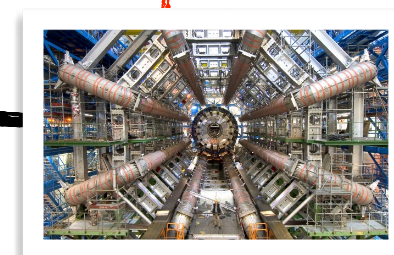
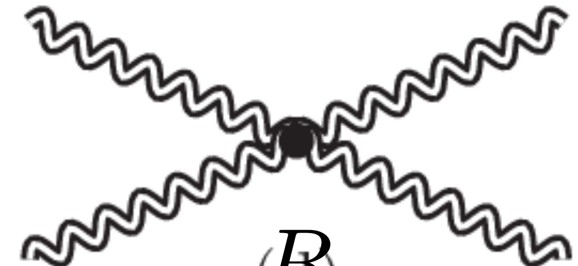
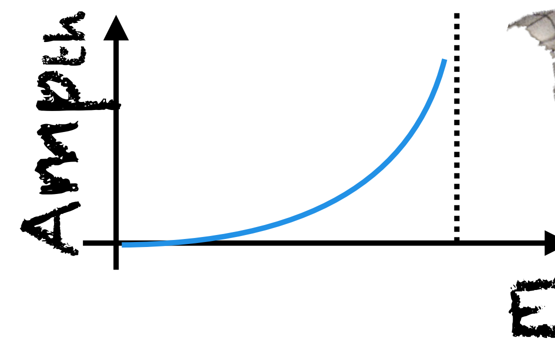
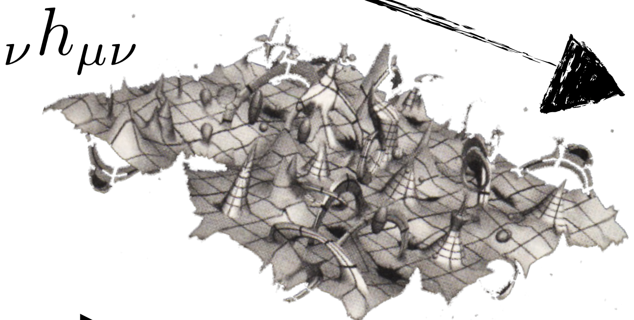




$$\frac{R}{M_{Pl}^2}$$

$h_{\mu\nu}h_{\mu\nu} \to h_{\mu\nu}h_{\mu\nu}$





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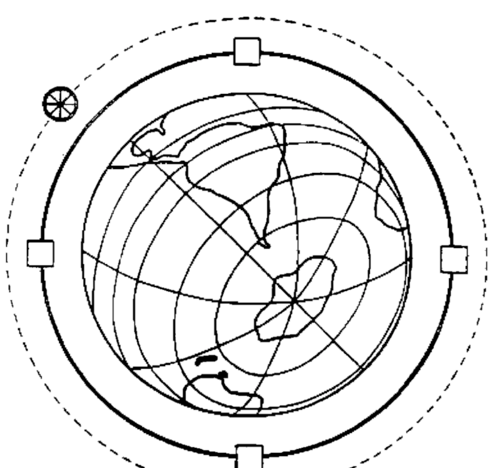

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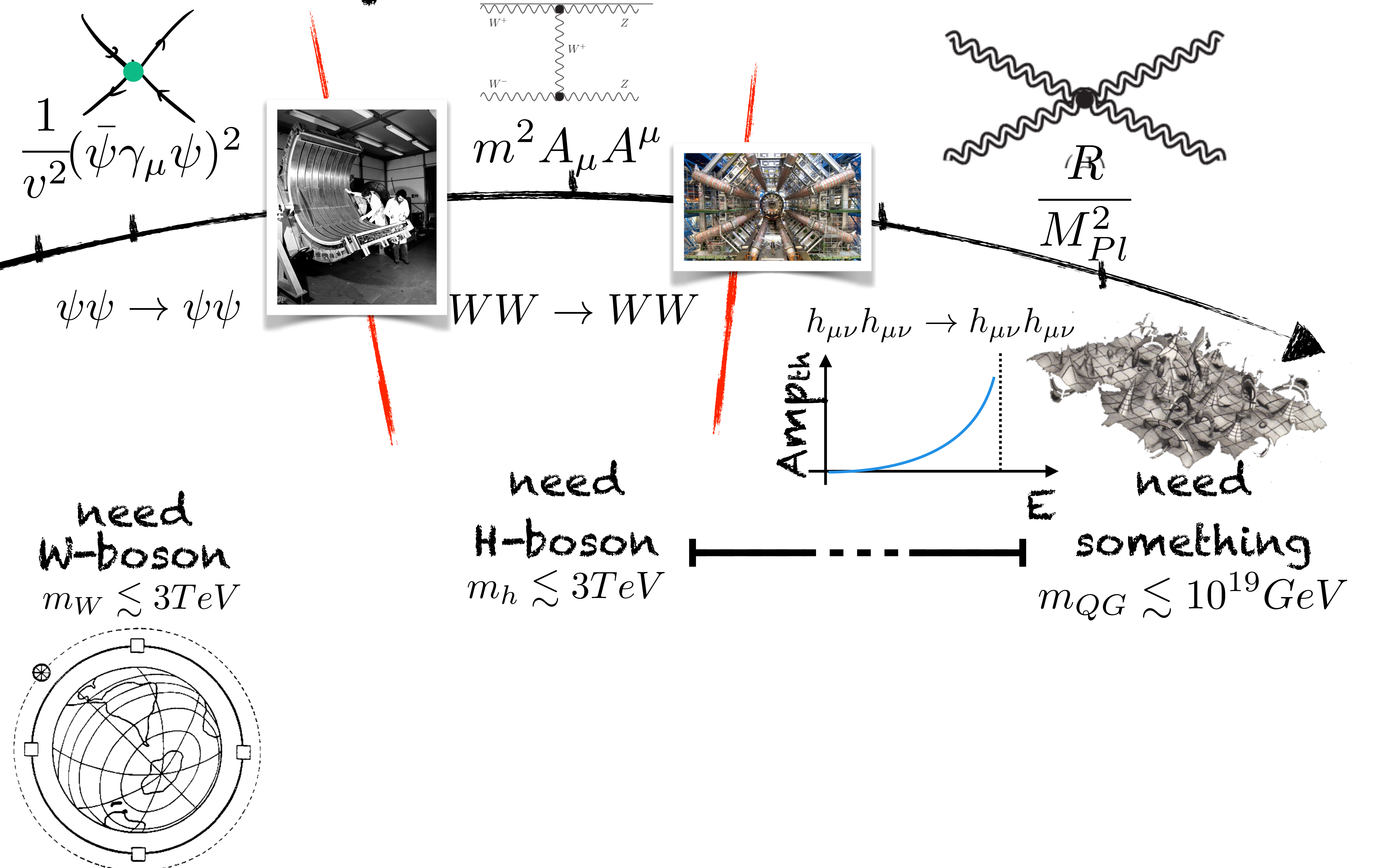

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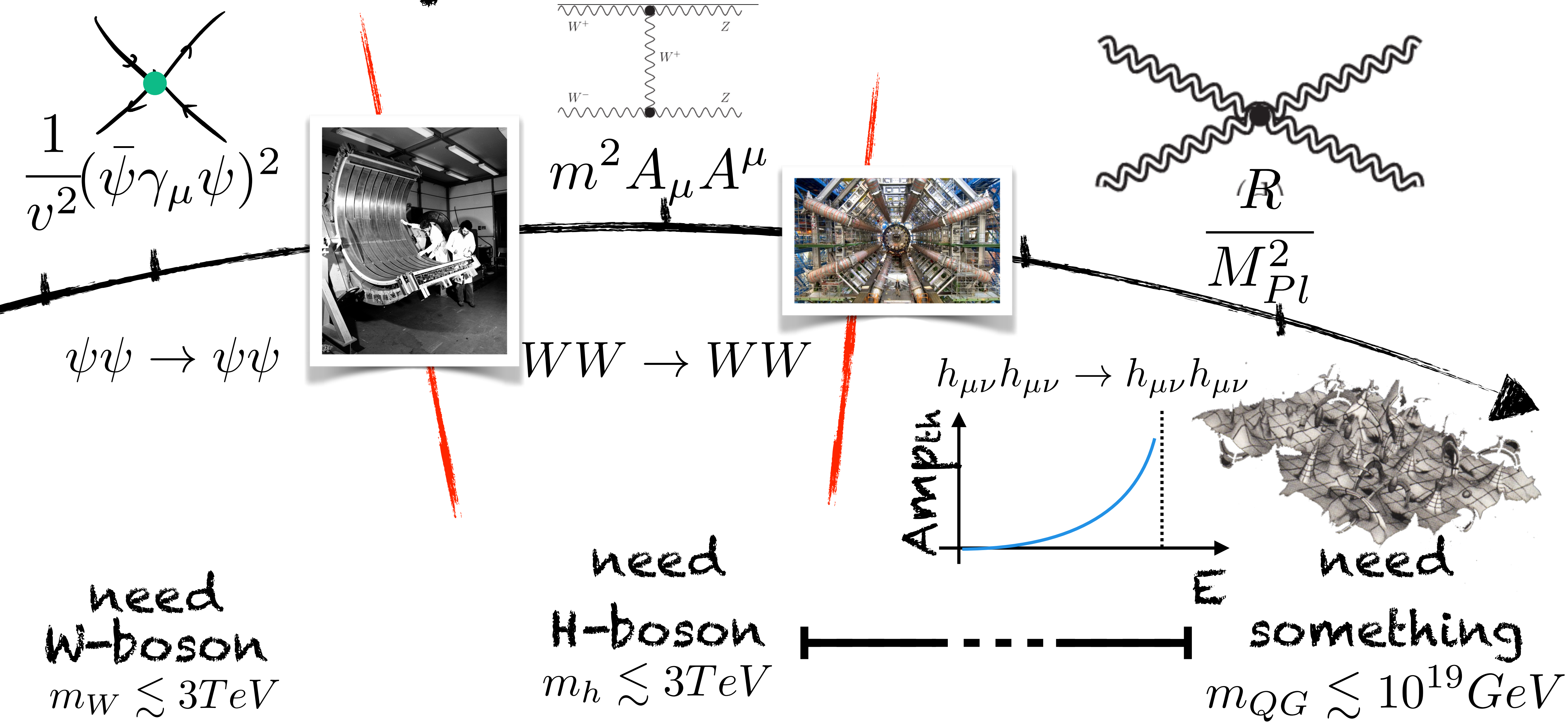

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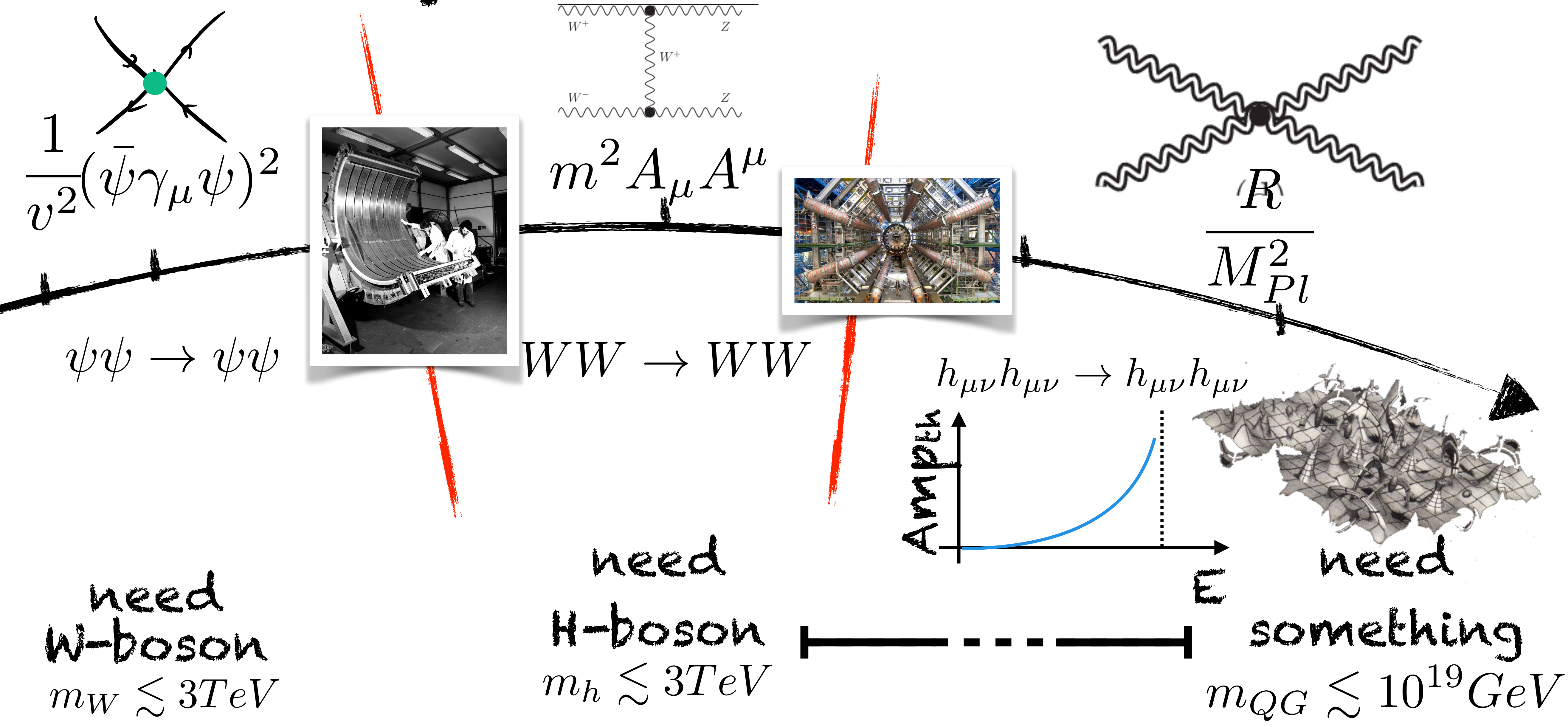

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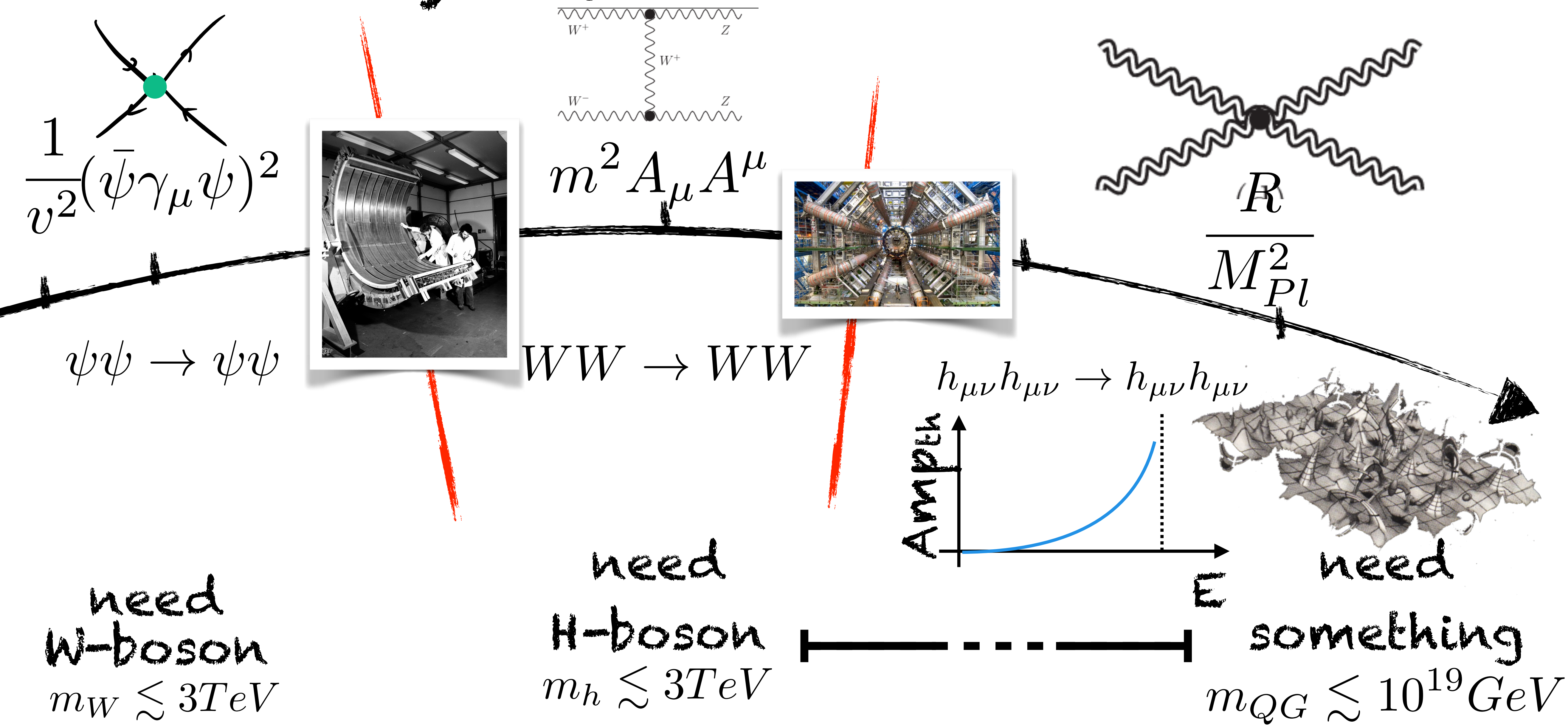
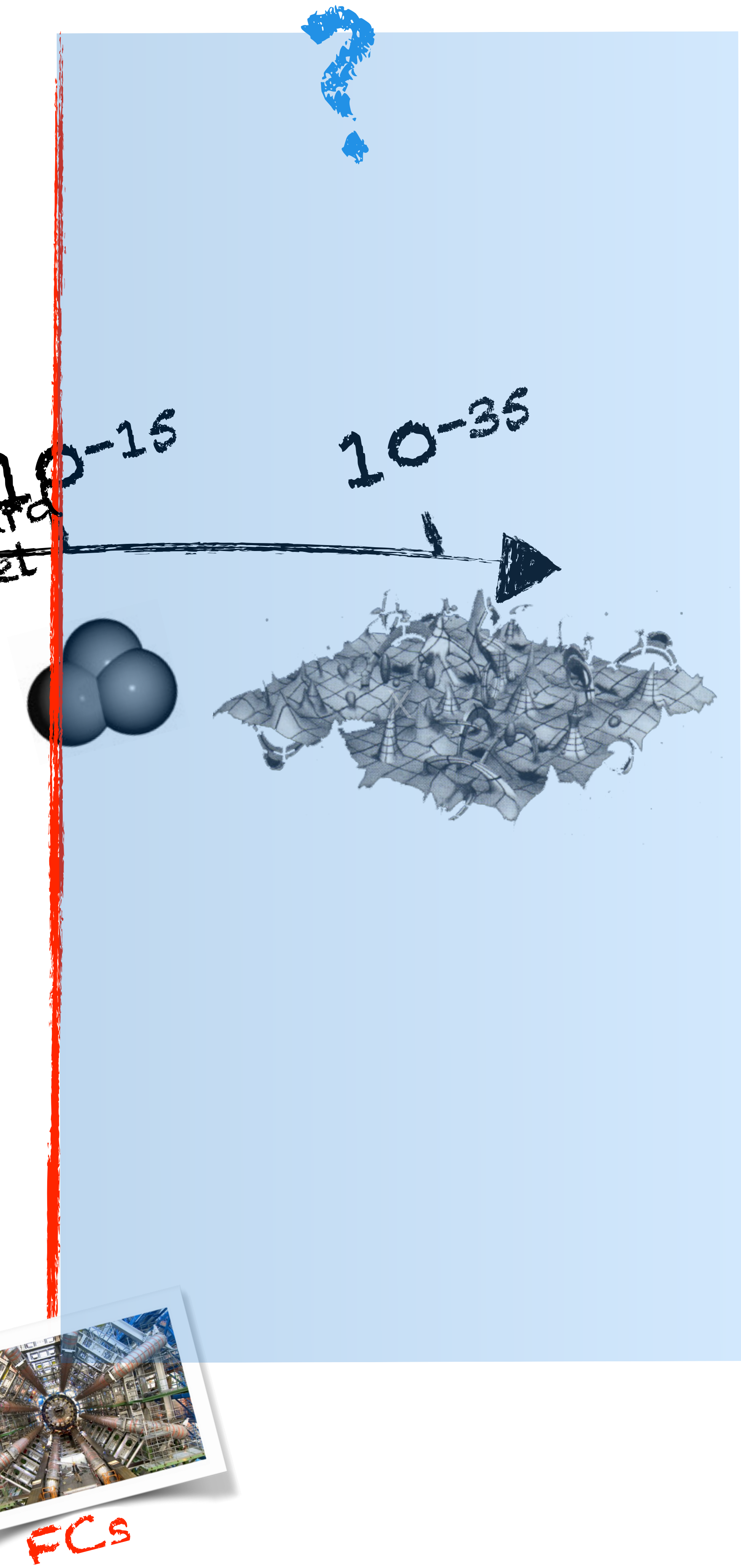


- Exceptional story, but science is not about no lose theorems
- What will we learn from this exploration?

High-Energy Particle Physics Mindset



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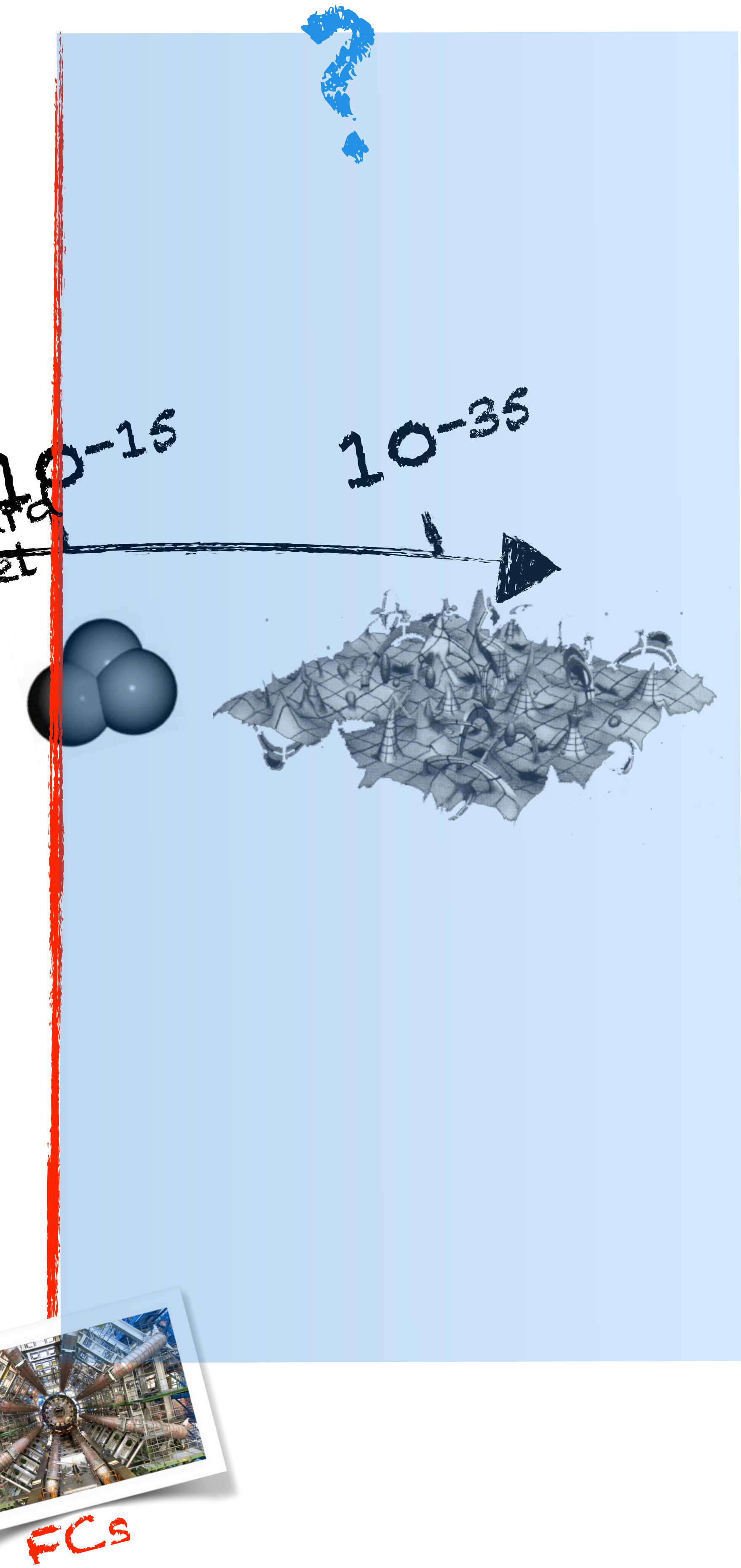

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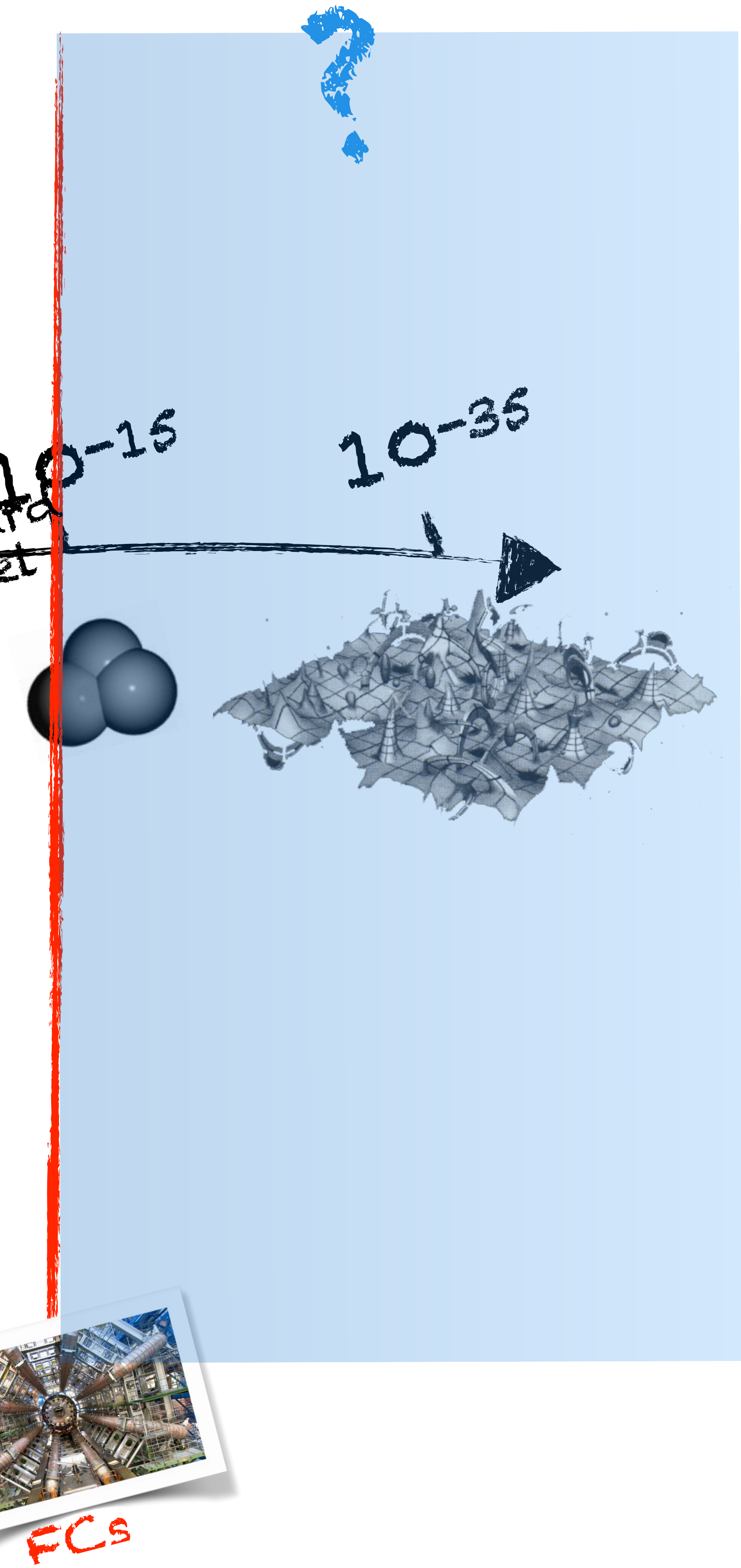

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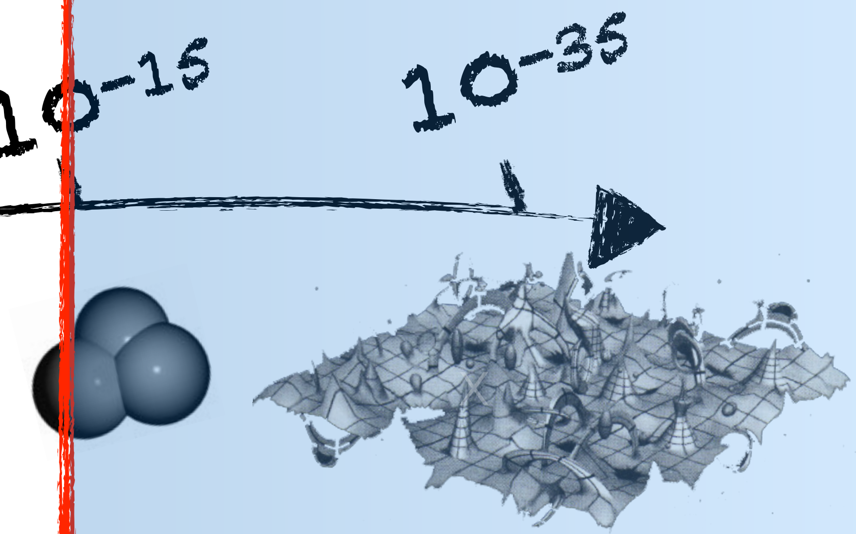
- The SM really is an EFT with many possible features: every new measurement teaches us something new about these

microscopic laws of nature

$$\mathcal{L} = \sum_i c_i \frac{O_i^{(n)}}{\Lambda_i^{n-4}}$$

High-Energy Particle Physics

$$\frac{1}{\Lambda_{\not B}^2}\left[(d_p^{\alpha})^T C u_r^{\beta}\right]\left[(q_s^{\gamma j})^T C l_t^k\right]$$

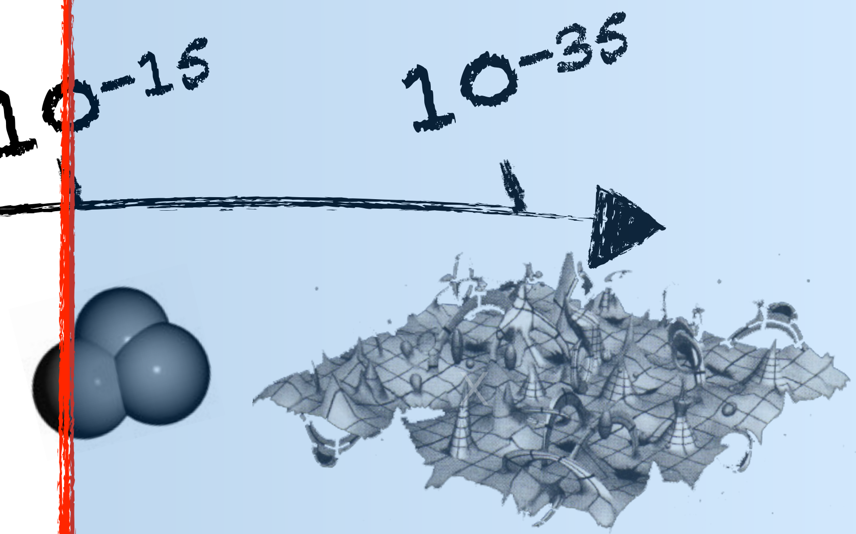


FCs

High-Energy Particle Physics

$$\frac{1}{\Lambda^2_{\not B}}[(d_p^{\alpha})^T C u_r^{\beta}]\,[(q_s^{\gamma j})^T C l_t^k]$$

Proton Lifetime $t_p > 10^{34} y$



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$\Lambda_{\not B} > 10^{16}\,\mathrm{GeV}$

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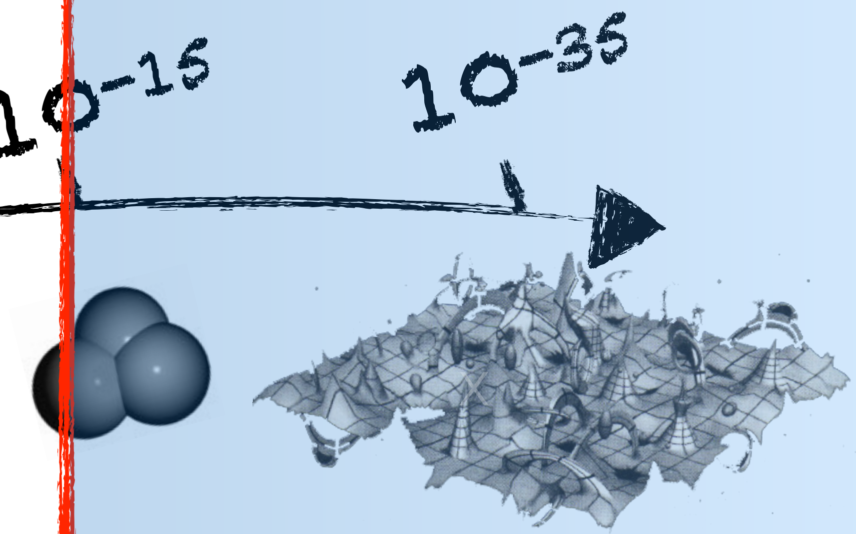

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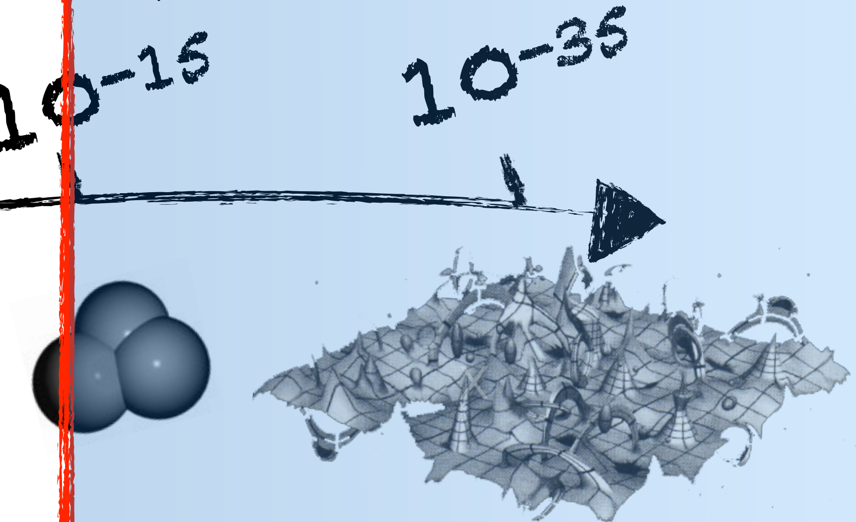
$\Lambda_{\not{L}} > 10^{14}\,\mathrm{GeV}$ $\qquad \frac{1}{\Lambda_{\not{L}}}\,(\widetilde{\varphi}^{\dagger} l_p)^T C (\widetilde{\varphi}^{\dagger} l_r)$ **Neutrino mass** $m_{\nu} \sim 0.1\,\mathrm{eV}$



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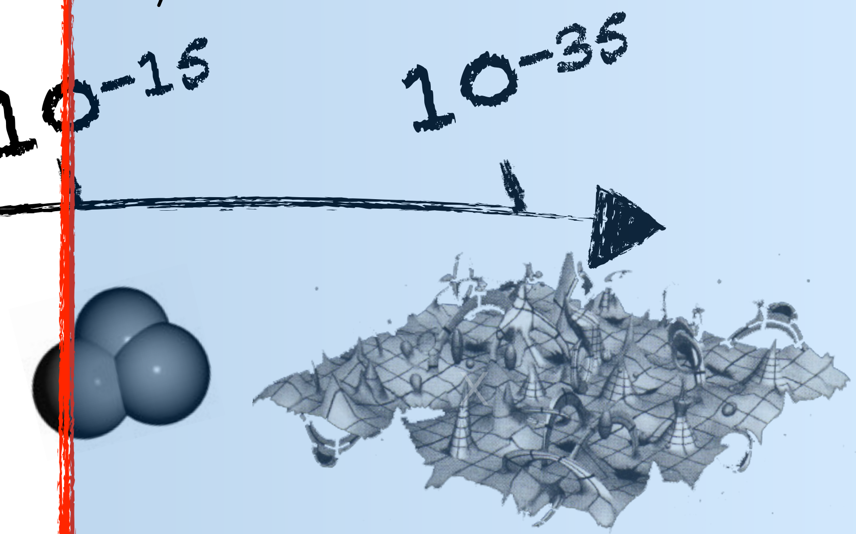

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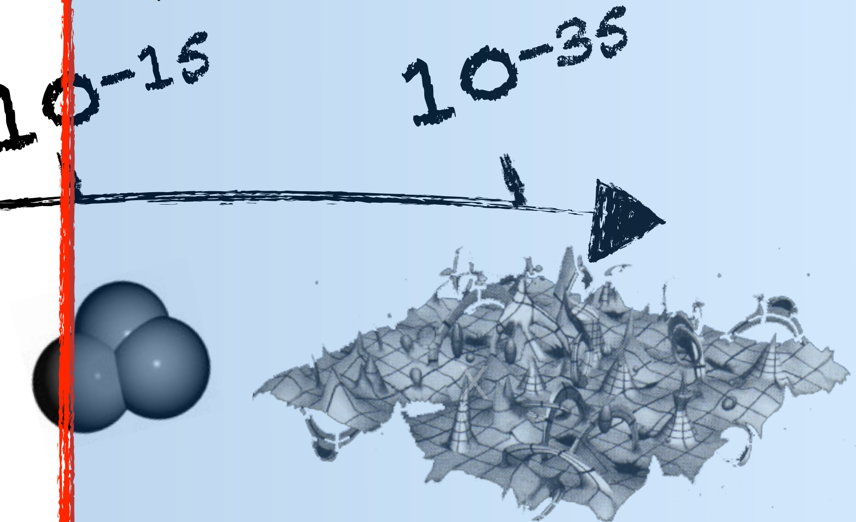

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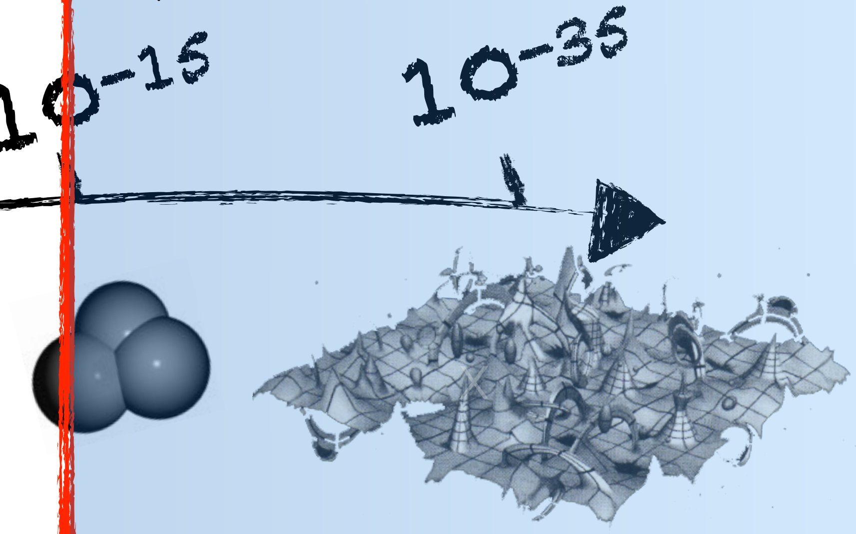

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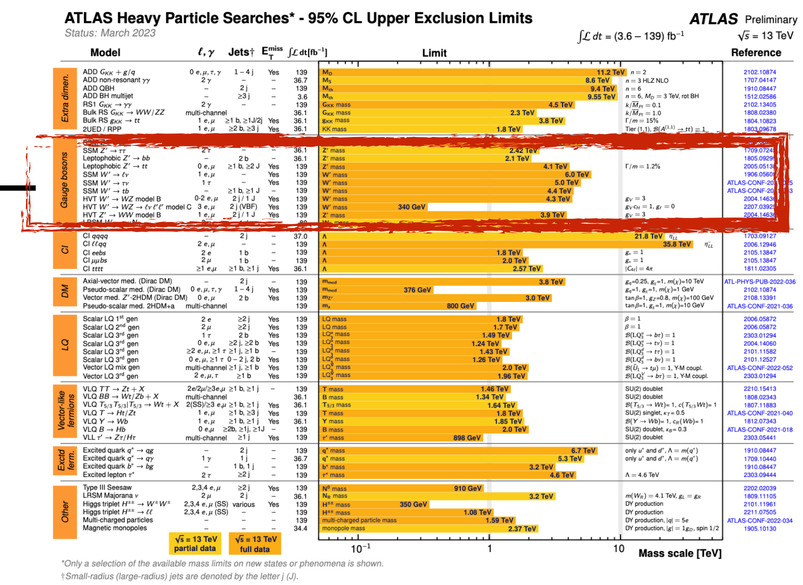

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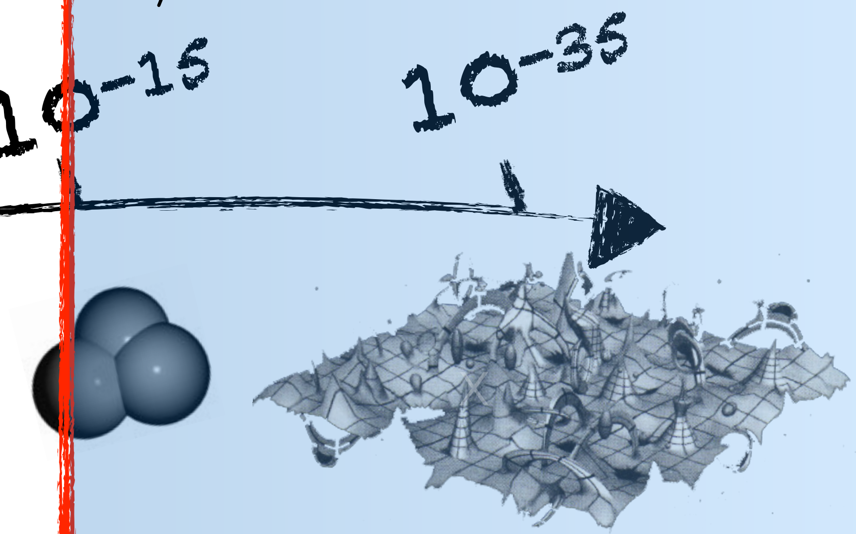

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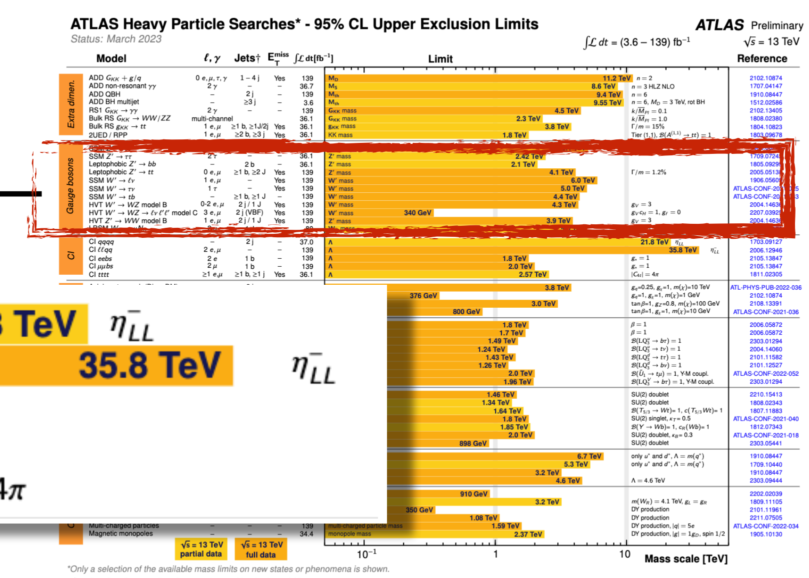

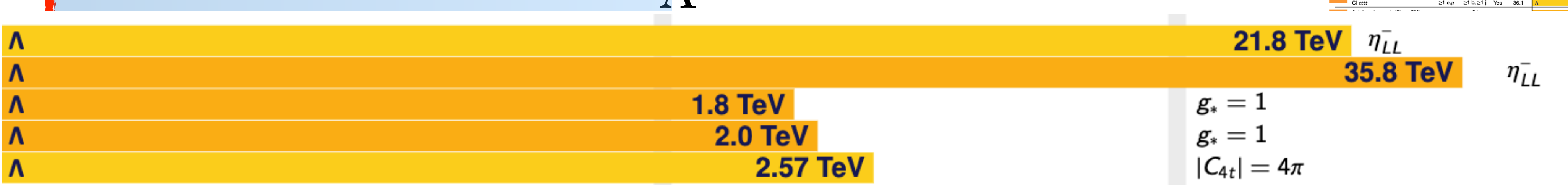

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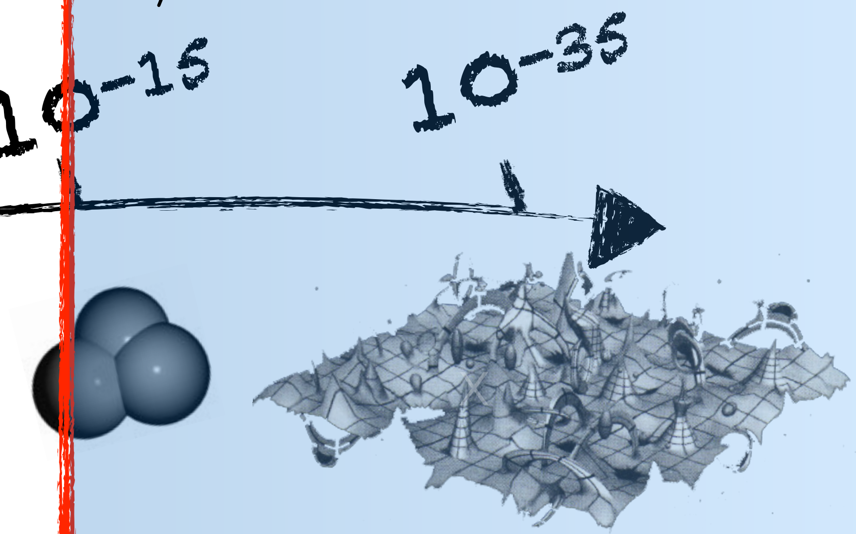

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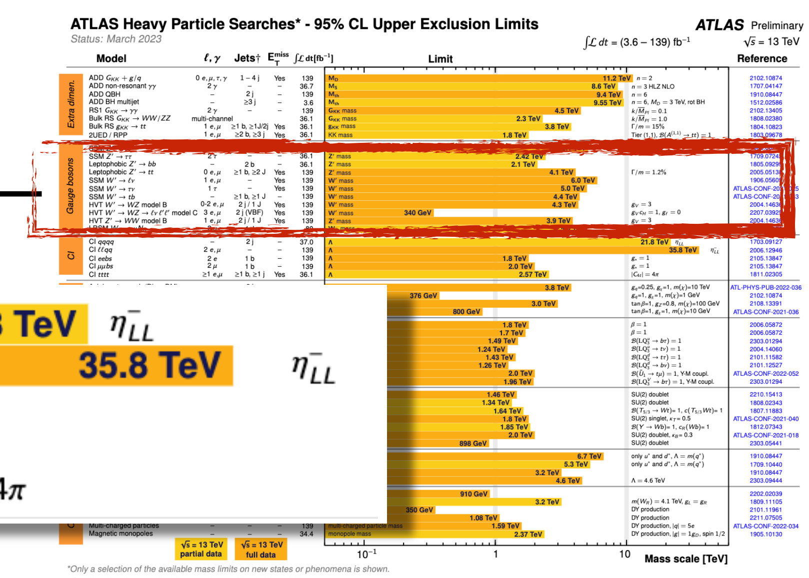

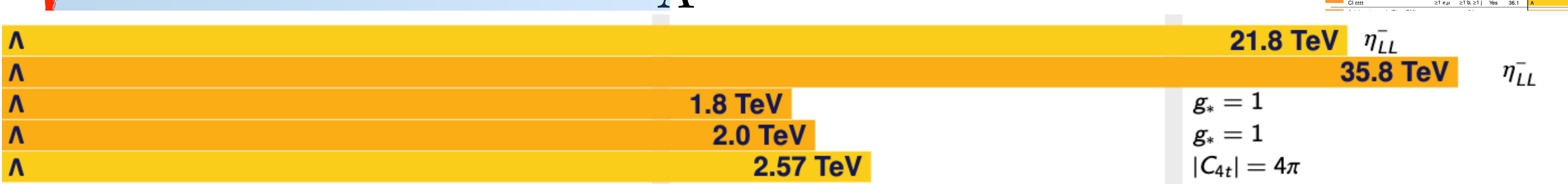

- Quark/Lepton size smaller than 10^{-20} m

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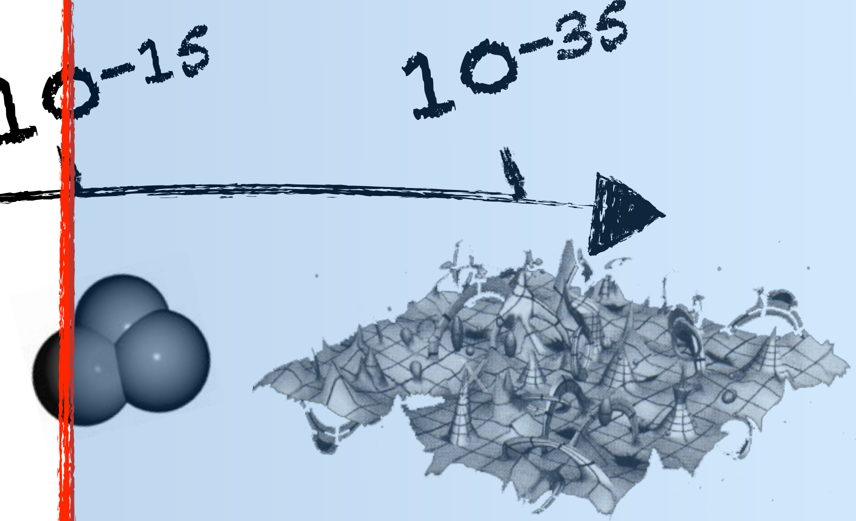

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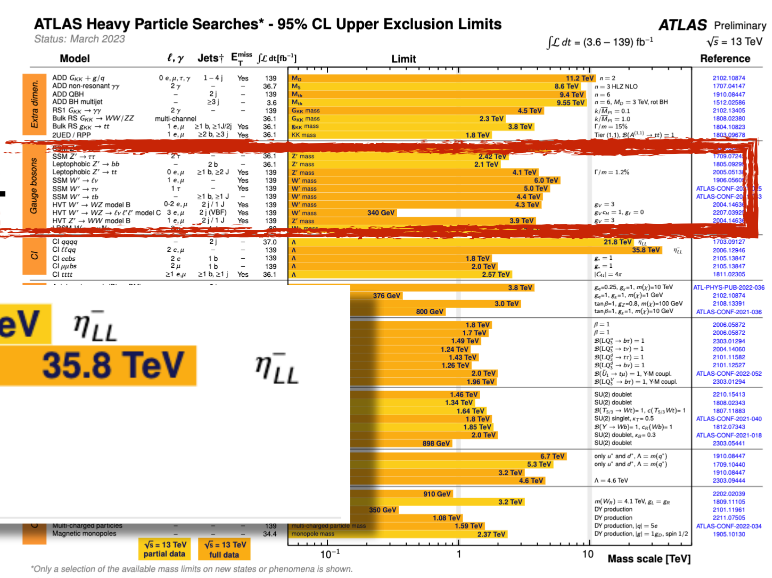

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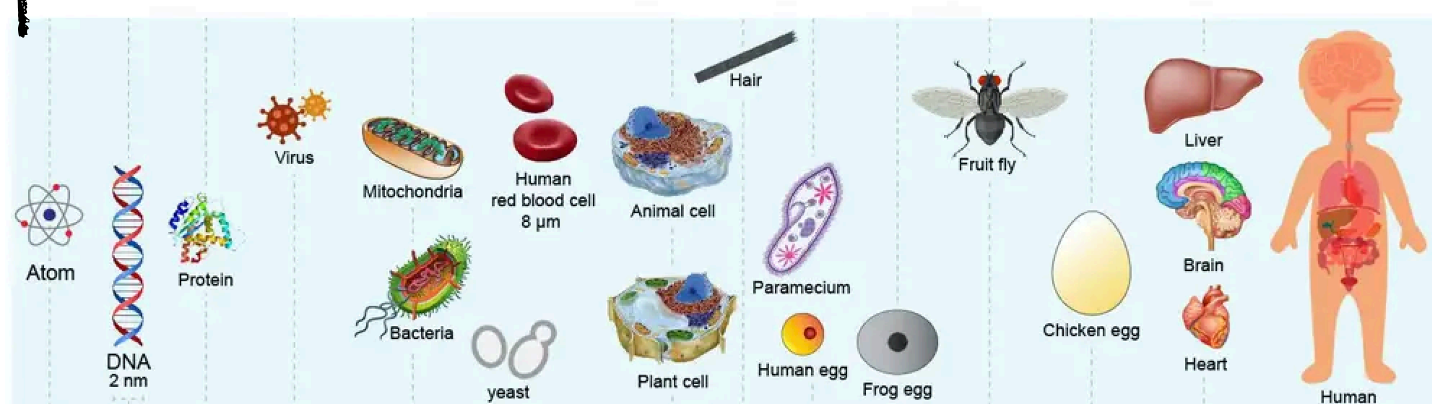

FCs

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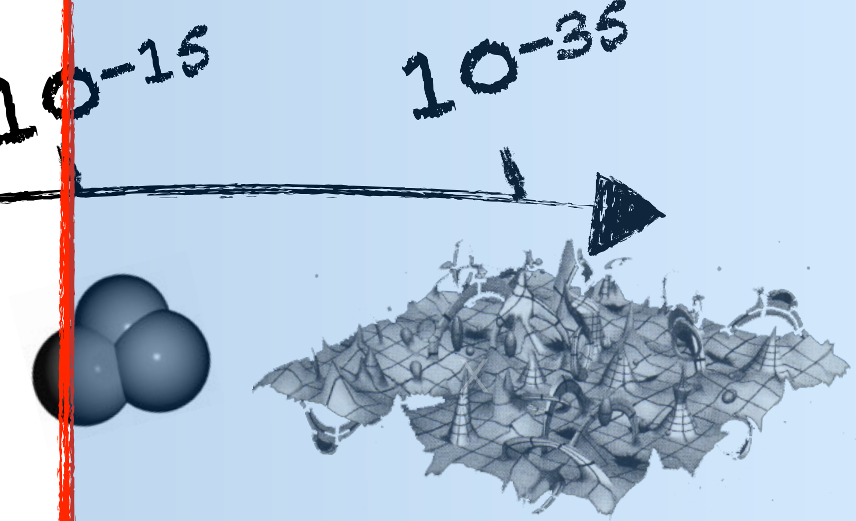

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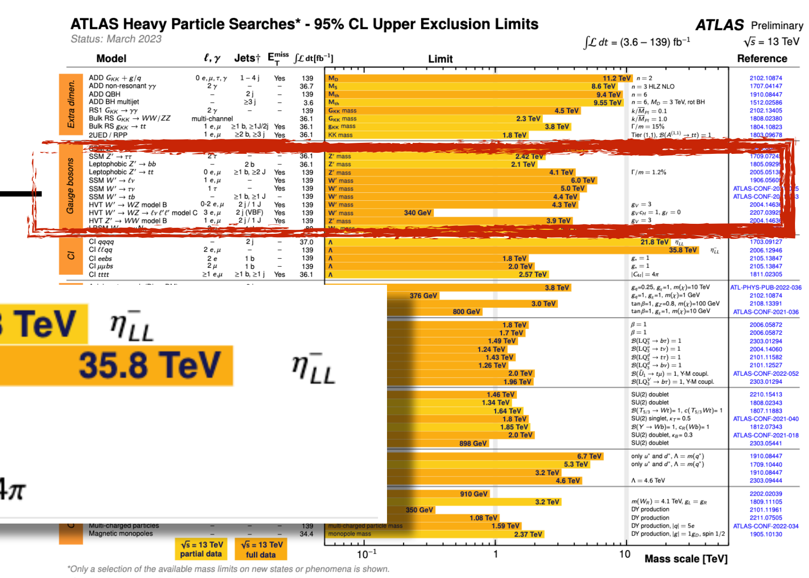

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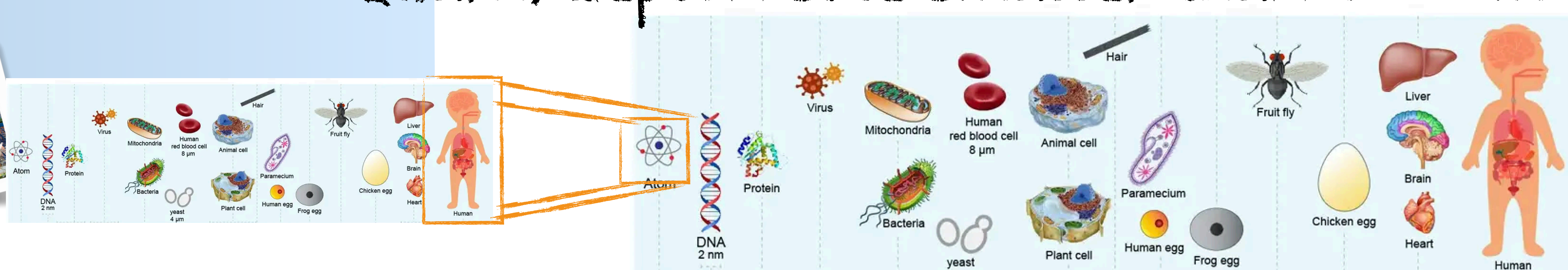

If you have to chose on ONE question for future colliders, what will it be?

(for me...)

What is the size of the Higgs boson?

The size of spin-0 particles in HEP

$$L_{compton} \sim \frac{1}{m}$$

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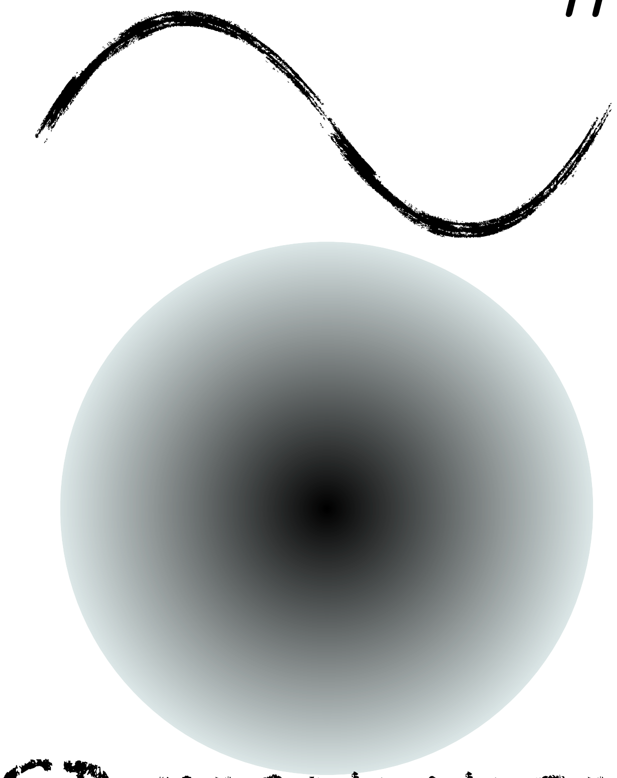

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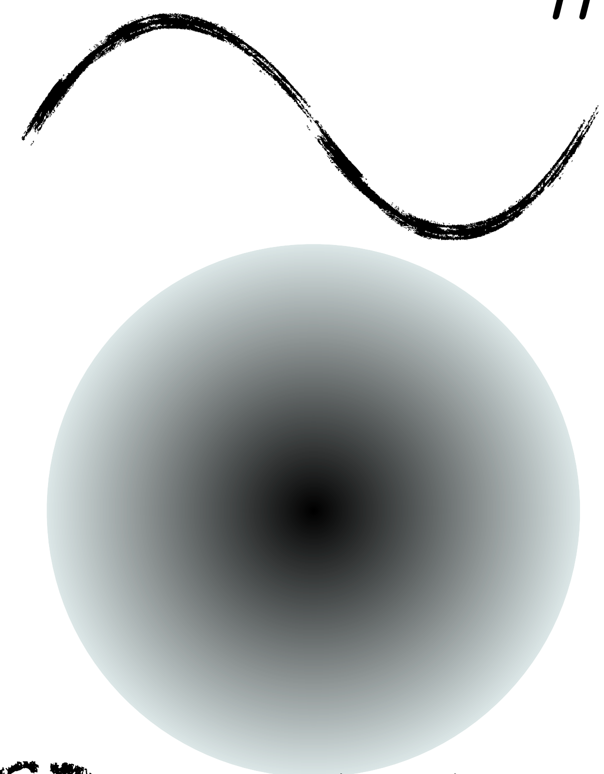

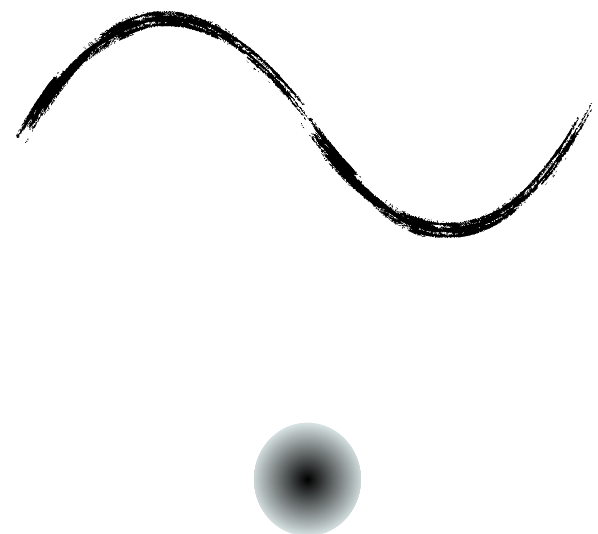

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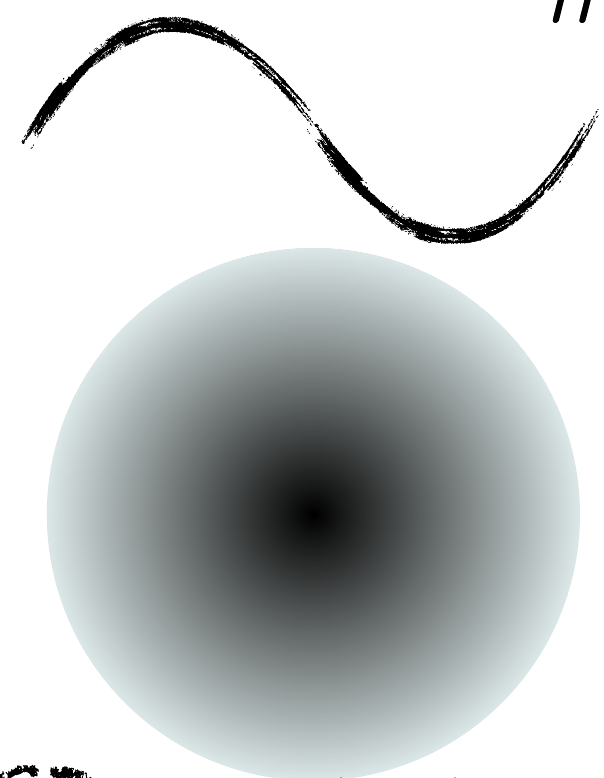

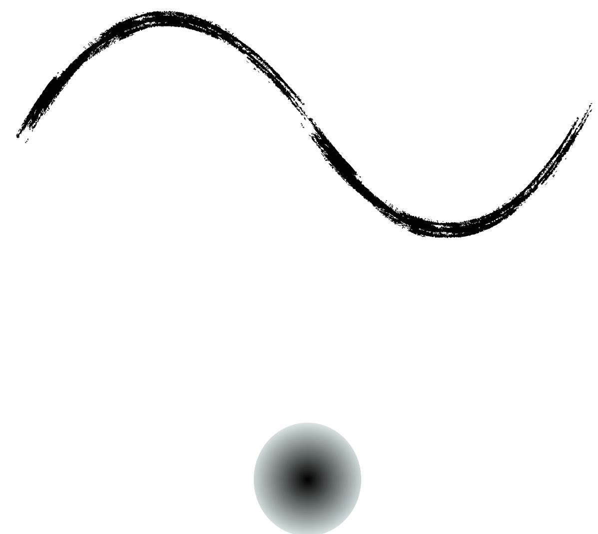

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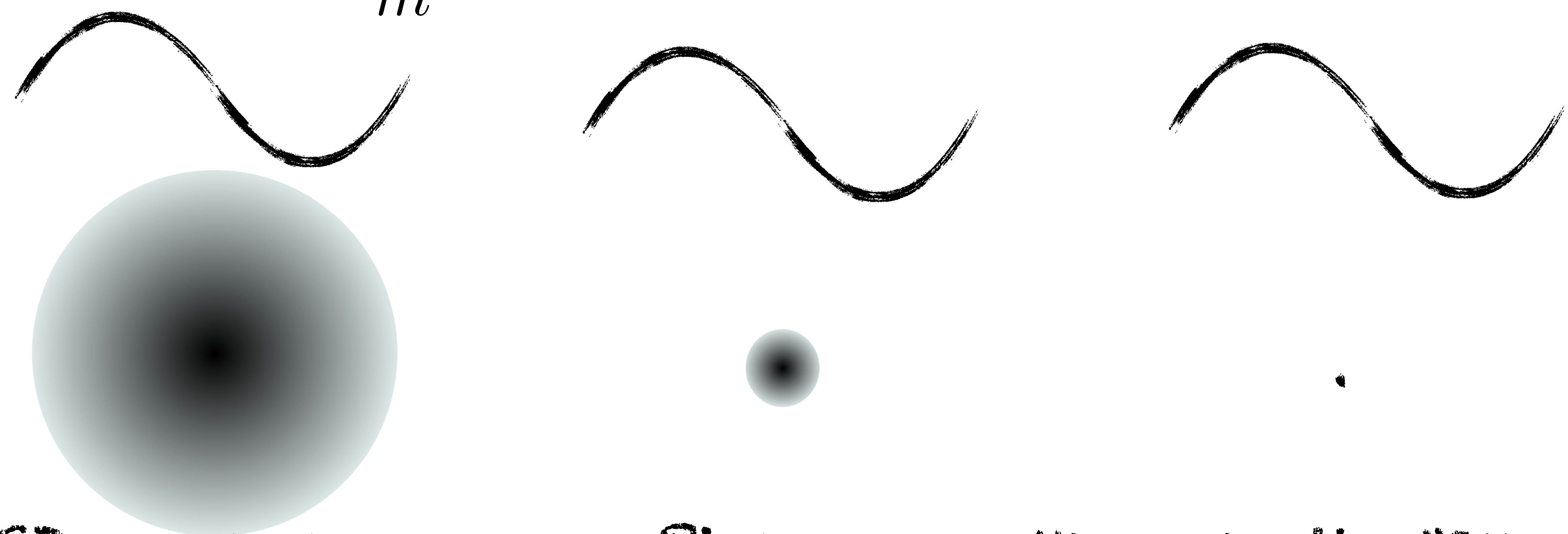

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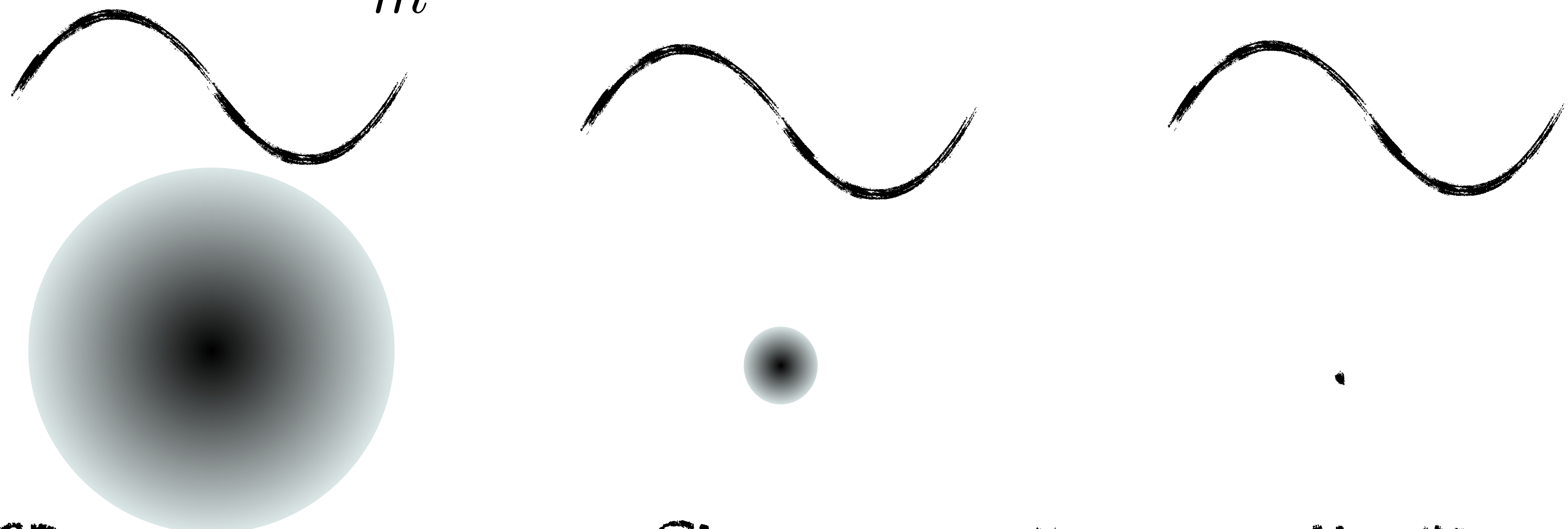

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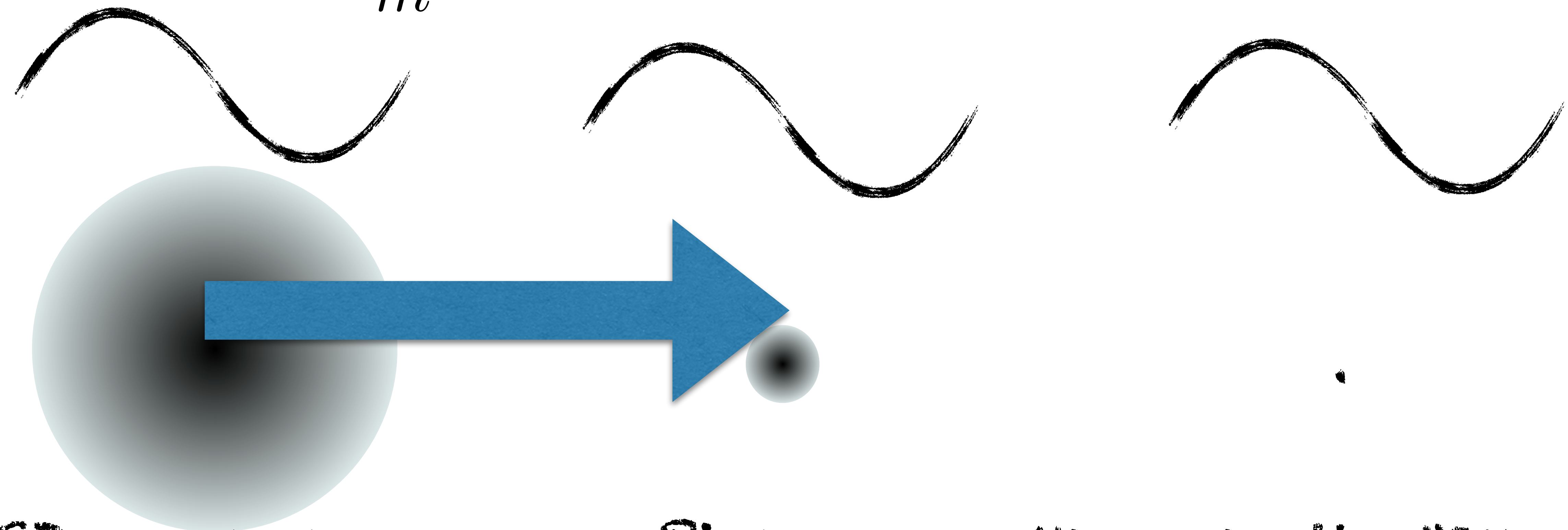

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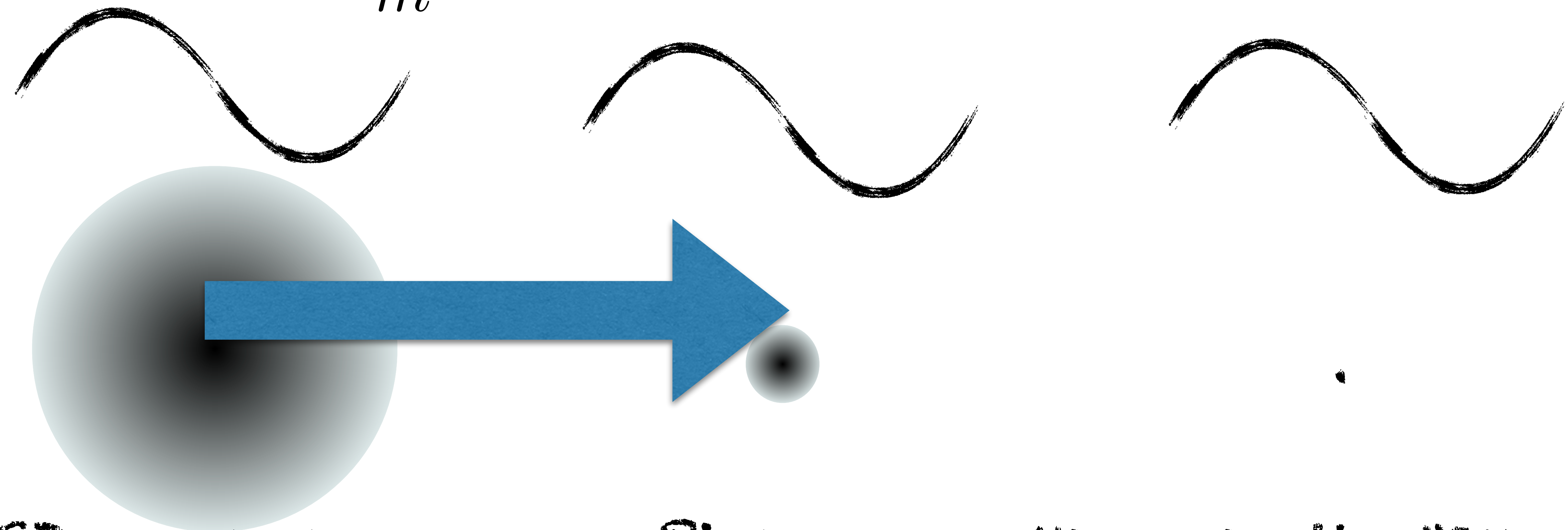

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Intuitively*: as localized to smaller distances, quantum fluctuation have large energy/mass

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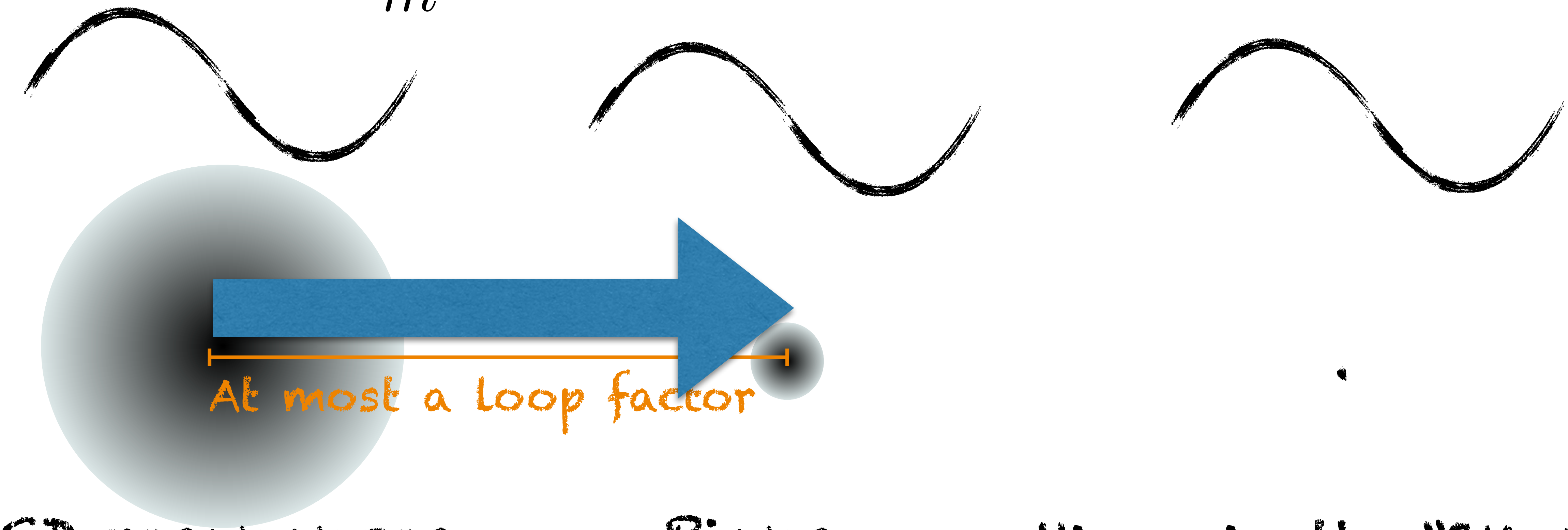

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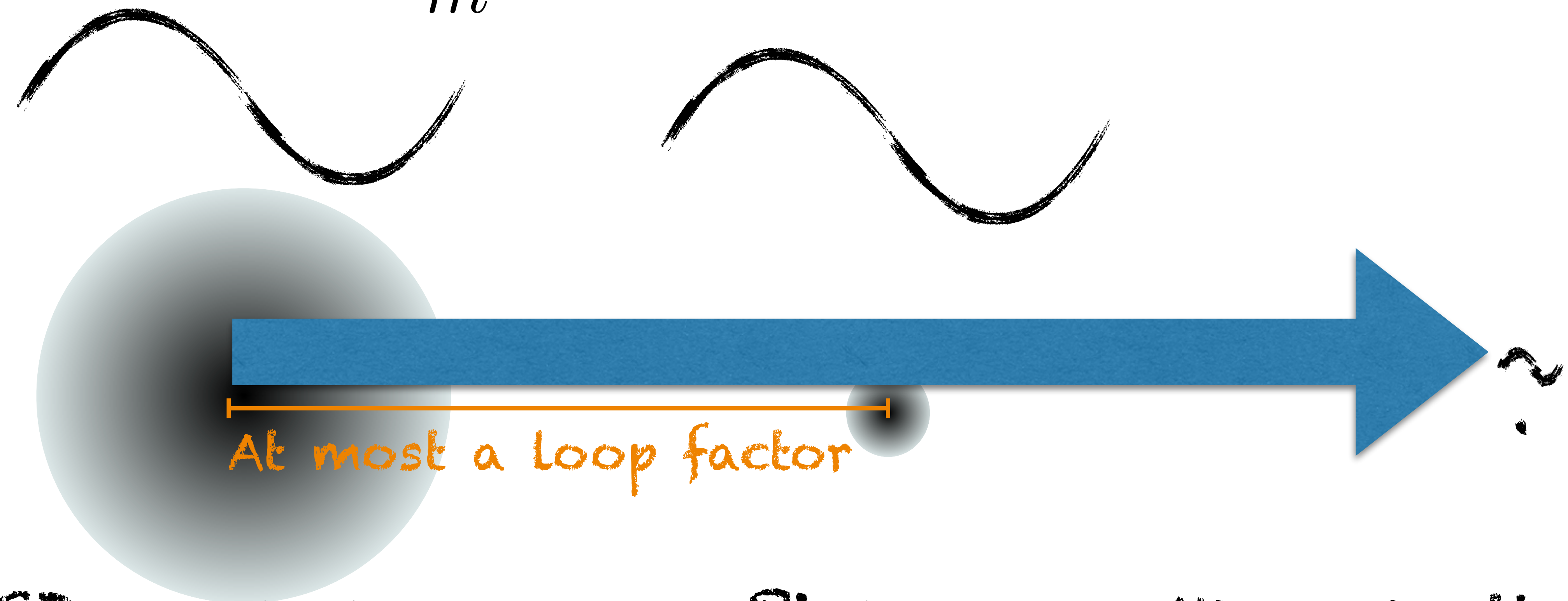

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The size of the Higgs

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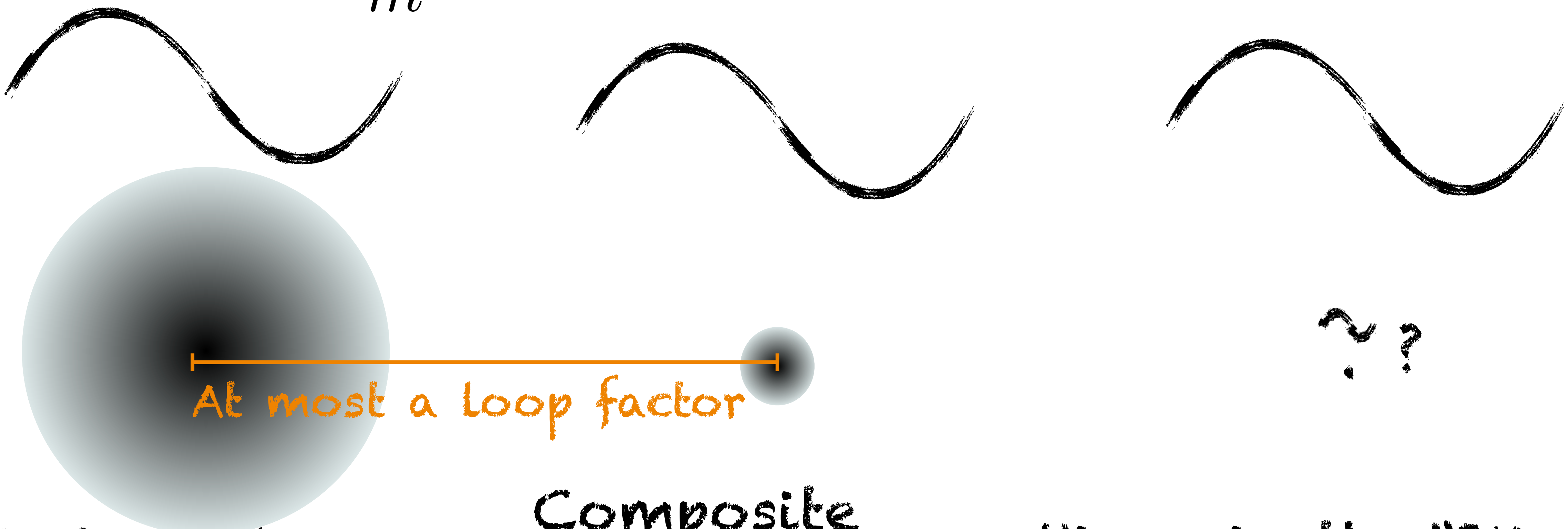

Technicolor

$$L \sim \frac{1}{m} \sim \frac{1}{125GeV}$$

Composite PGB Higgs

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At most a loop factor

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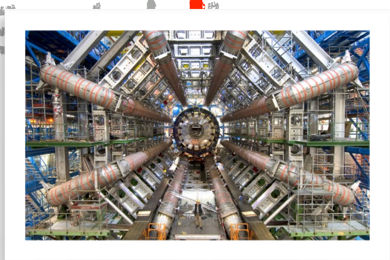

LHC

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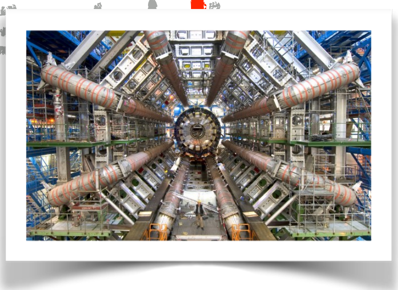

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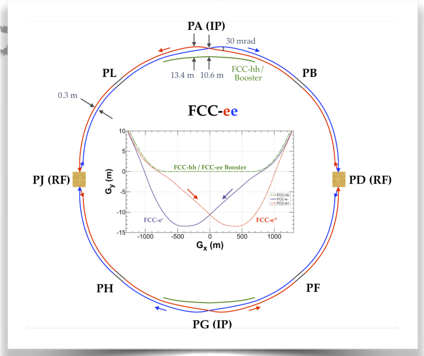

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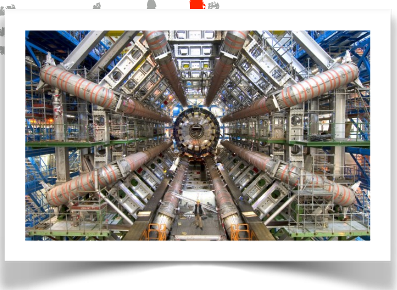

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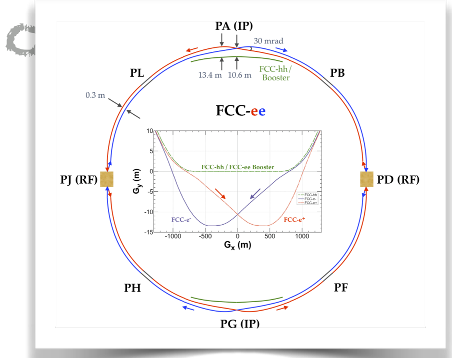

FCs

Future colliders will tell us how much the Higgs resembles one of the spin-0 particles that we already know, by measuring its size

Is this a good question for e+e- machines?

To create composites with size, we need UV theories that are strongly coupled,

$$g_* \gtrsim 1$$

These have particles with substructure, like pions or protons, but are also little understood and unexplored.

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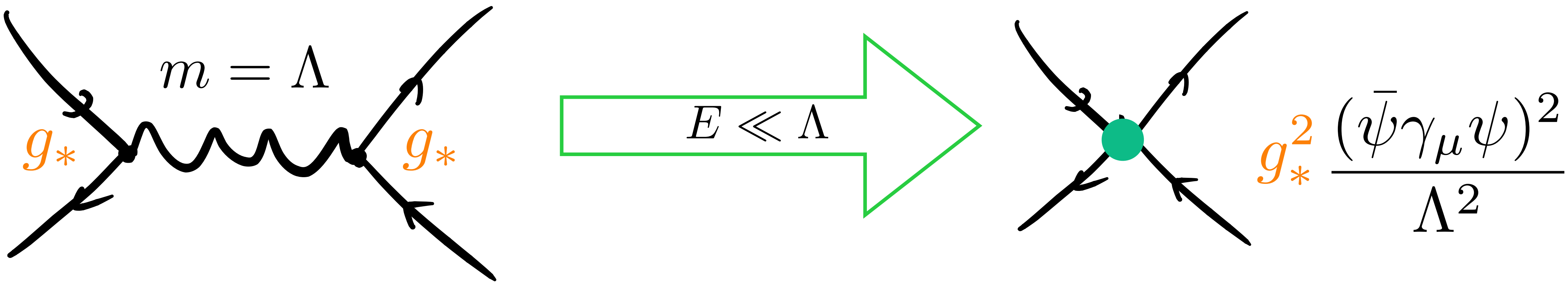

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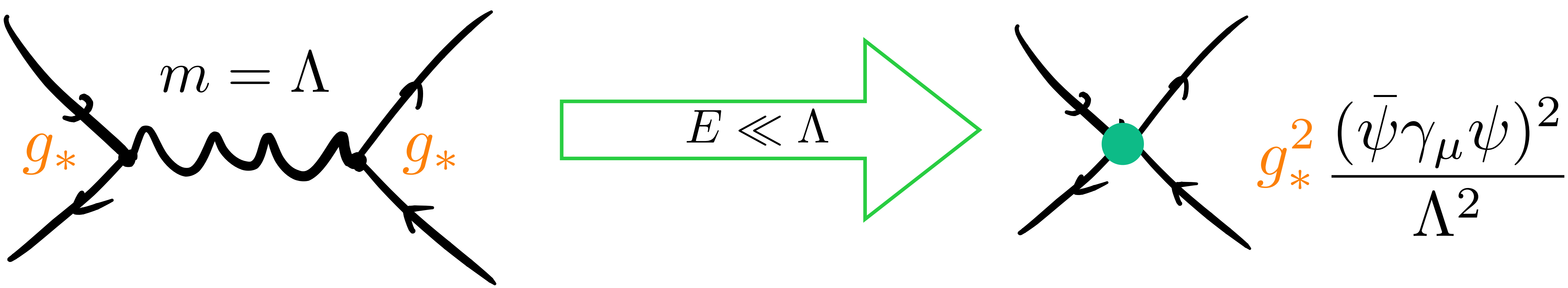
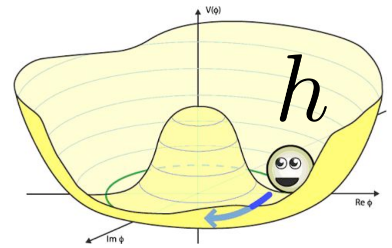


- Strongly coupled theories are the ones that have the largest effects in EFTs and are more visible at FCCee!

A Higgs smaller than its size?

To be composite and lighter than its size, it must be a (Pseudo) Goldstone Boson:



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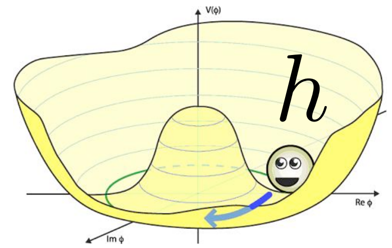

SM		BSM
h	→	$\sin\frac{h}{f} = \frac{h}{f} - \frac{h^3}{3!f^3} + \cdots$
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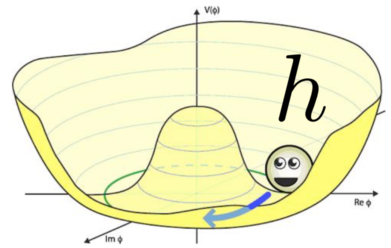

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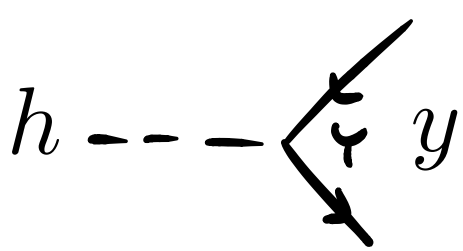
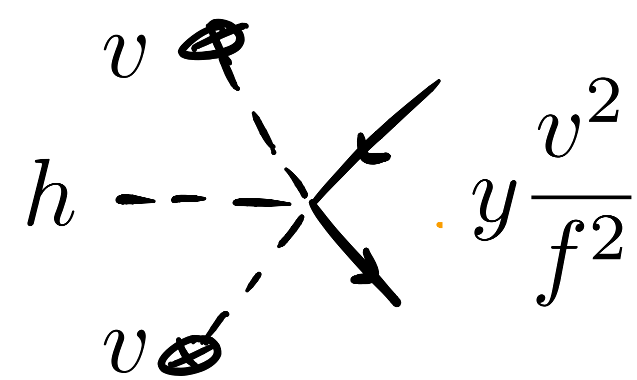




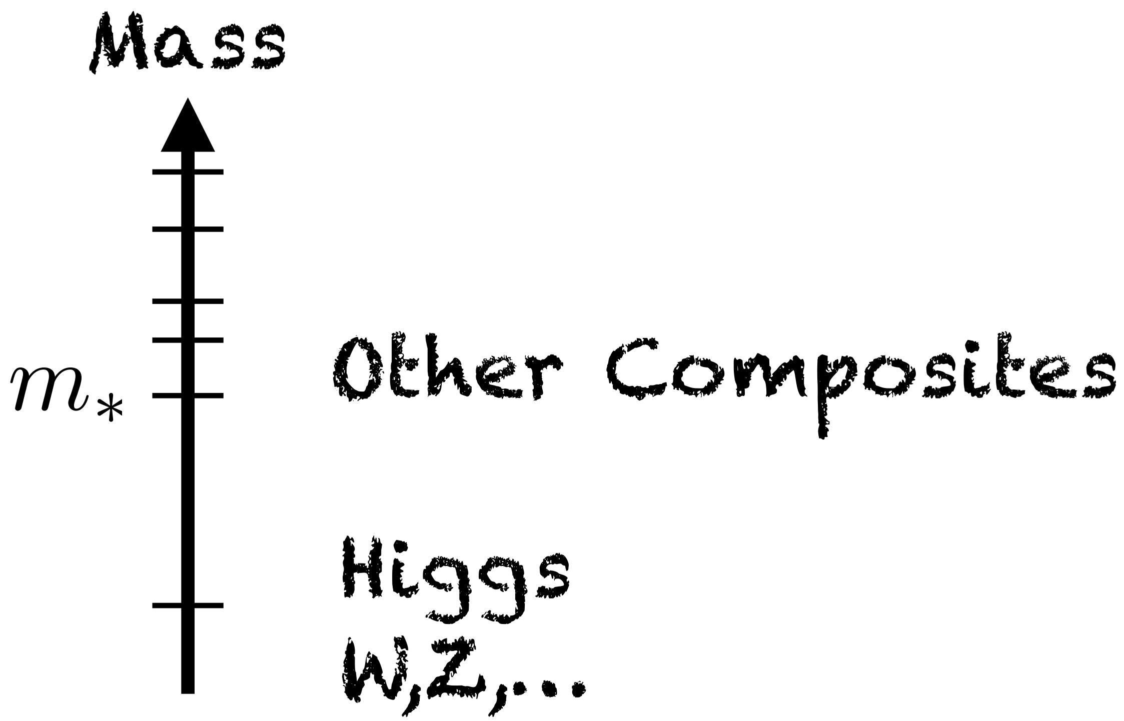
tree-level **Higgs Couplings** are modified

Strongly Interacting Light Higgs

Giudice,Grojean,Pomarol,Rattazzi'08

The same constituents that make up the Higgs can make up other composites with

$$m_* \sim \frac{1}{L_H}$$



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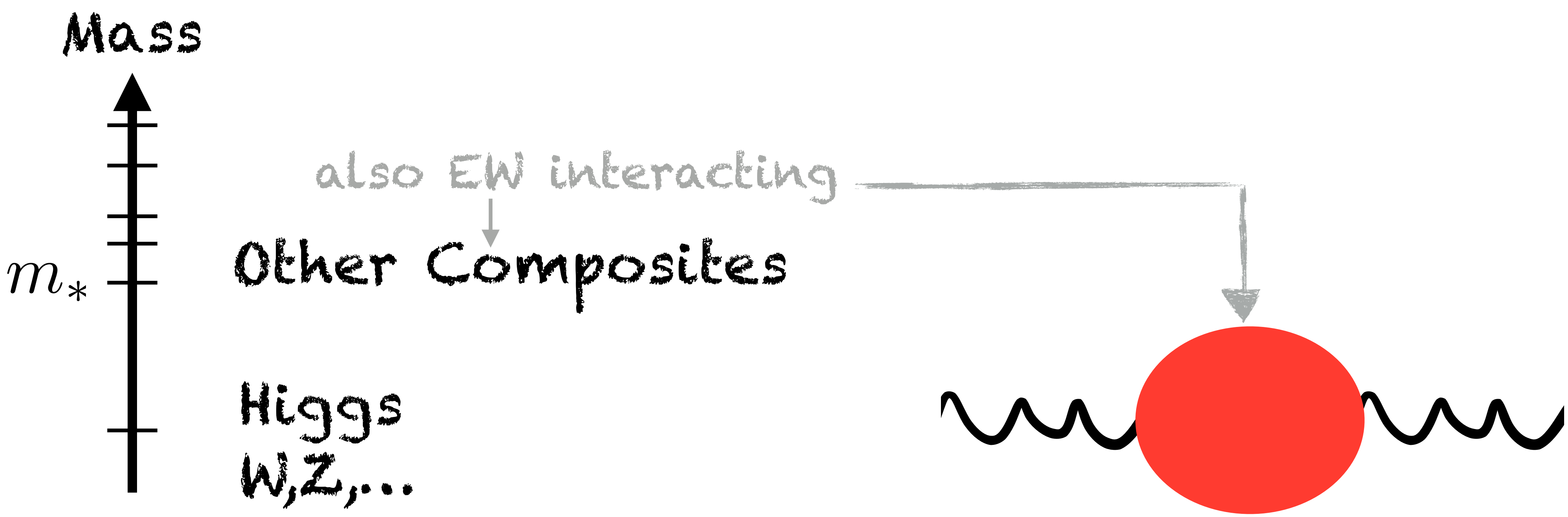

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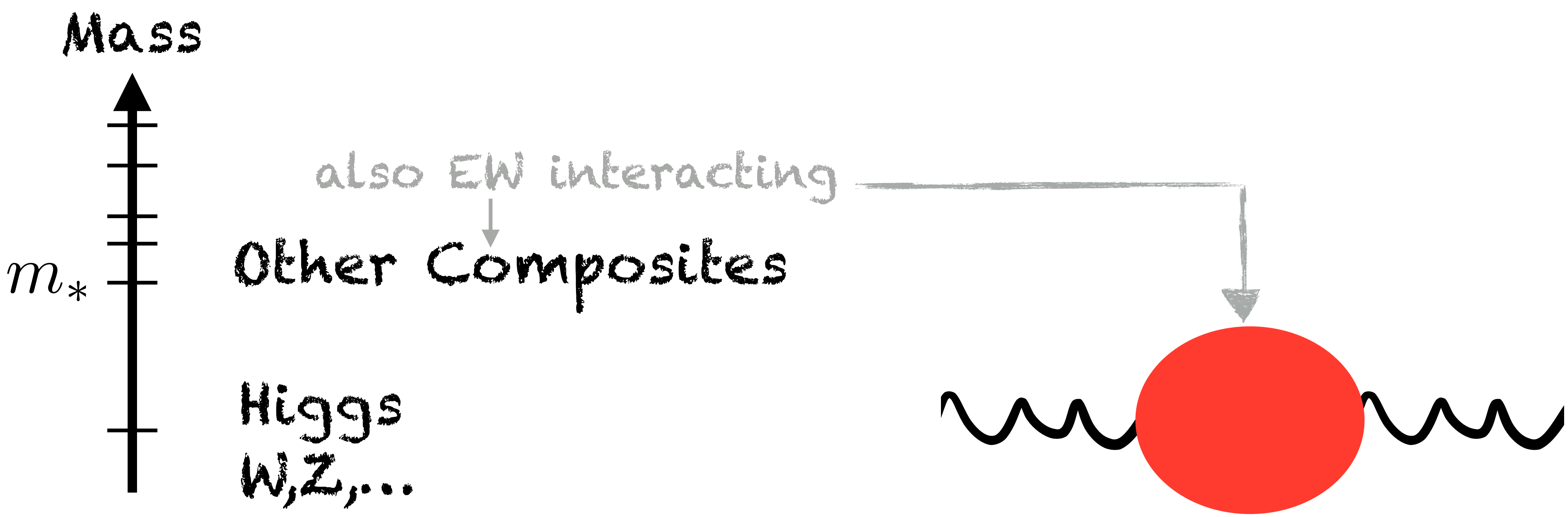

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modify Z-boson propagation (S-Parameter)

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Higgs size reflected into EFT effects:

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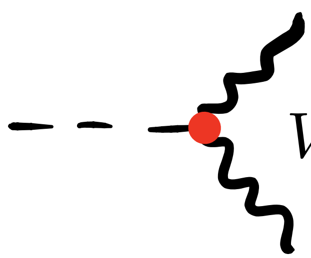

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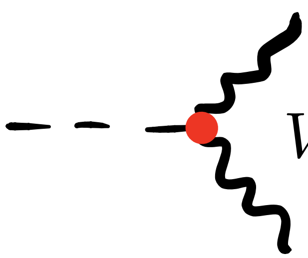

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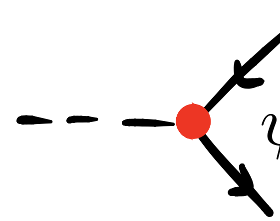

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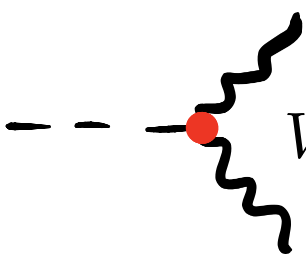

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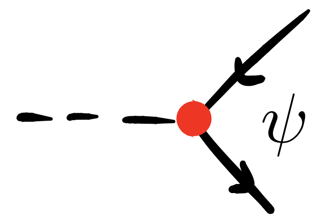

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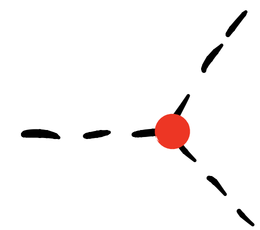

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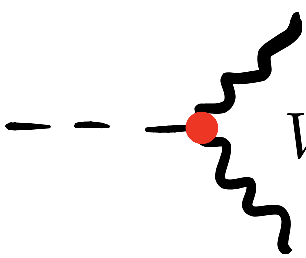

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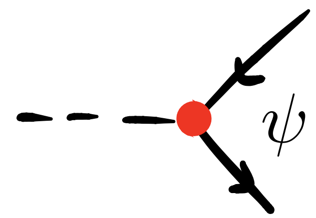

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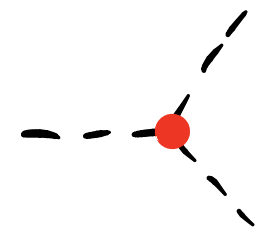

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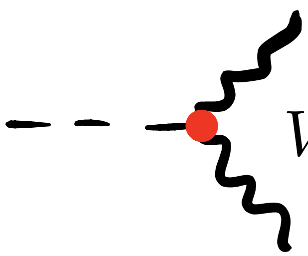

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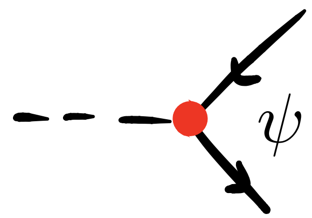

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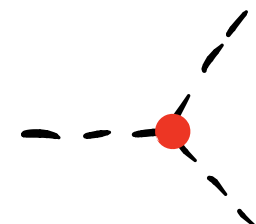

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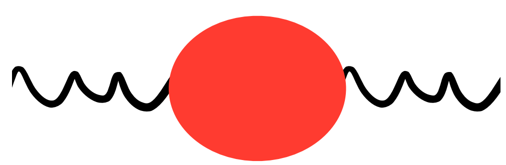

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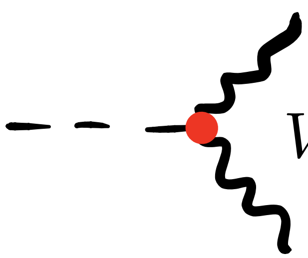

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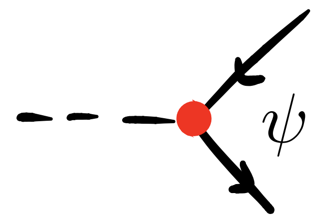

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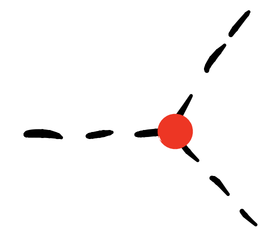

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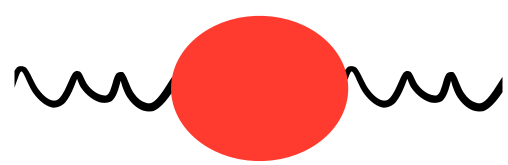

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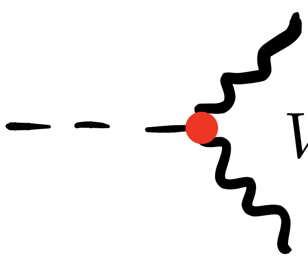

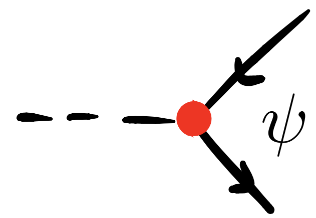

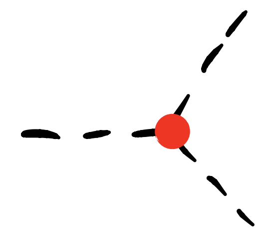

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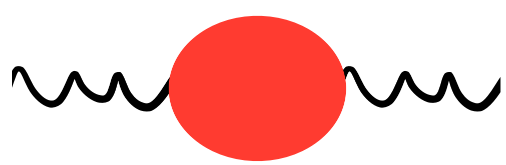

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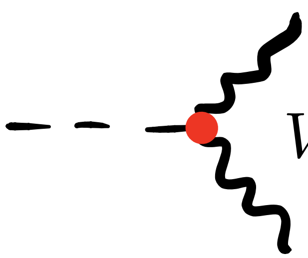

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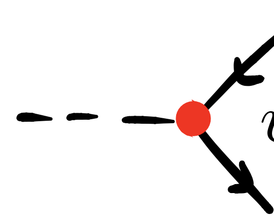

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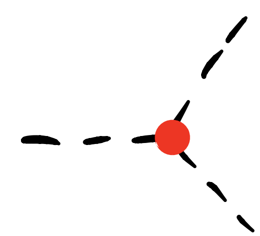

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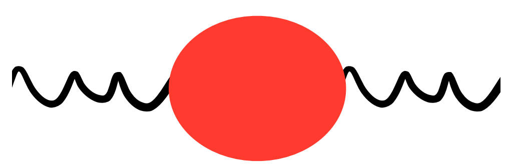

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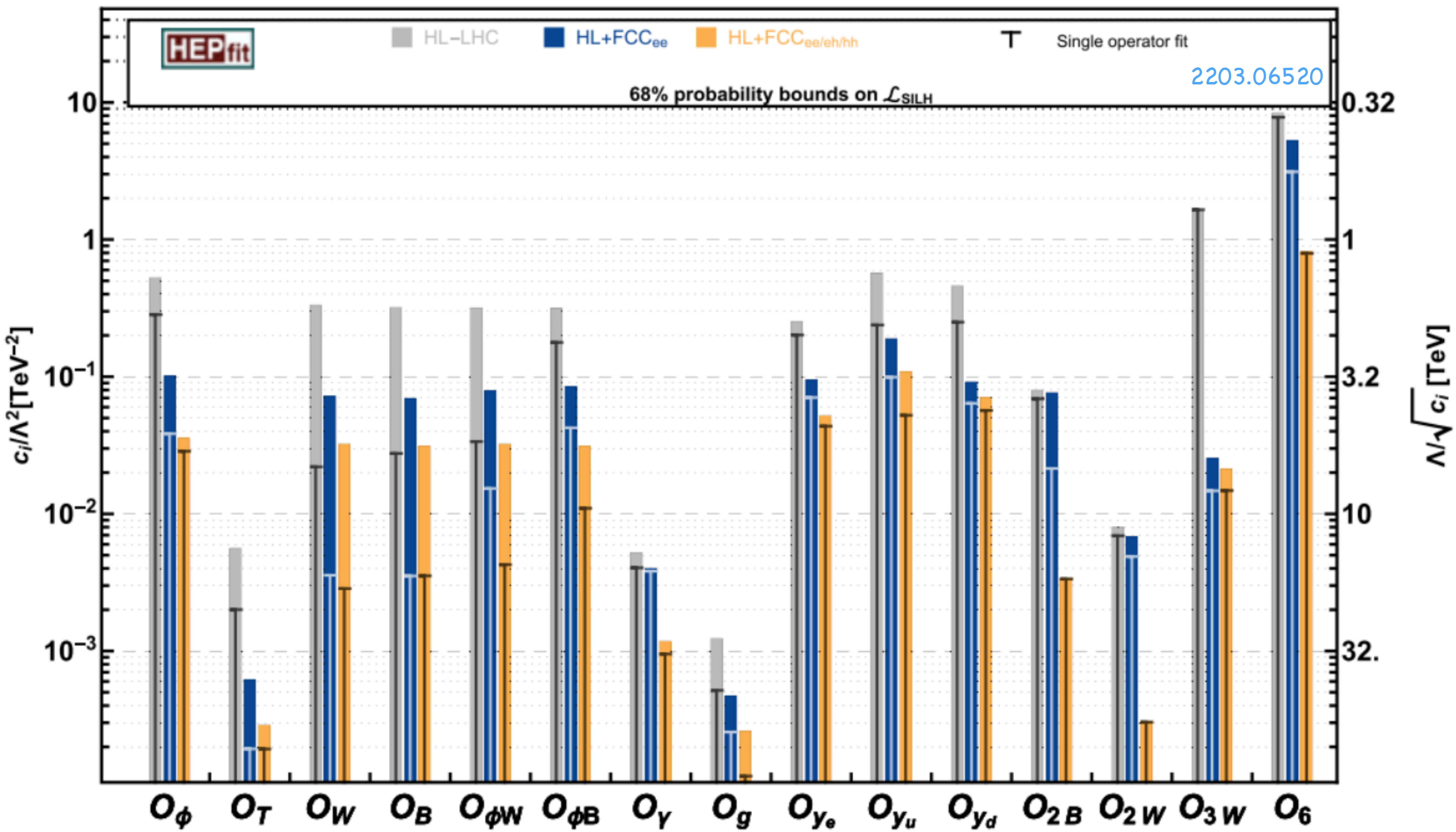
Pions would have v=f → v/f measures how SM-like the Higgs size is

Physics Questions vs Global Fits



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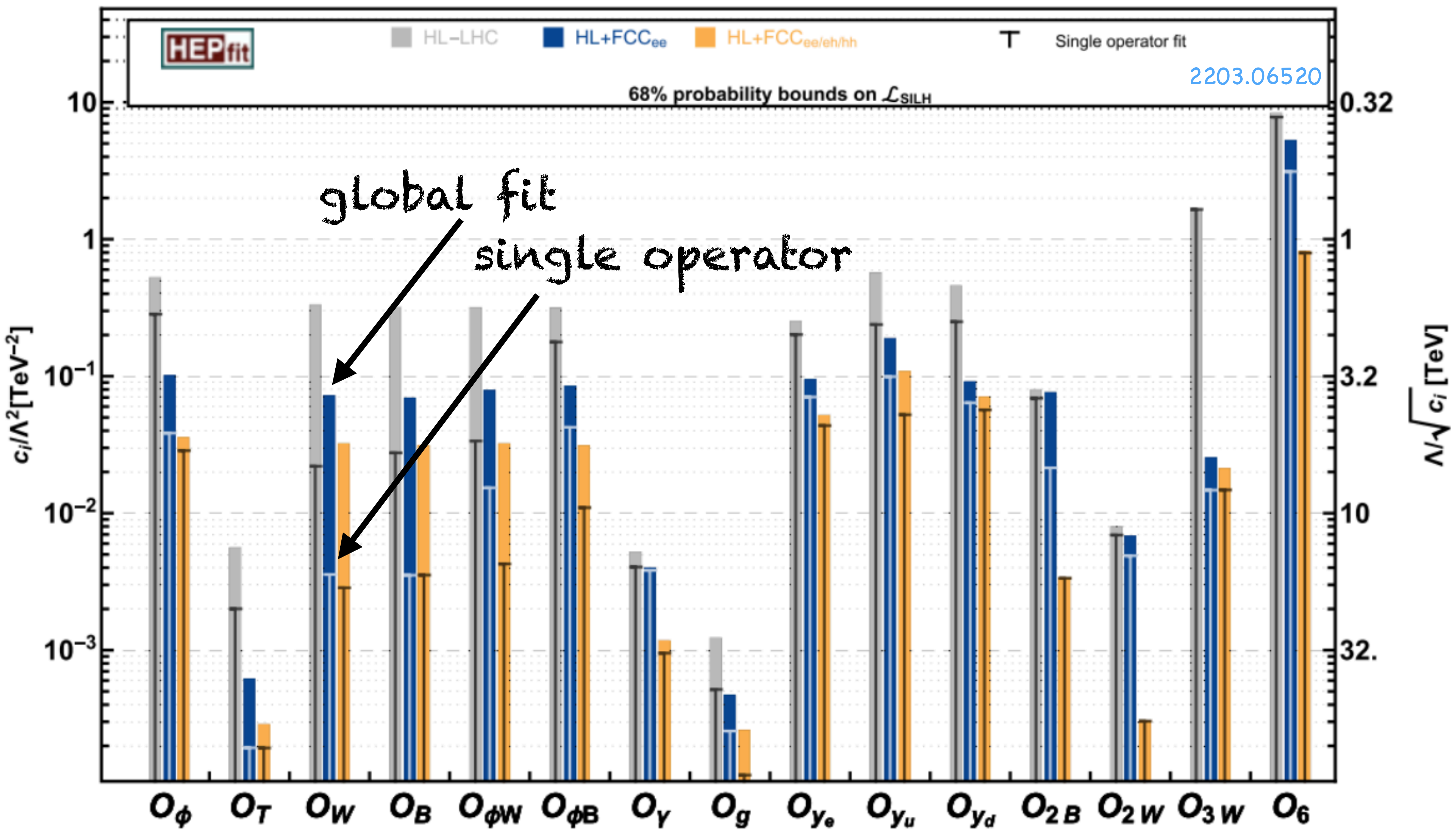

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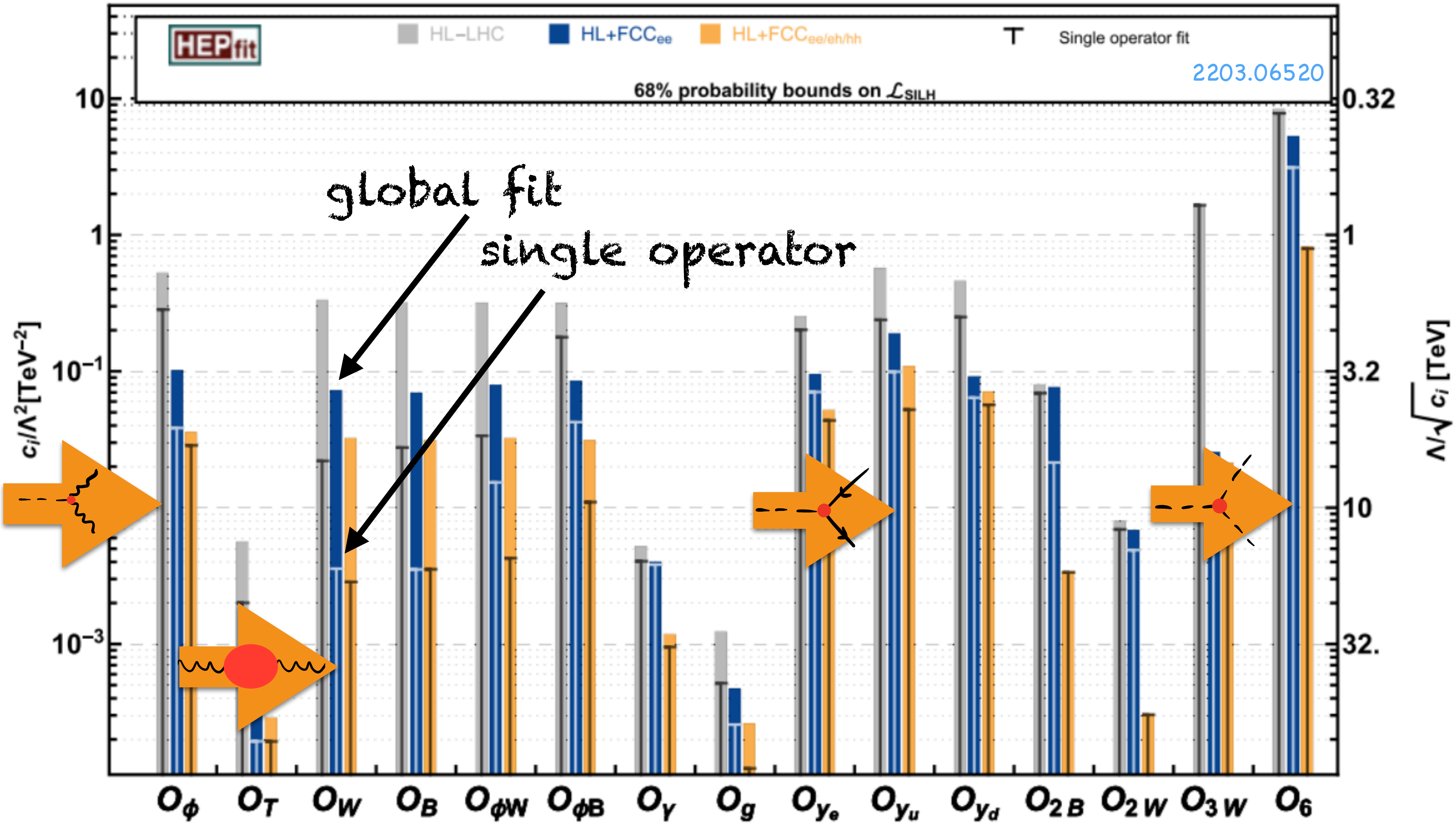

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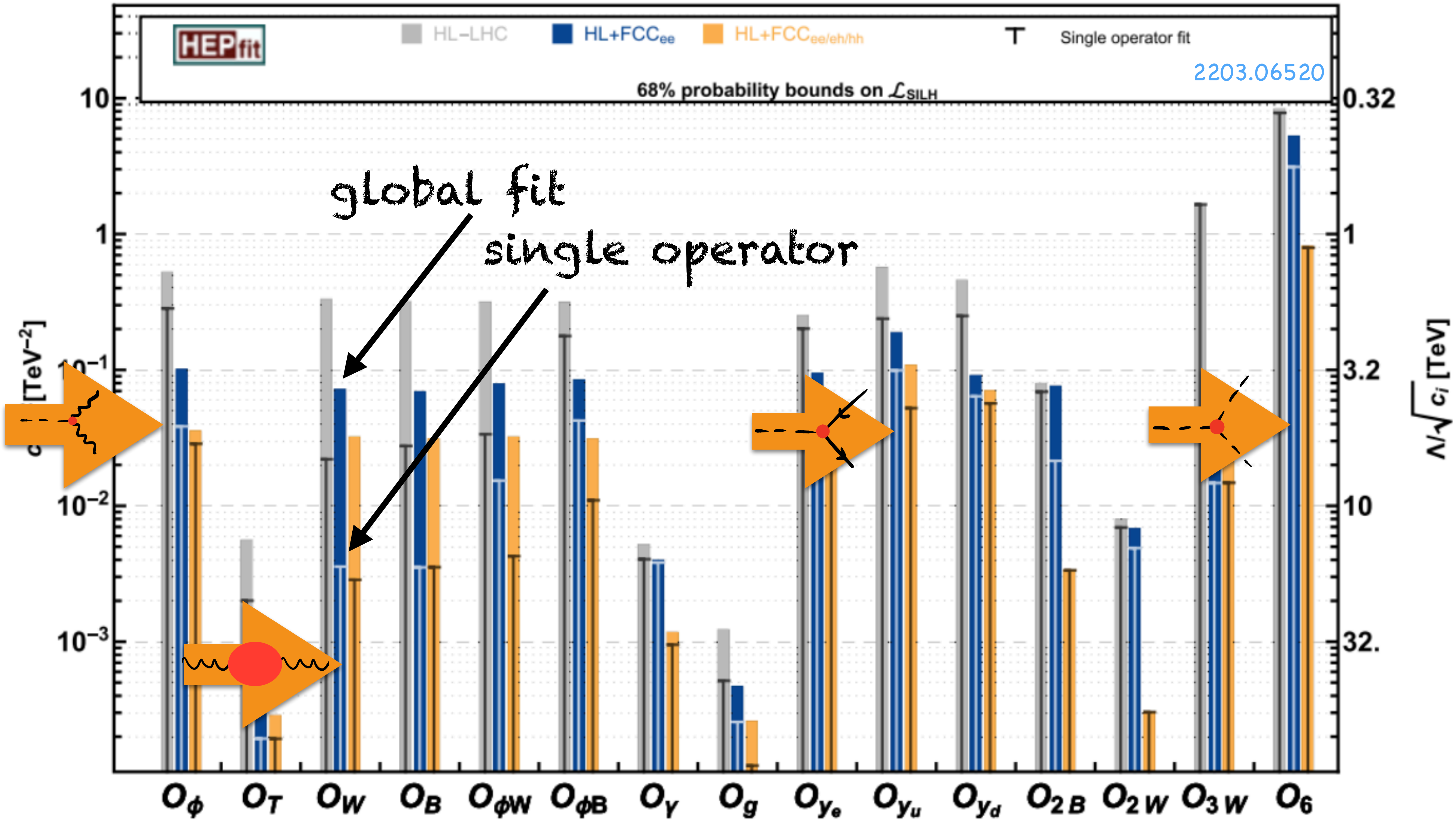

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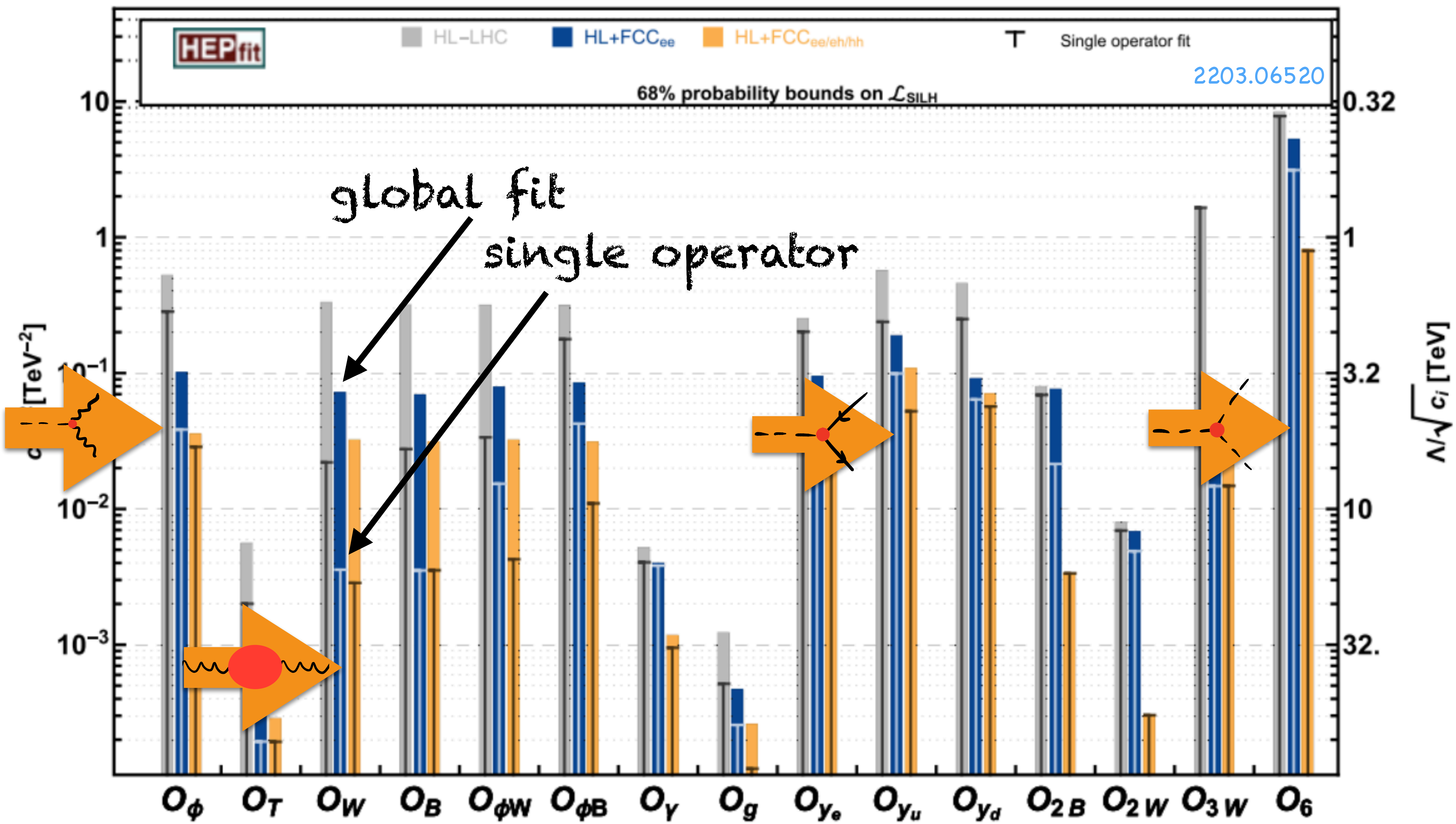

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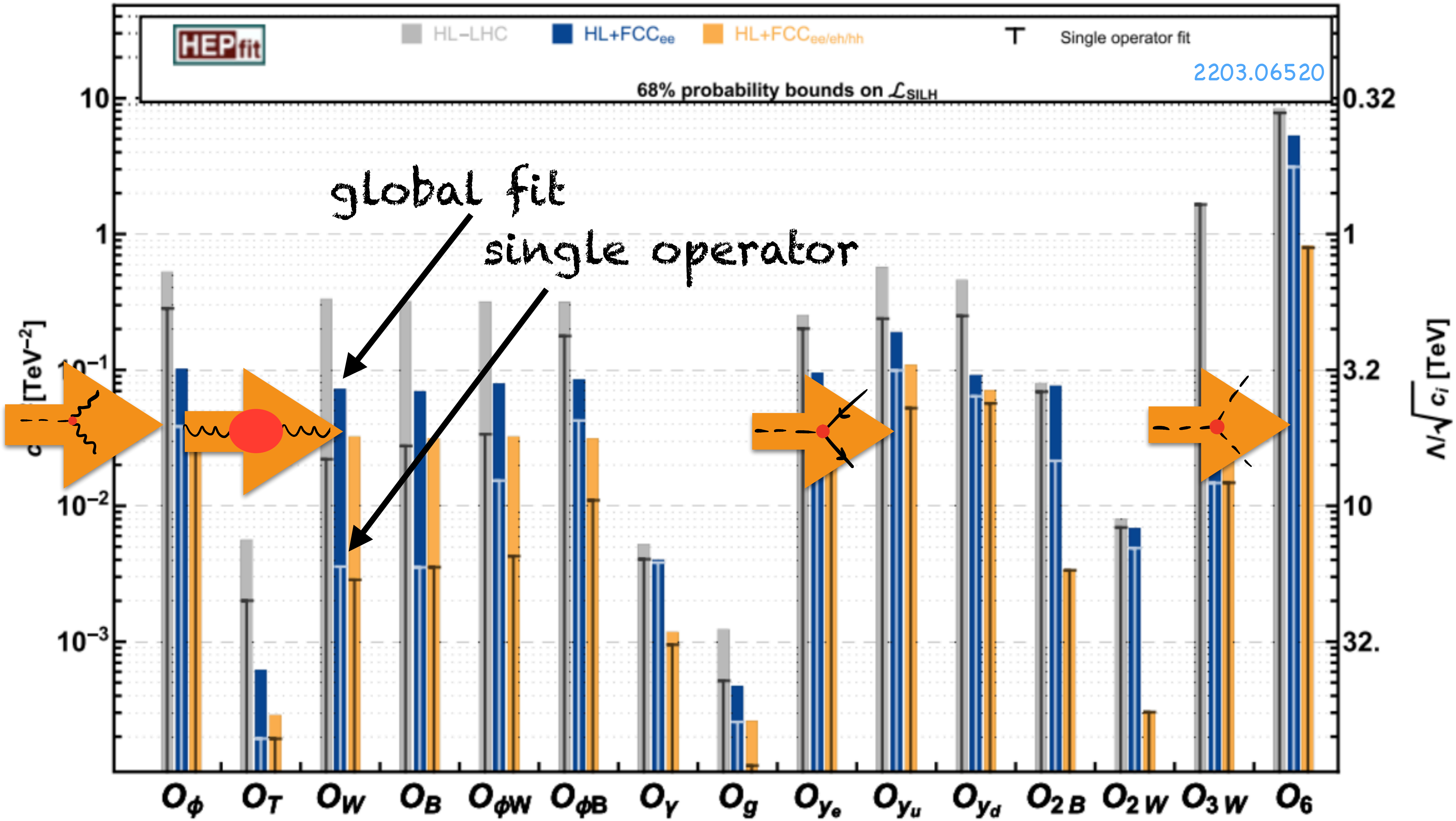

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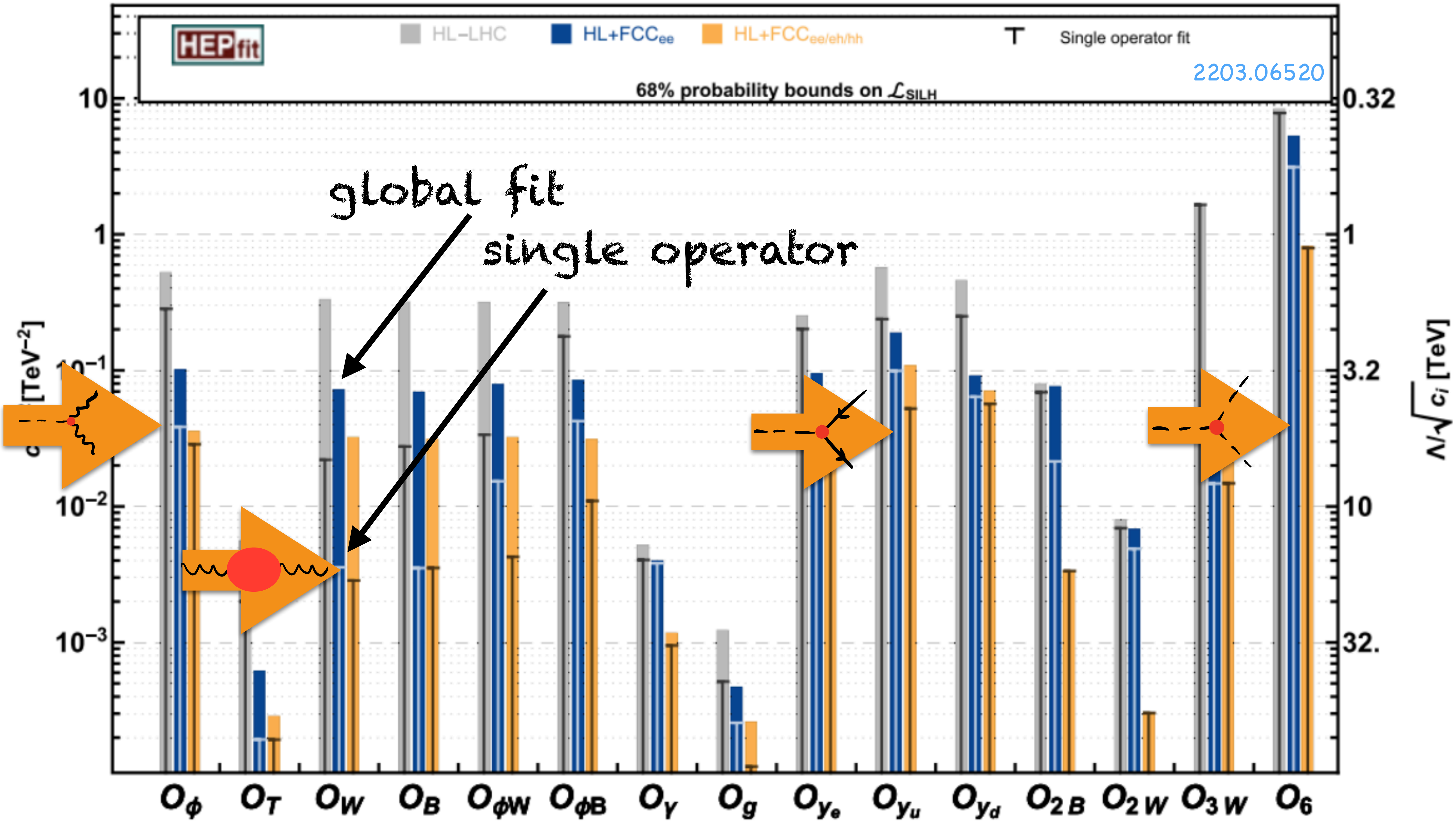

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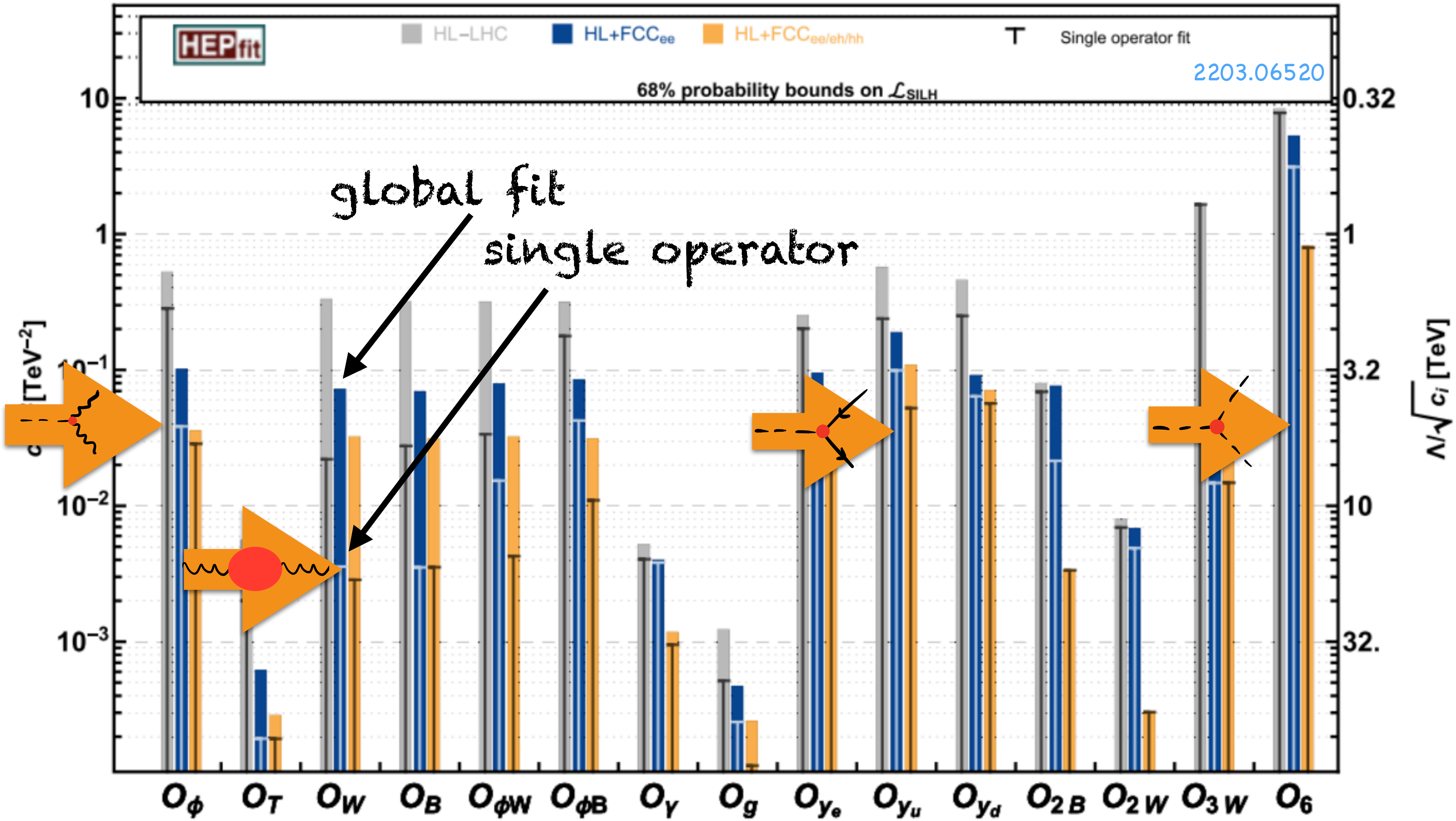
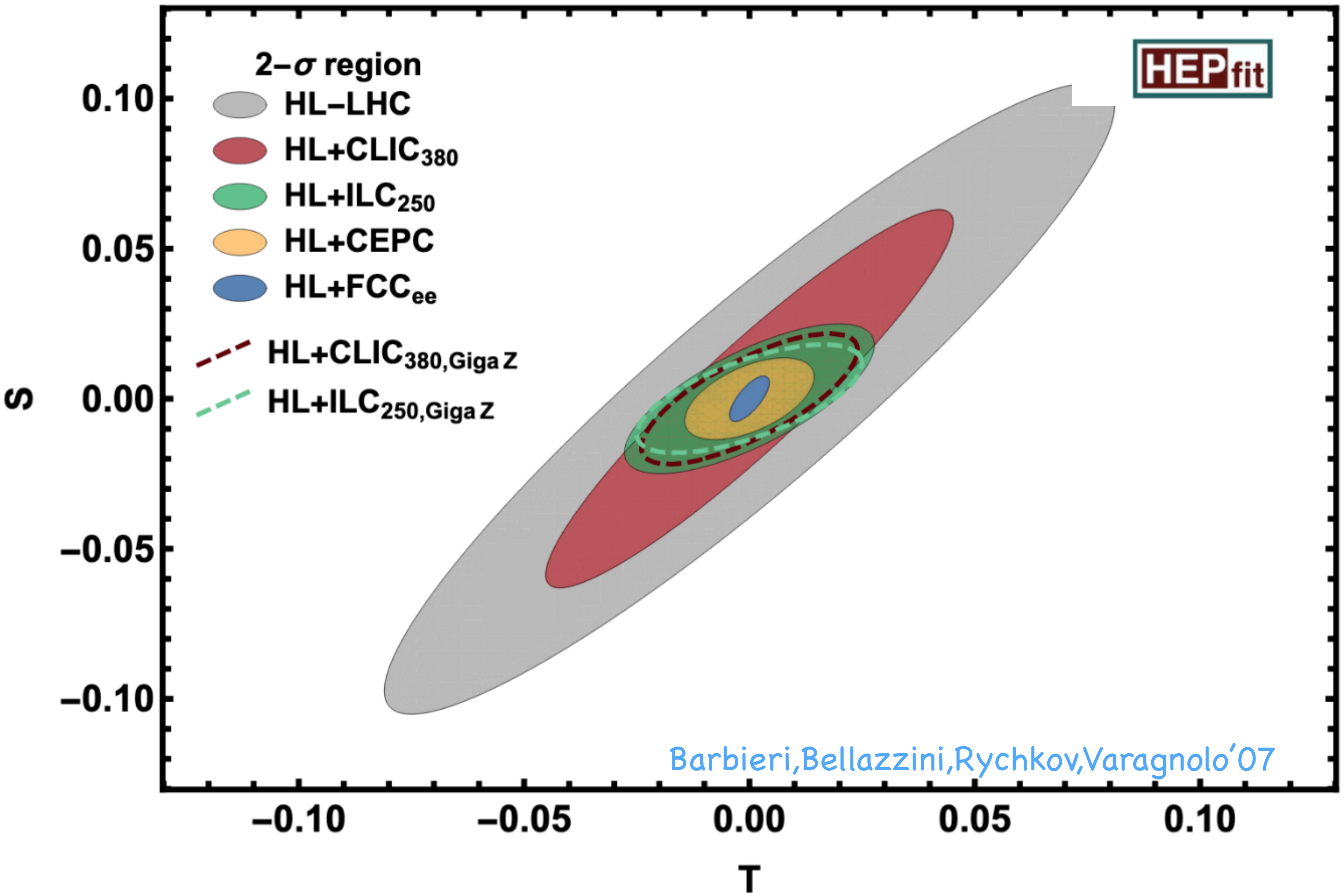
EW physics: $\frac{v^2}{f^2} \lesssim 10^{-3} \left(\frac{g_*}{5}\right)^2$



The Z-Boson run and the Higgs

S (and T) parameters:

- best universal tests for EW related physics
- if it couples to the Higgs it must enter in S,T



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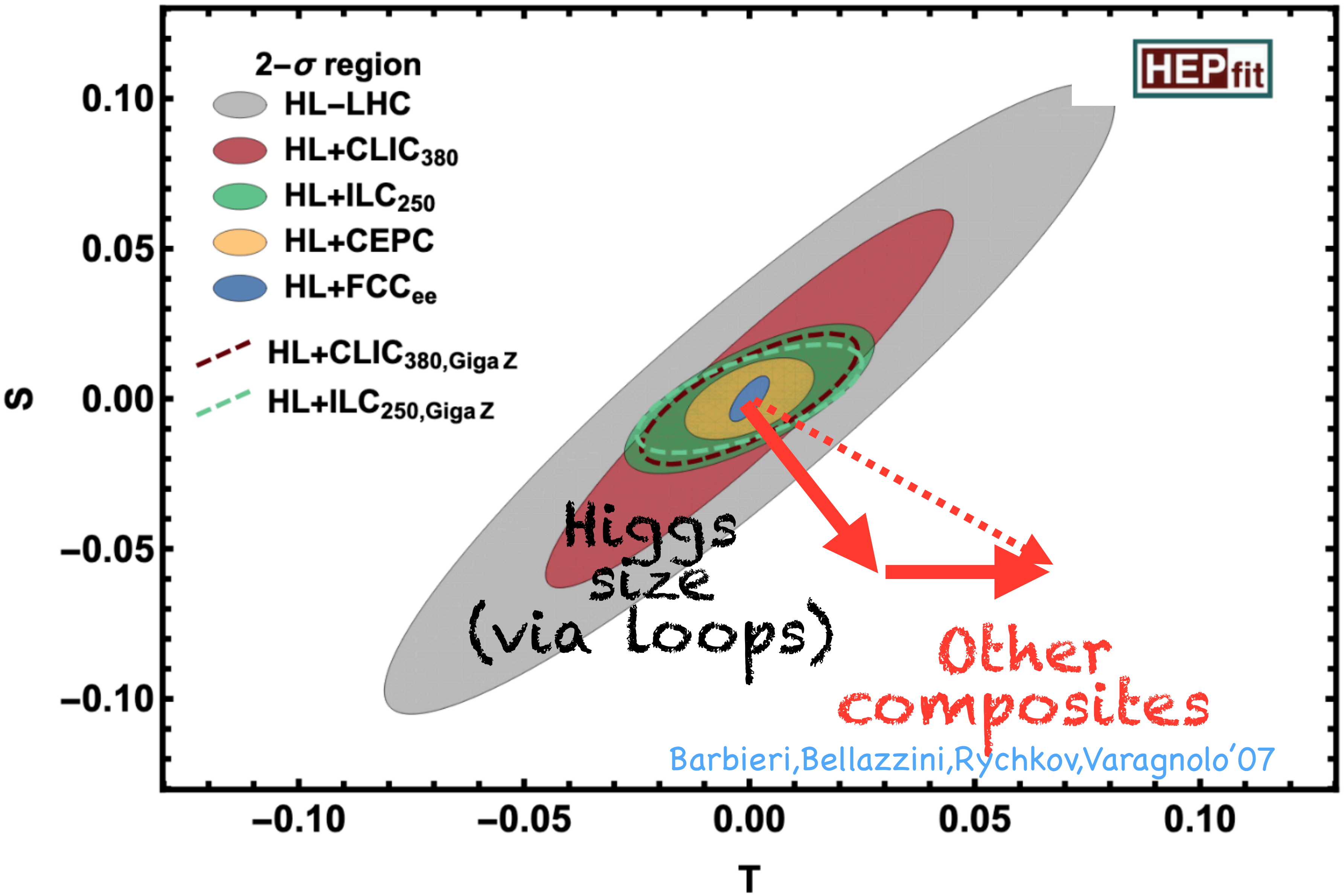

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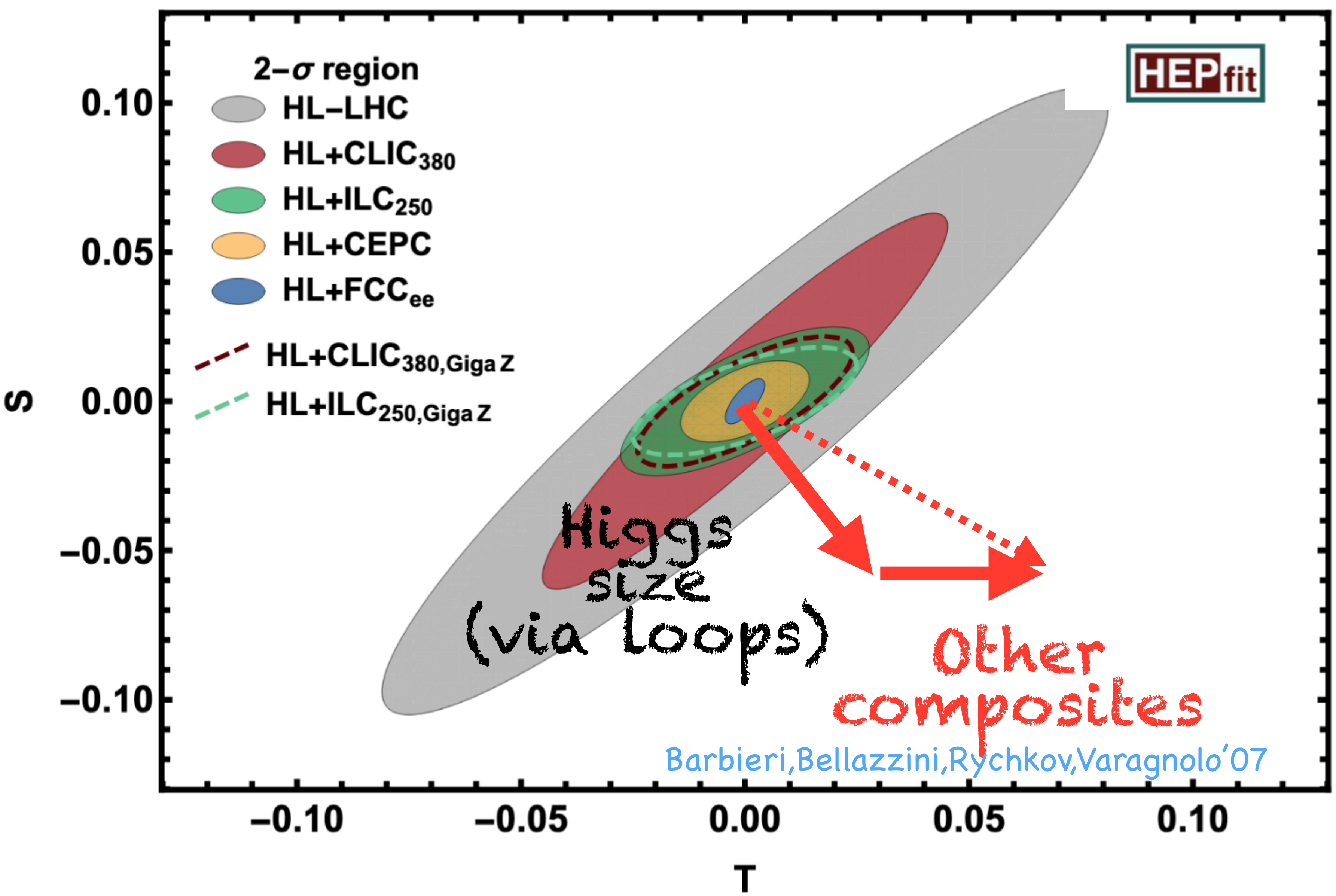

- A Z-pole run is crucial!

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Future colliders can discover many exciting new physics

(new particles, Dark Matter, matter asymmetry...)

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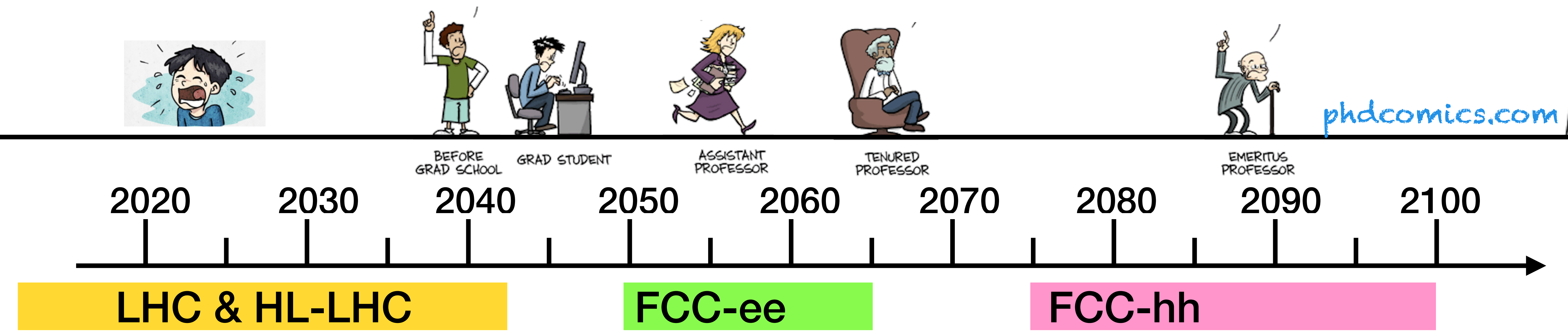
Z-Pole run will teach us much about the Higgs, as well

Outreach - TUTTI QUANTUM



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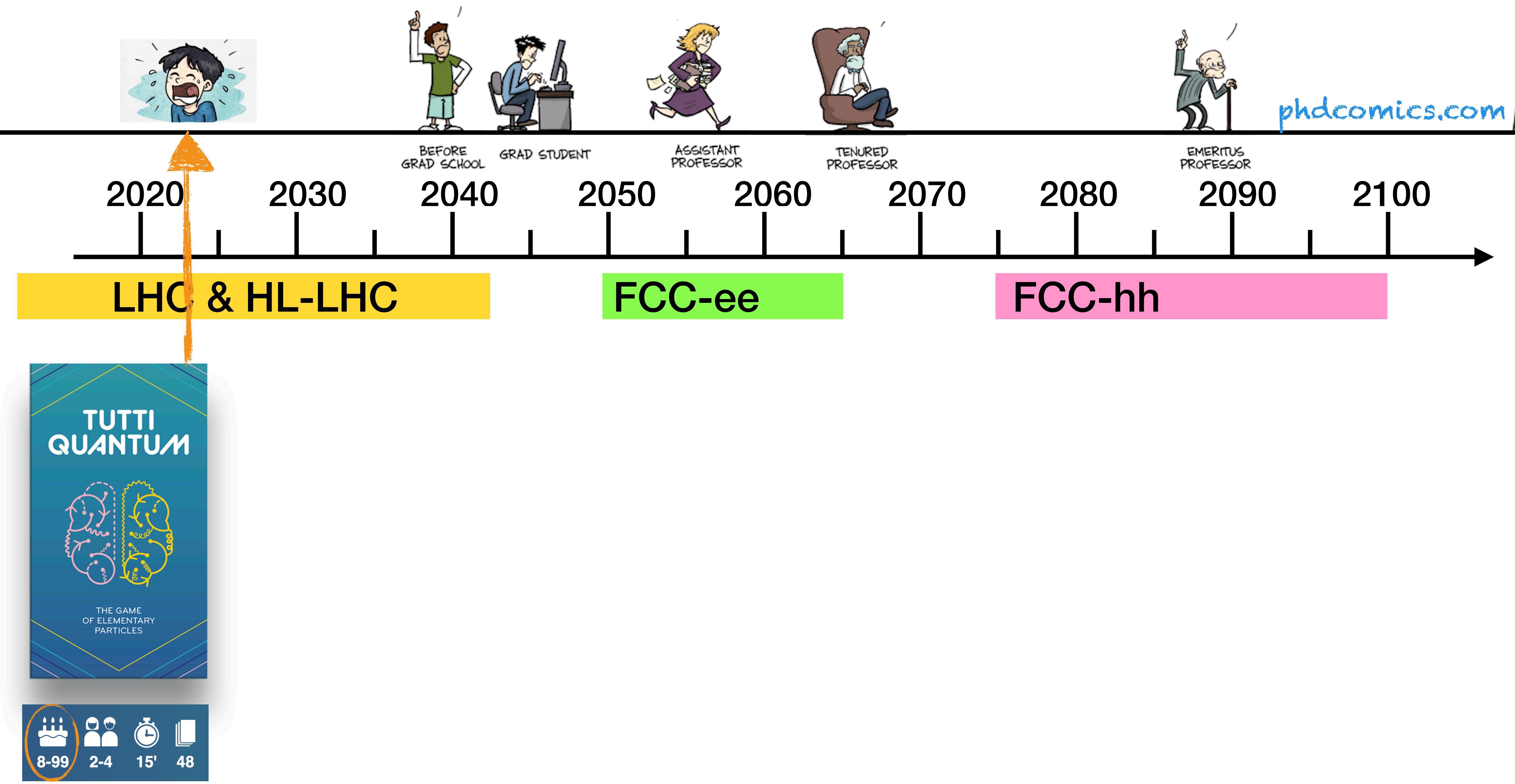

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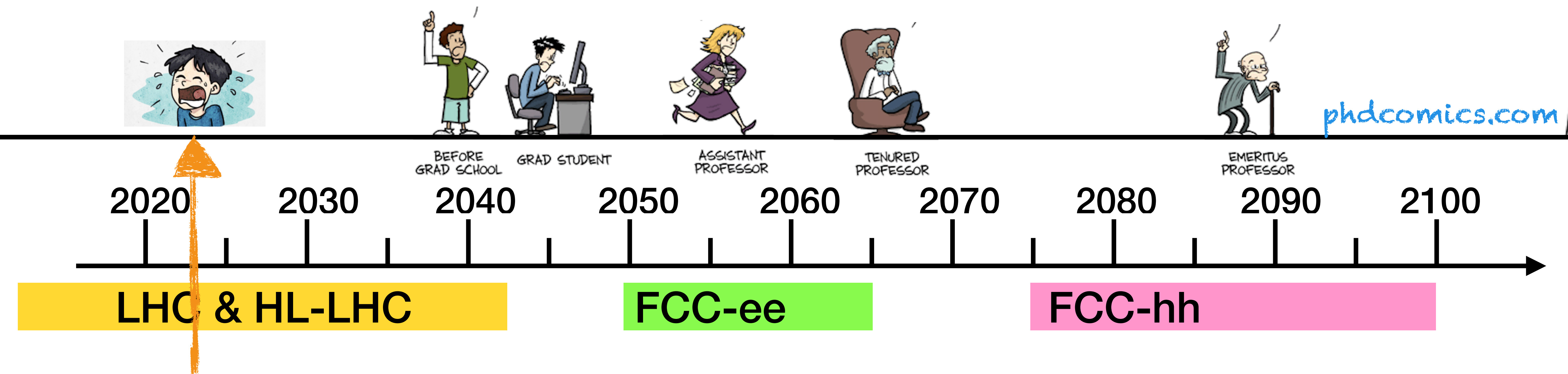
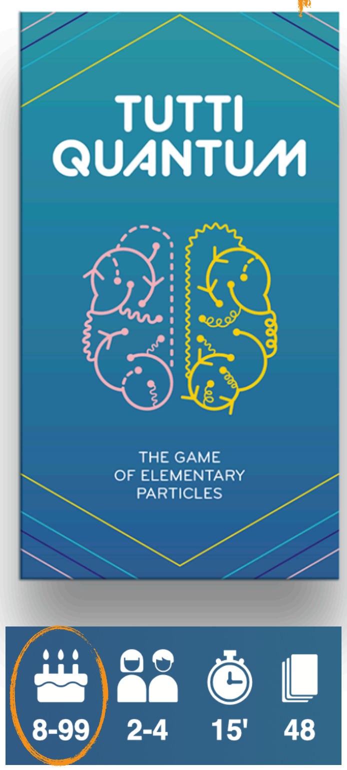
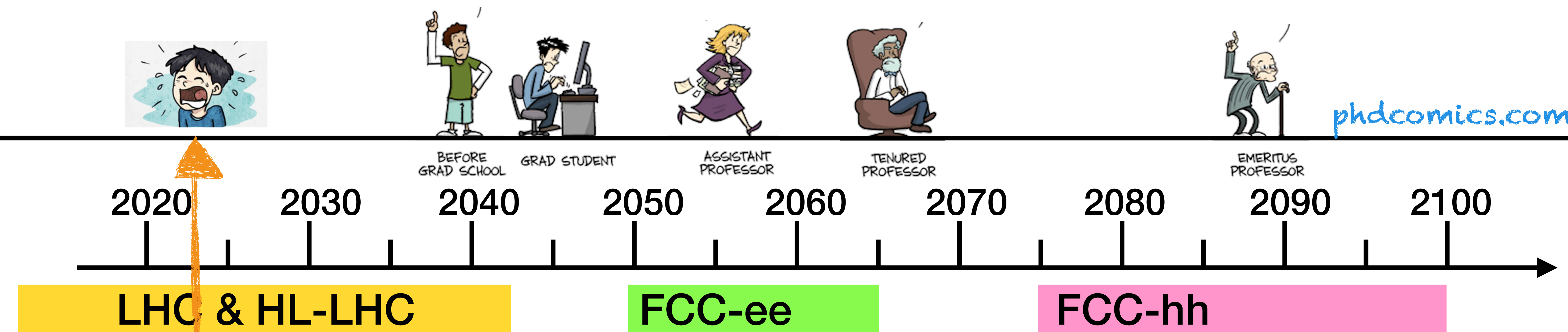
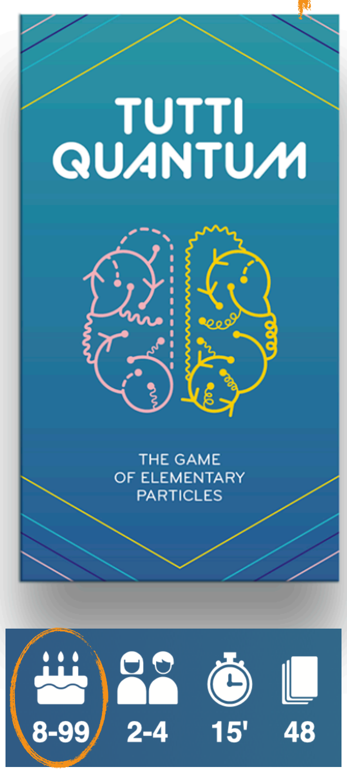




Particles are simple (simpler than e.g. cells)

Outreach – TUTTI QUANTUM





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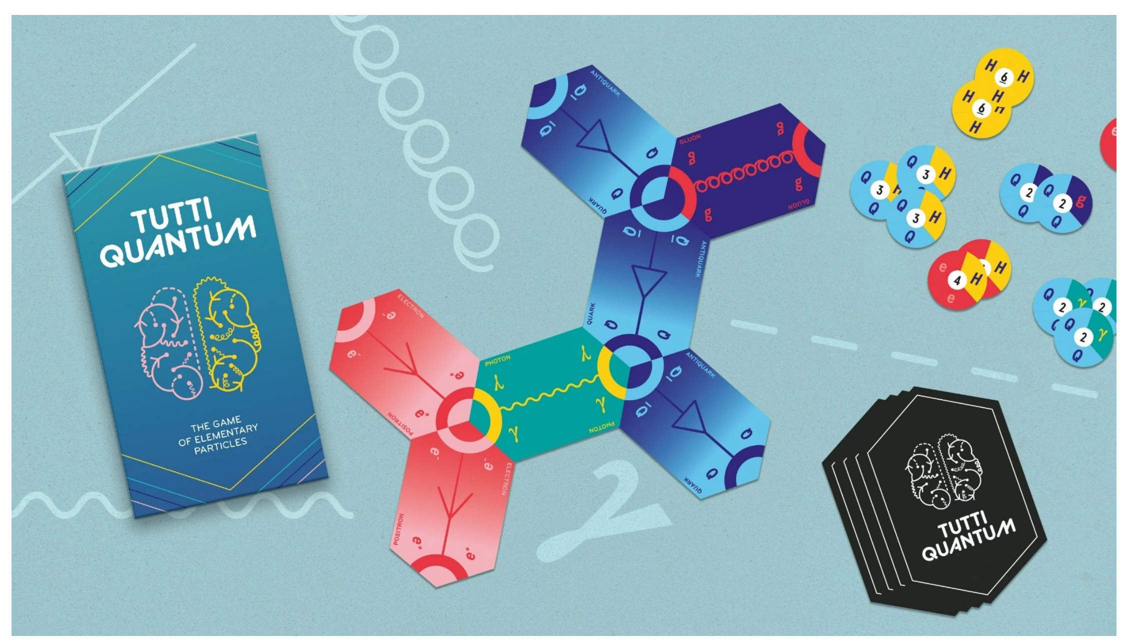
→ Learn laws of nature as rules of a card game

(even before you realize you are learning physics)



The Hierarchy Problem

EFT decouples: $\dfrac{O_i^{(n)}}{\Lambda_i^{n-4}}$ Details of UV not important

- Small observables $\Leftrightarrow$ larger scales

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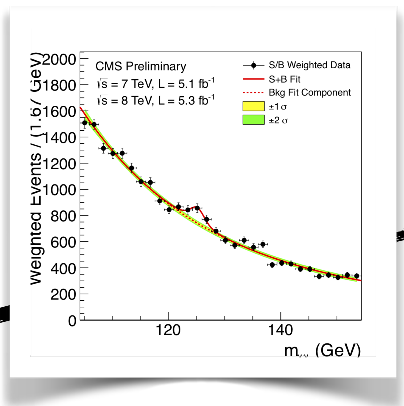

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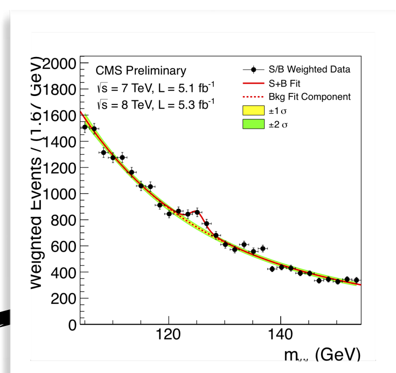

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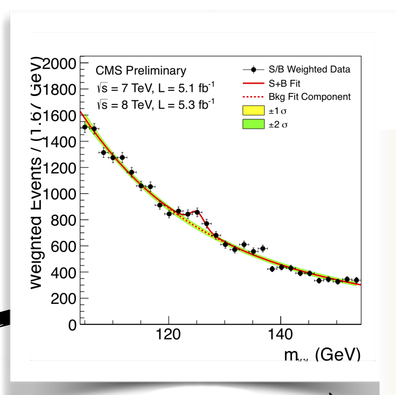

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Theories with finite size Higgs screen us from our QG ignorance, and are computable and testable at FCC