Explain like I'm 5: The Higgs Boson

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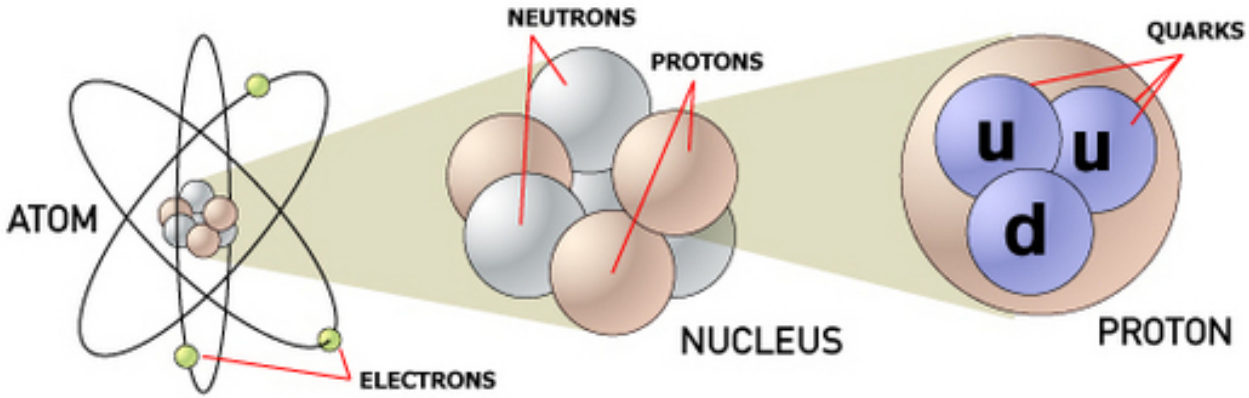
July 4, 2012: Higgs boson announcement

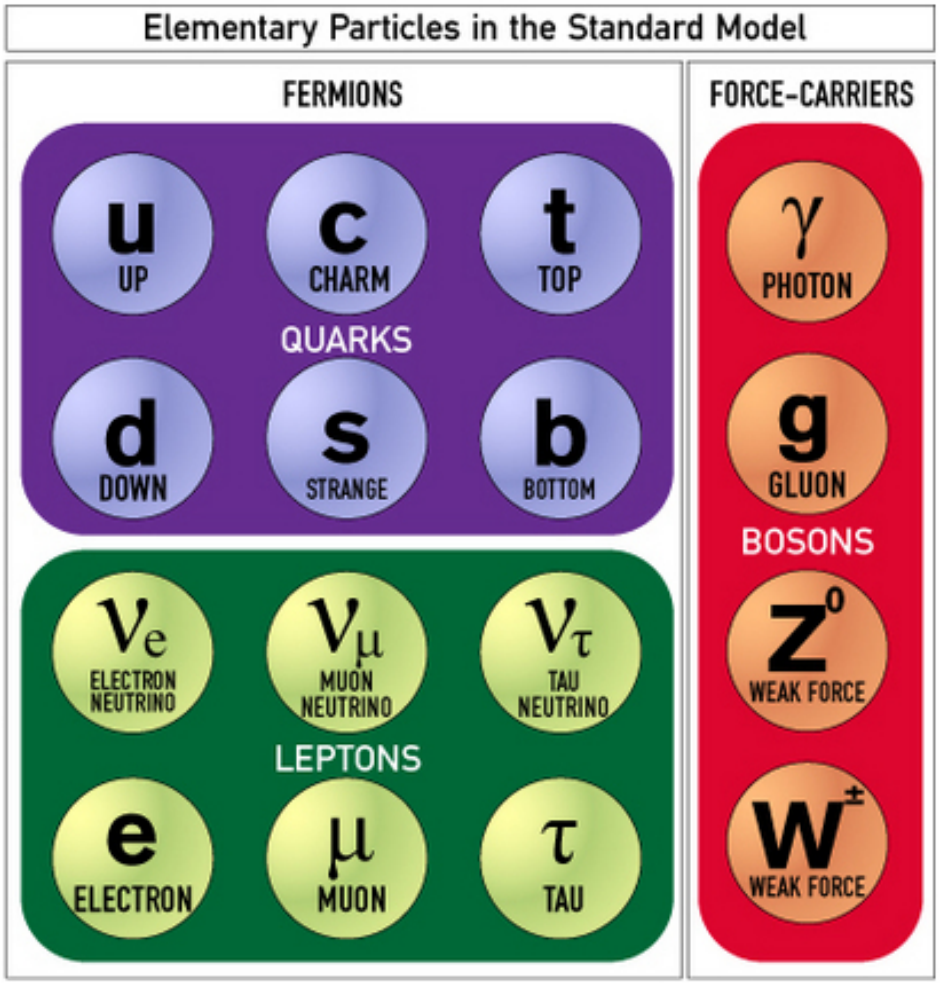
What is the world made of?



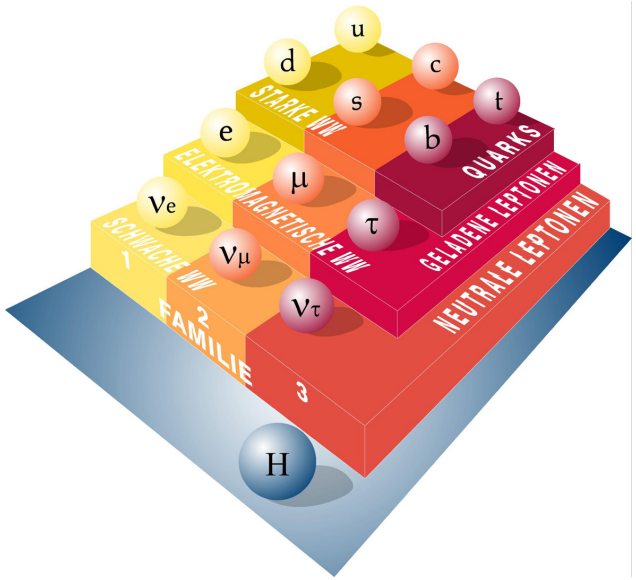
3 families of

- Quarks
- Leptons

What is the world made of?



The "period system" of elementary particle physics



What is the world made of?

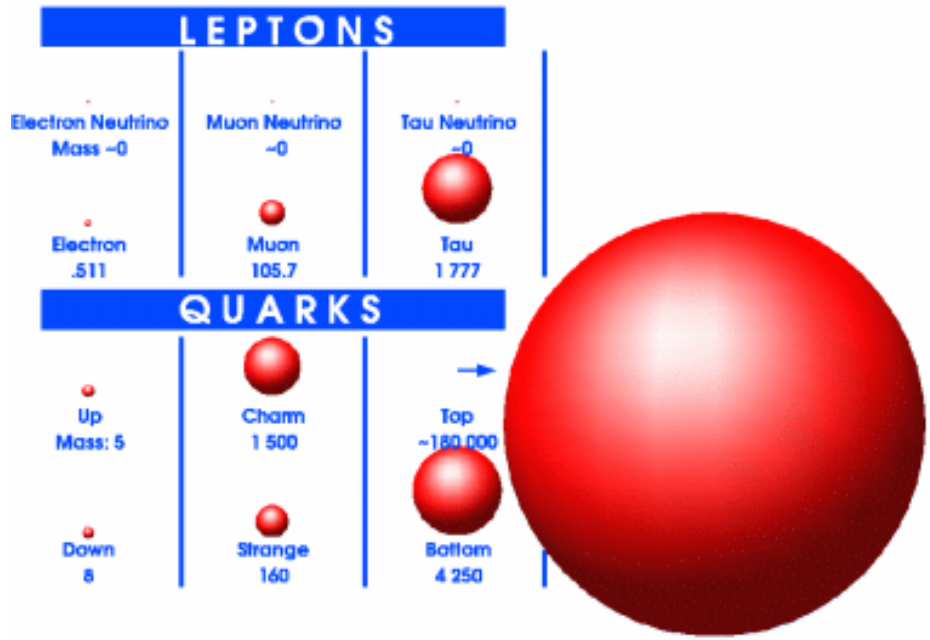
The everyday world can be build from just 3 particles: u, d, e

➟ What about the rest???

Organize particles by their properties and come up with a theory...

Biggest issue:

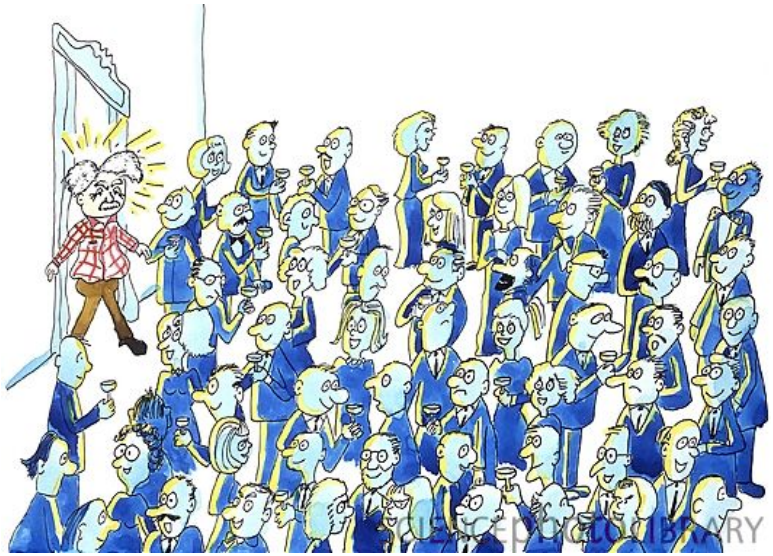
How to explain the particle masses?

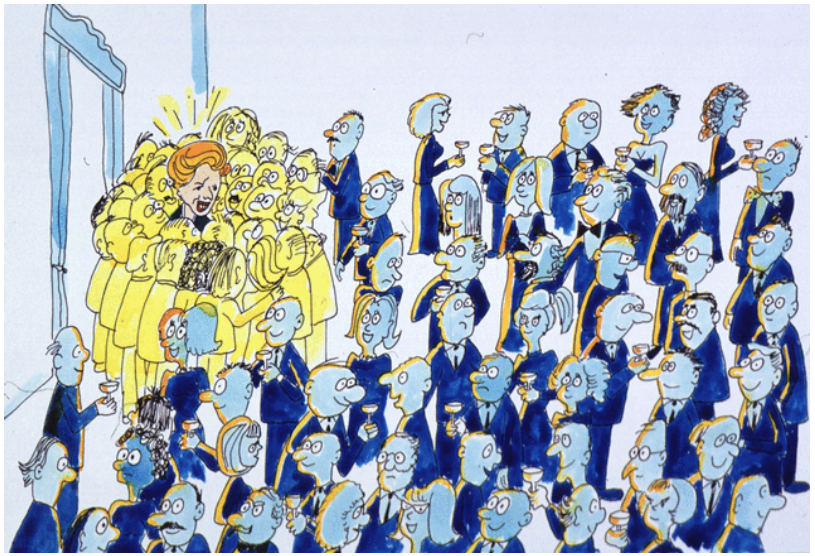


The Higgs Mechanism

The mathematical framework underlying the standard model does not allow for massive particles?!?!?!

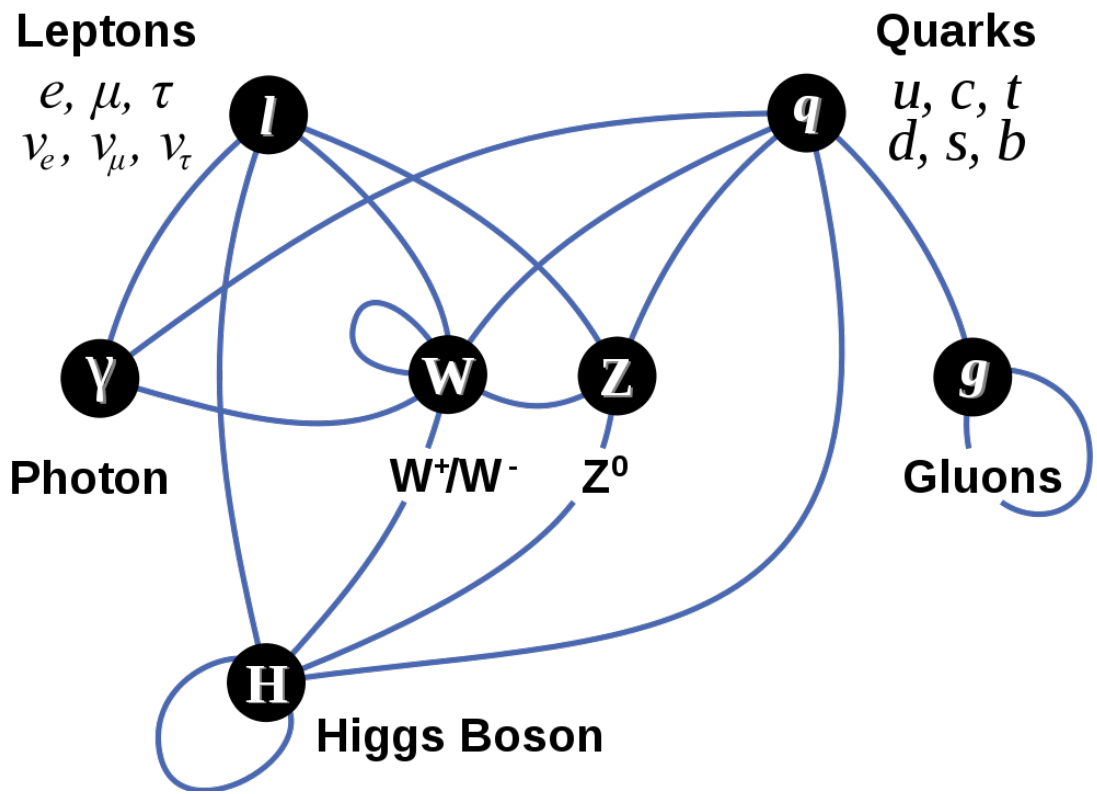
Idea: Fill the space with a "Higgs field" that permeates all space and indirectly gives mass to all other fields!





The Higgs Mechanism

The Higgs field couples to every massive field in the standard model:



The Higgs Mechanism

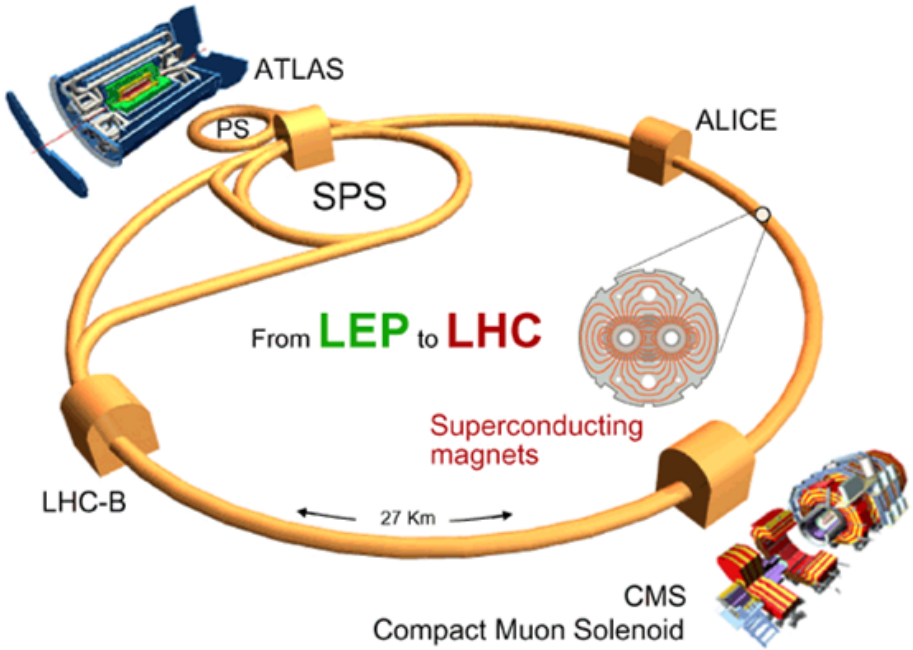
The Higgs mechanism is somewhat awkward, but seems to explain particle masses very well...

But how can we **verify that this idea it is correct?**

➙ "Kick" a minimal amount of the Higgs field out and try to find it.

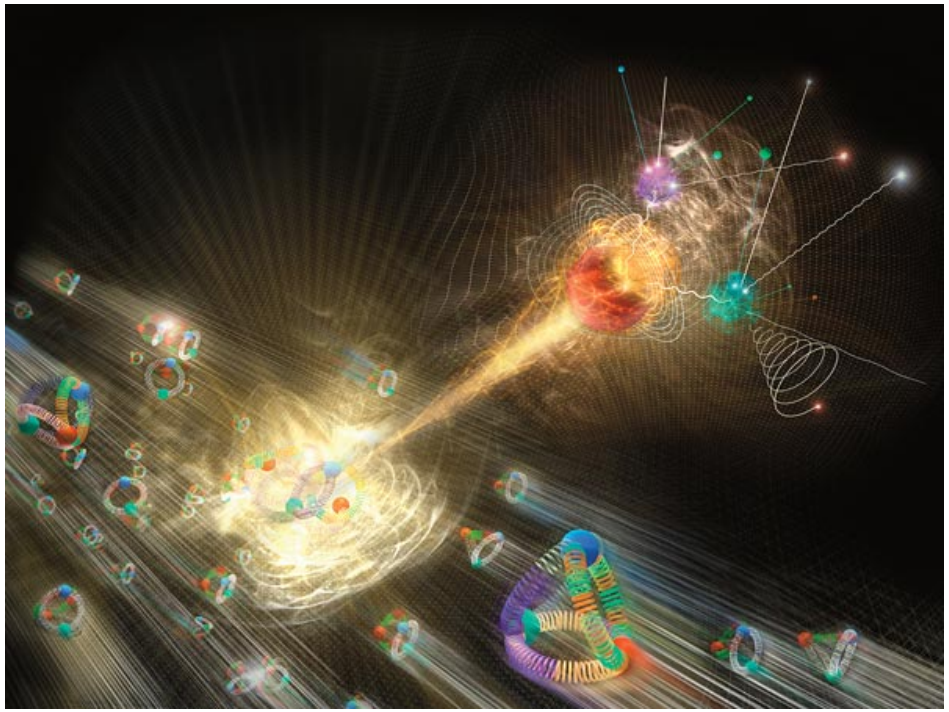
Detecting the Higgs Boson

The smallest piece of the Higgs field is the Higgs boson. Detaching it from the Higgs field requires tremendeous amounts of energy — only found in a **big particle accellerator**.



Detecting the Higgs Boson

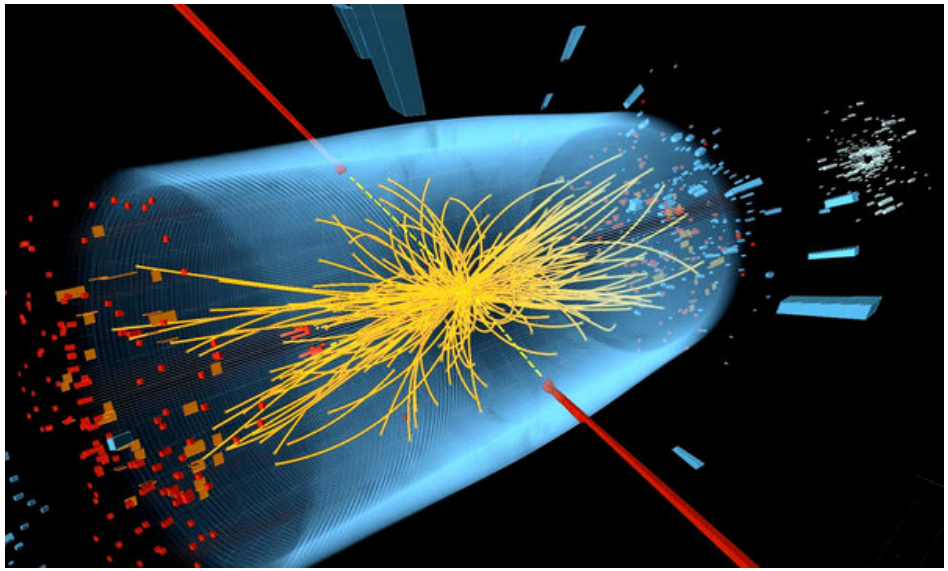
Thanks to Einstein's $E = mc^2$ ("Energy is equal to mass"), smashing together more energetic, i.e. "fast", particles allows to create heavier particles.



Detecting the Higgs Boson

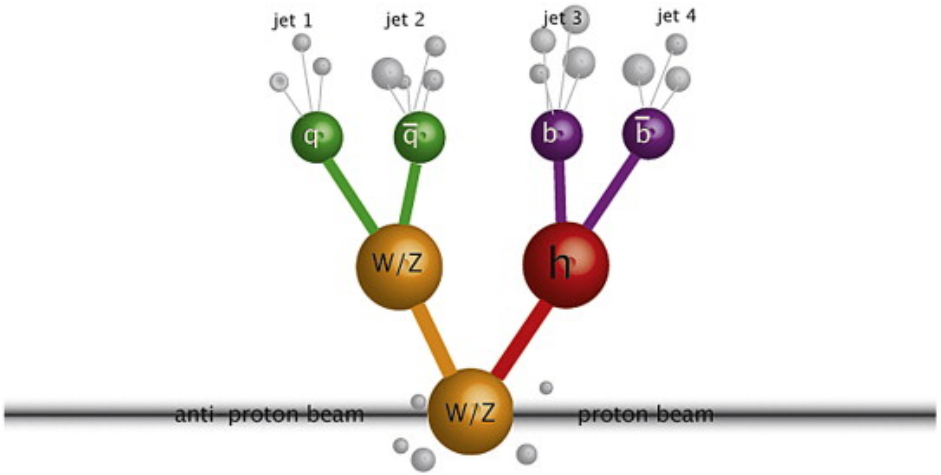
However, given a certain energy range, you cannot control which particles are created. There is **only a certain probability** of a particle being created from such a collision...

...means that you create a giant amount of garbage:



Detecting the Higgs Boson

Also the Higgs particle is not stable and almost immediately decays:

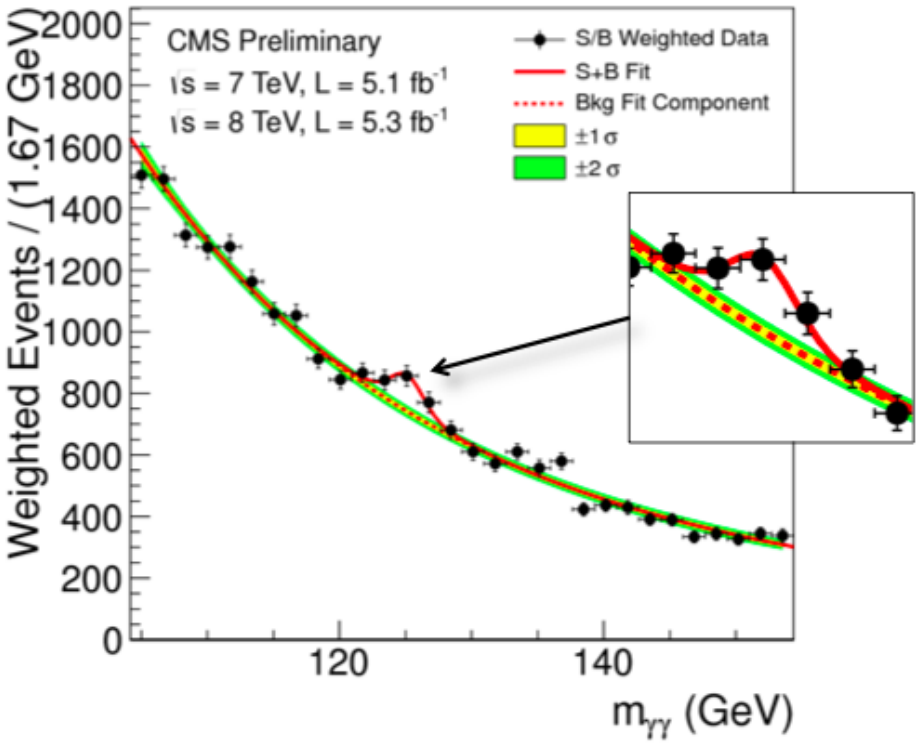


So you are trying to find the **leftovers** of the Higgs boson in a bunch of other garbage...

➞ This is what makes finding the Higgs boson so difficult!

Detecting the Higgs Boson

In the end, the effect you can measure in the detector is really tiny:



➞ accumulate a huge amount of events for statistical significance...
(5σ means 99.9999426697% confidence or $1 : 1744278$ error chance)

Implications of finding the Higgs Boson

What makes finding the Higgs boson such a huge discovery?

- Finding the Higgs boson shows that in the Standard Model **the indirect method of mass generation is correct!** (open issue for 40+ years)

  ↓

  Solidifies the mathematical framework which has been the fundament of theoretical physics for the past 50+ years.
- Upcoming fine measurements of the Higgs boson have profound implications for physics beyond the Standard Model.

Implications of finding the Higgs Boson

- Allows to understand the vacuum structure of the universe.