

Balancing the Cosmic Destiny

A Glimpse into Creation and Collapse through Di-Higgs Production

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You probably heard of ...

The Higgs Boson

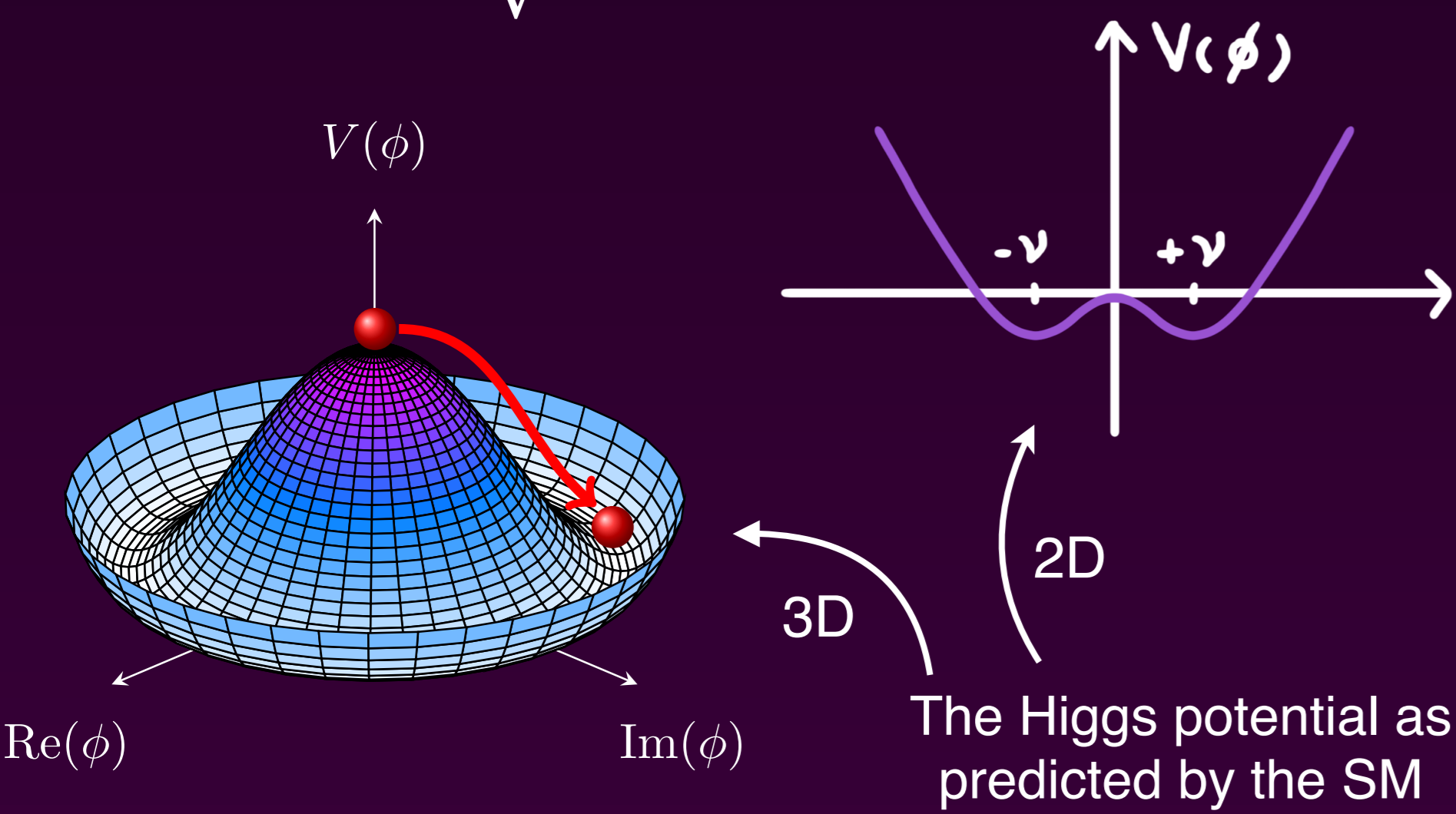
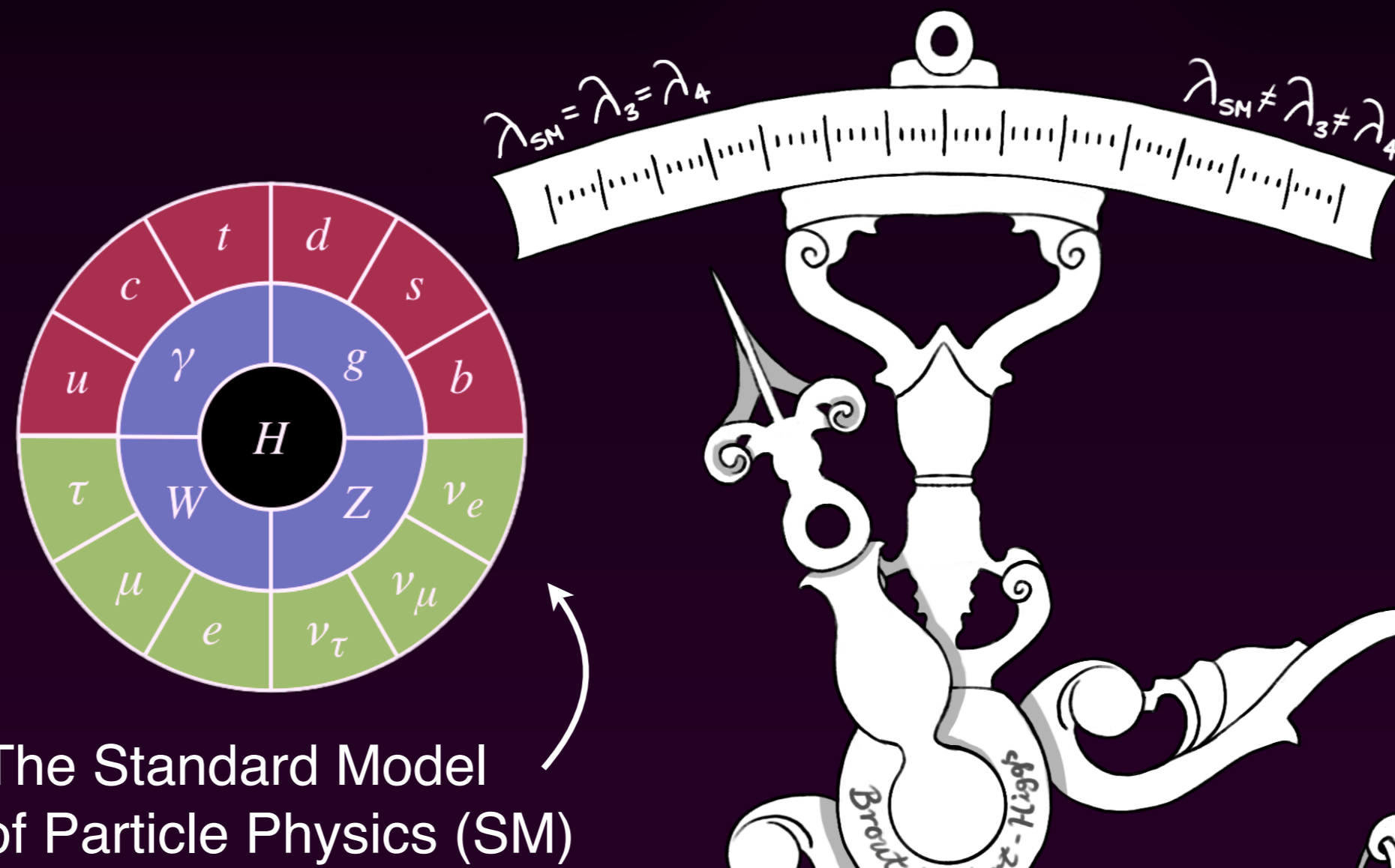
Where does mass come from?

Fundamental particles acquire mass when the Higgs field develops a non-zero vacuum expectation value (v), spontaneously breaking the electroweak symmetry*.

The Higgs potential, which has a Mexican hat shape, is given by

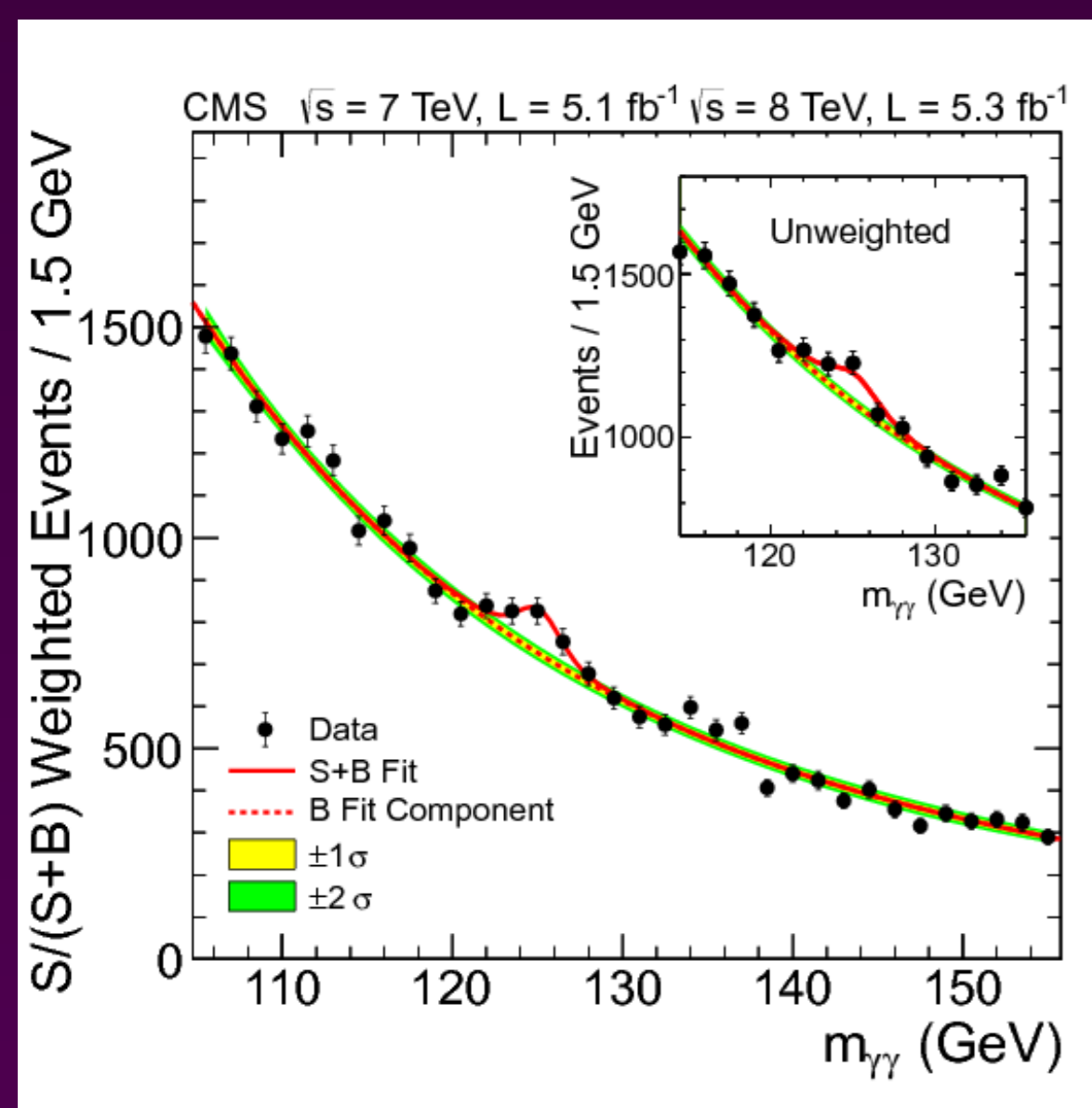
$$V(\phi) = \mu^2 \phi^\dagger \phi + \lambda (\phi^\dagger \phi)^2$$

where $\phi = \frac{1}{\sqrt{2}} \begin{pmatrix} 0 \\ v + H(x) \end{pmatrix}$



A New Particle:

The Higgs field predicts the existence of a new quantum excitation, the Higgs boson. This was discovered in 2012 by the CMS and ATLAS Collaborations at CERN.



Fun Fact: The Higgs boson was nicknamed the "God particle" in popular media - a name physicists themselves never liked!

... but have you heard of Di-Higgs and

The Stability of the Universe

What is in the vacuum?

The "vacuum" isn't empty space but the lowest energy state of all quantum fields filling the universe. The Higgs field has a constant value throughout space - its vev.

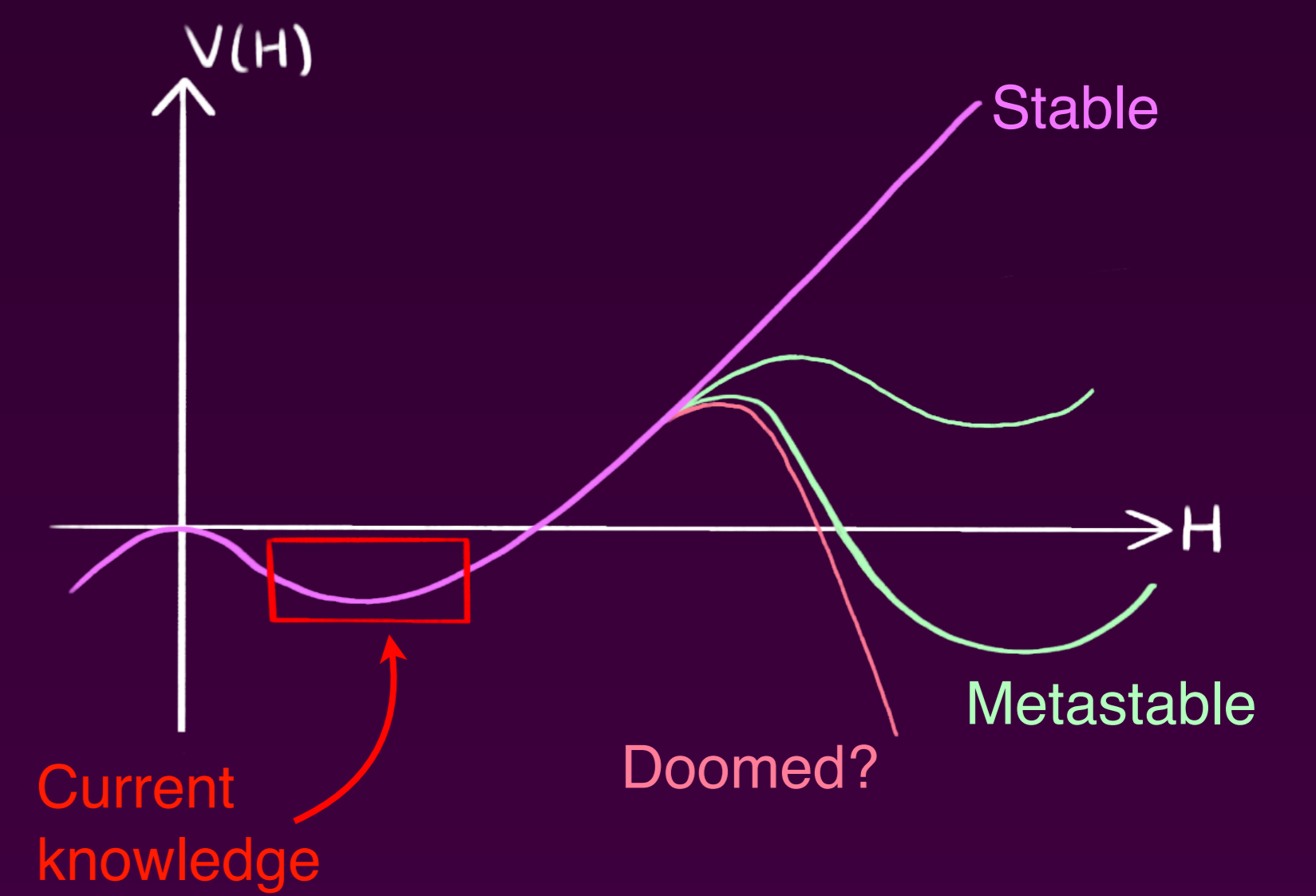
$$V(H) = \frac{1}{2} m_H^2 H^2 + \lambda_3 \nu H^3 + \frac{1}{4} \lambda_4 H^4 + const$$

Mass term
Higgs-Boson

Higgs self-coupling

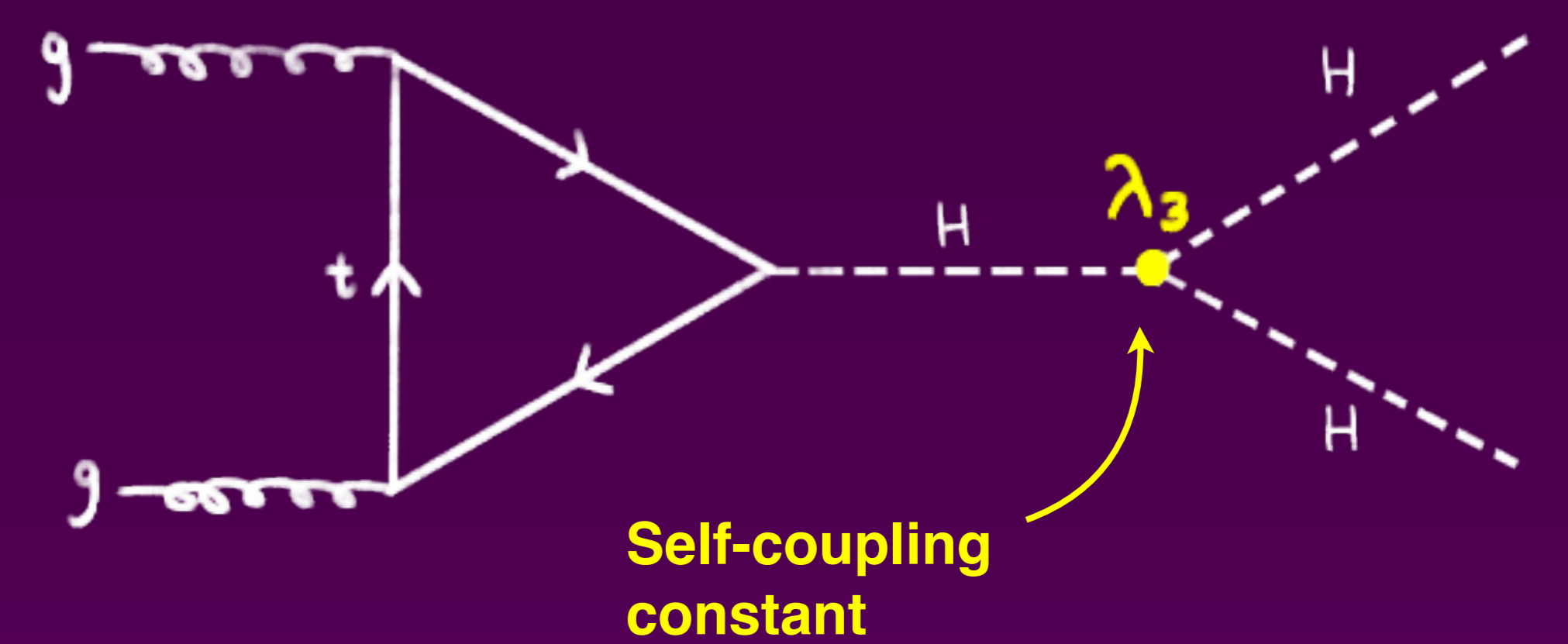
The SM predicts that: $\lambda_{SM} = \lambda_3 = \lambda_4$

The exact shape of the Higgs potential determines whether this vacuum is stable or metastable. If metastable, quantum tunnelling could one day shift the Higgs field to a lower-energy state, rewriting the laws of physics and destroying everything. The SM predicts we're right on the edge of metastability, and we've only measured a tiny part of the potential!



Where does di-Higgs come in?

In di-Higgs production, the Higgs boson couples to itself, allowing us to measure λ_3 . Studying di-Higgs production probes the self-interaction of the Higgs field which shapes its potential.



Finding Di-Higgs Bosons at the LHC

How can we produce and detect di-Higgs events

Di-Higgs events are produced in proton-proton collisions at the CERN LHC. The Higgs boson can only be observed indirectly through the particles it decays into. The Higgs boson can decay into several final states. When selecting one to analyse, we consider:

- Branching ratio (BR):** how likely is the di-Higgs decay into this channel?
- Signal-to-background (S/B):** how clearly can we distinguish signal from background?

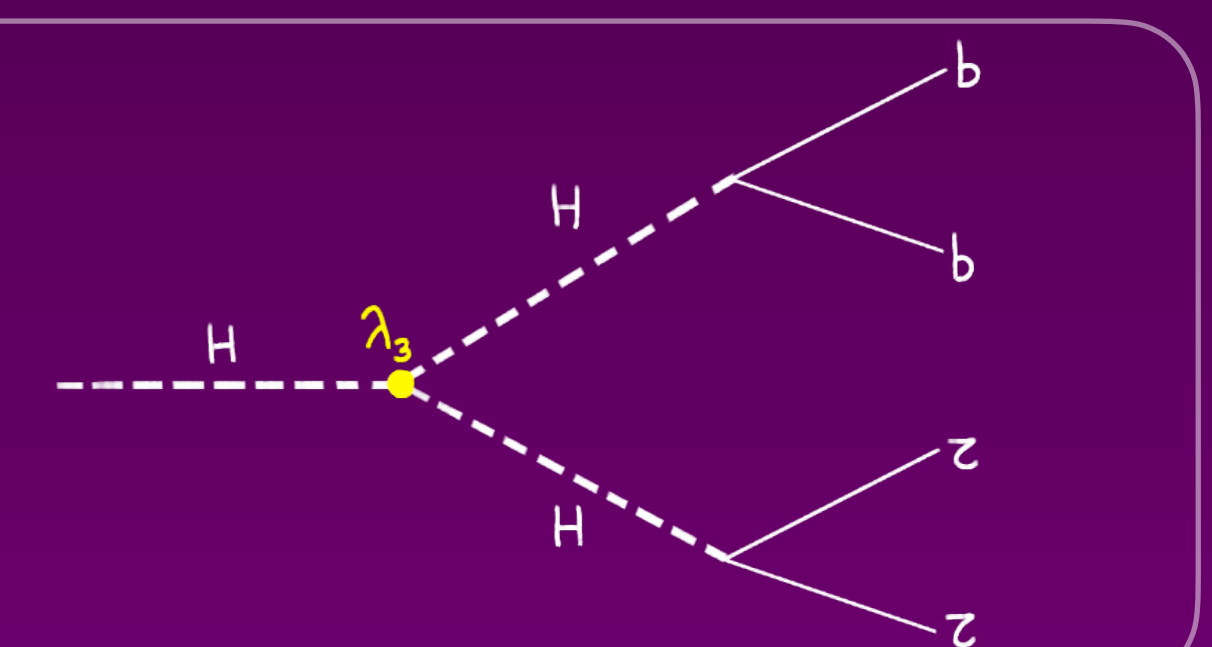
At UZH:

We focus on two specific di-Higgs decay channels that offer an optimal balance between abundance and a clean signature.

Branching Ratios	bb	WW	tau tau	ZZ	gamma gamma
bb	34 %				
WW	25 %	4.6%			
tau tau	7.3%	2.7%	0.39%		
ZZ	3.1%	1.1%	0.33%	0.069%	
gamma gamma	0.26%	0.10%	0.028%	0.012%	0.0005%

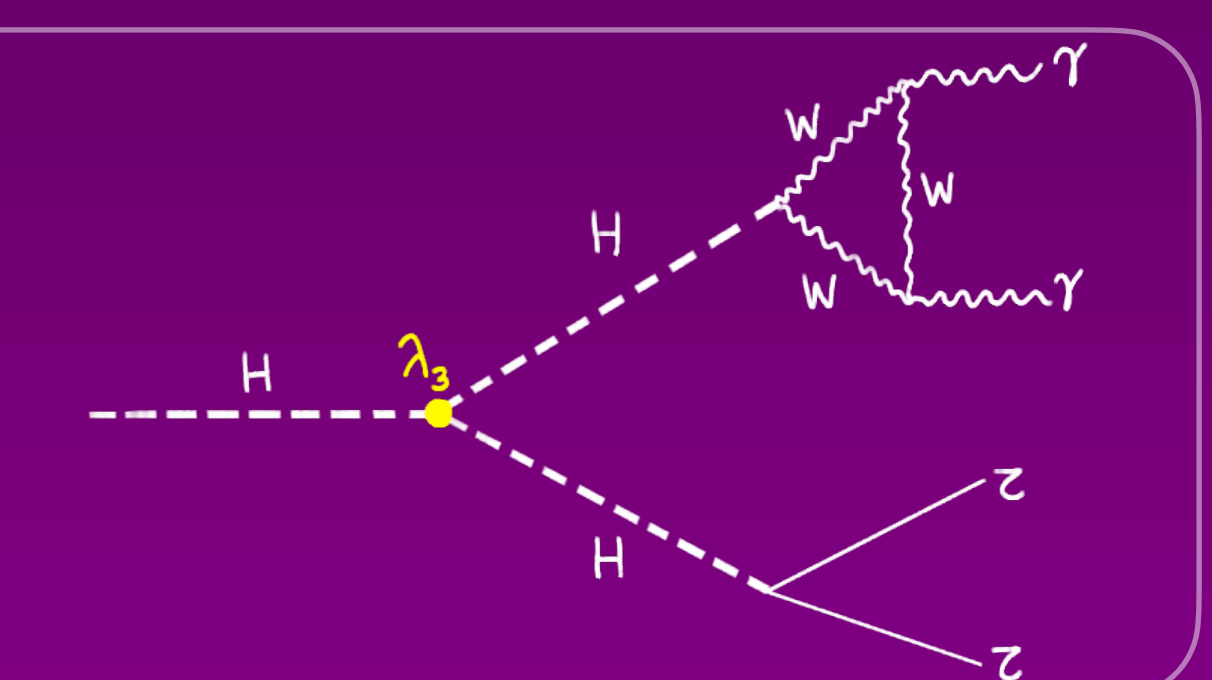
HH -> bb tau tau

Good BR (7.3%)
but large background



HH -> gamma gamma tau tau

Low BR (0.028%)
but small background



Want to join us?

Collaborate with physicists worldwide via CERN, and help advance our understanding of the Universe and uncover its fate!

Which skills would you gain?

- Explore the Standard Model & search for New Physics
- Develop your programming skills in Python and C++
- Work with Monte Carlo Simulations and real collision data
- Improve your presentation and scientific writing skills

Interested?

Scan me and find out more about the group of Prof. Dr. Florencia Canelli!



* This is a simplification: technically only the W^\pm and Z^0 bosons acquire mass through this mechanism; the fermions acquire mass via the direct Yukawa interaction with the Higgs field after the symmetry breaking.