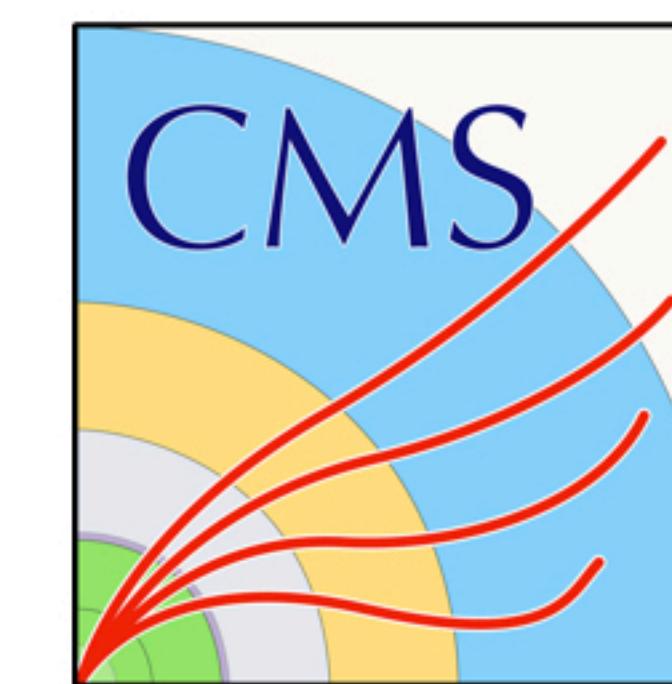


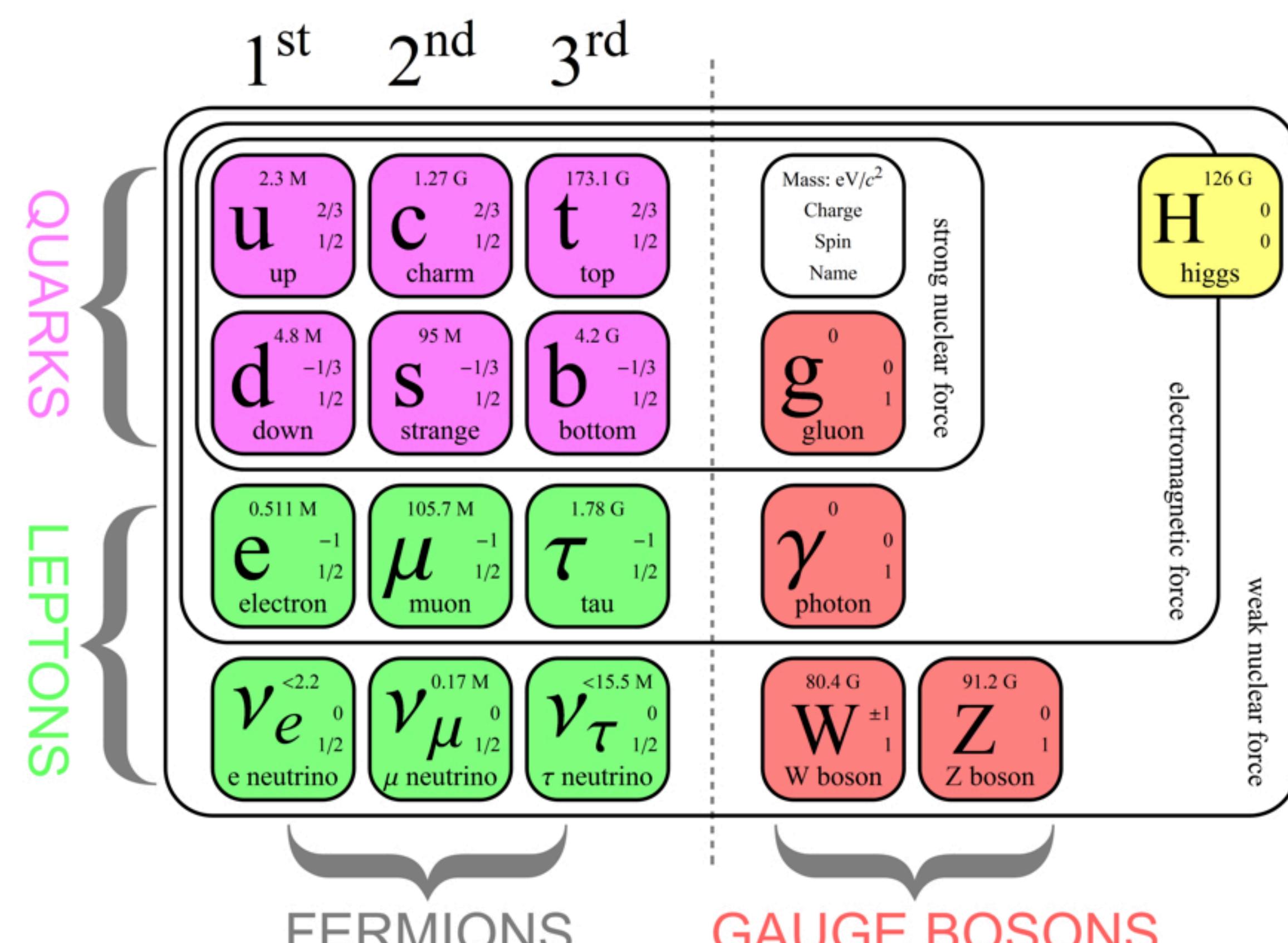


Experimental High Energy Physics with the CMS Detector at the LHC



Standard Model

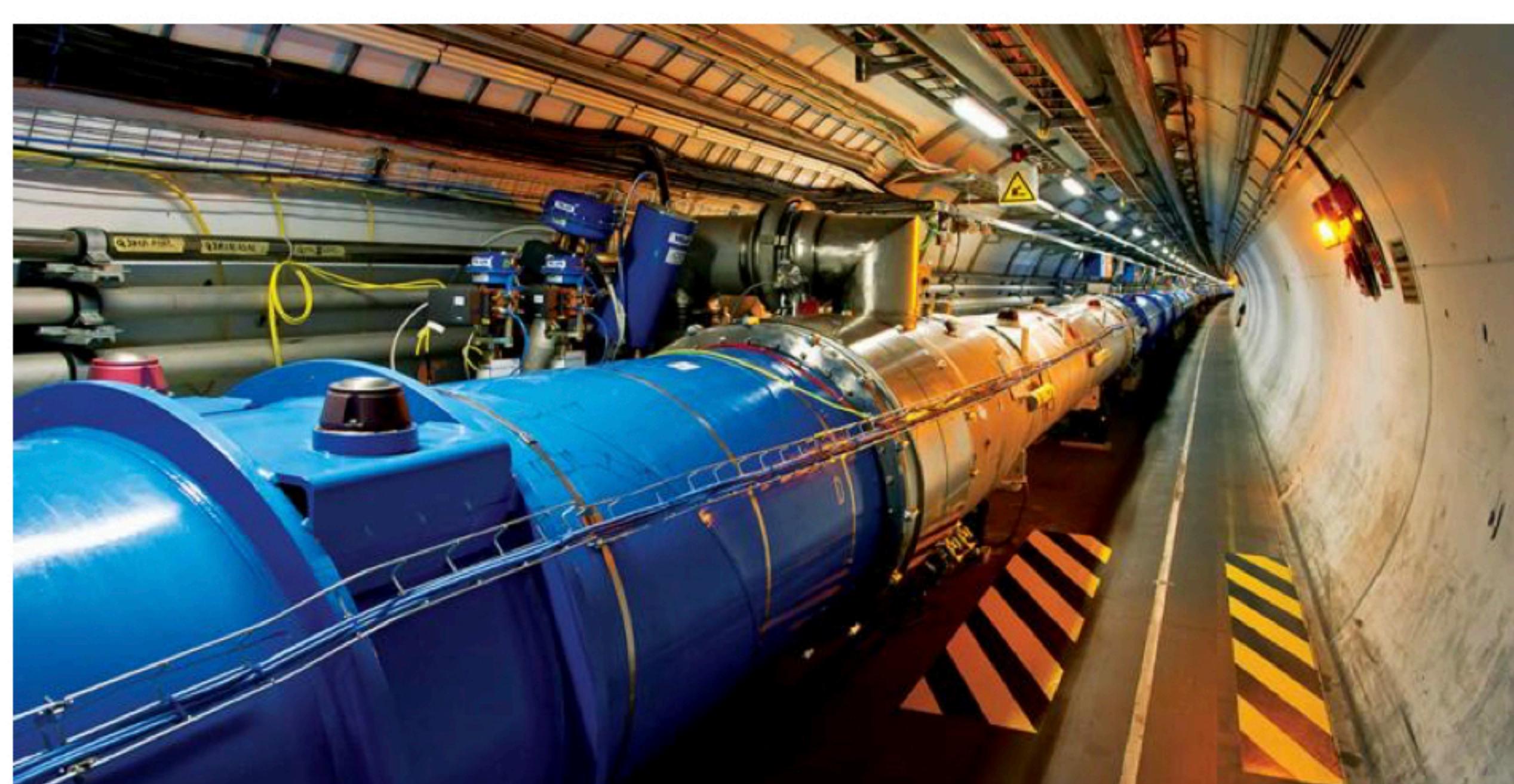
Everything in the universe is made from a few basic building blocks called fundamental particles, governed by the four fundamental forces. The building blocks of matter appear in two basic types called quarks and leptons. There are four fundamental forces at work in the universe: the **Strong** force, the **Weak** force, the **Electromagnetic** force, and the **Gravitational** force. Three of the four forces result from the exchange of force-carrier particles, called gauge bosons.



Standard Model of Particle Physics [Image: UZH - Physik Institut]

Large Hadron Collider (LHC)

LHC is the world's largest and most powerful accelerator. It consists of a **27-km** ring of superconducting magnets with a number of accelerating structures to boost the energy of the particles along the way. The electromagnets are operated in superconducting state, which requires chilling the magnets to **-271°C**.



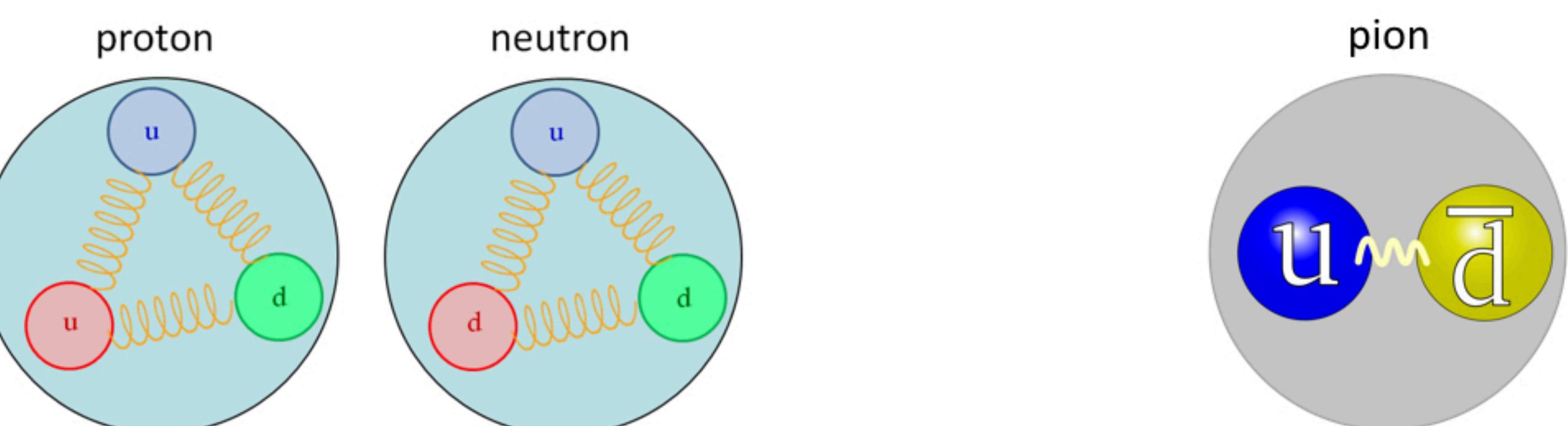
The Large Hadron Collider is the world's largest and most powerful particle accelerator [Image: CERN]

Nelson Ding, Colorado College
Daniel Salerno, PhD, Universität Zürich
Prof. Florencia Canelli, Universität Zürich

Hadron

Hadron is any particle that is made from quarks, anti-quarks and gluons. There are two basic types of hadron called baryon and meson.

- baryon: **three quarks** bound together by the Strong force.
- meson: **a quark and an anti-quark** bound together by the Strong force.

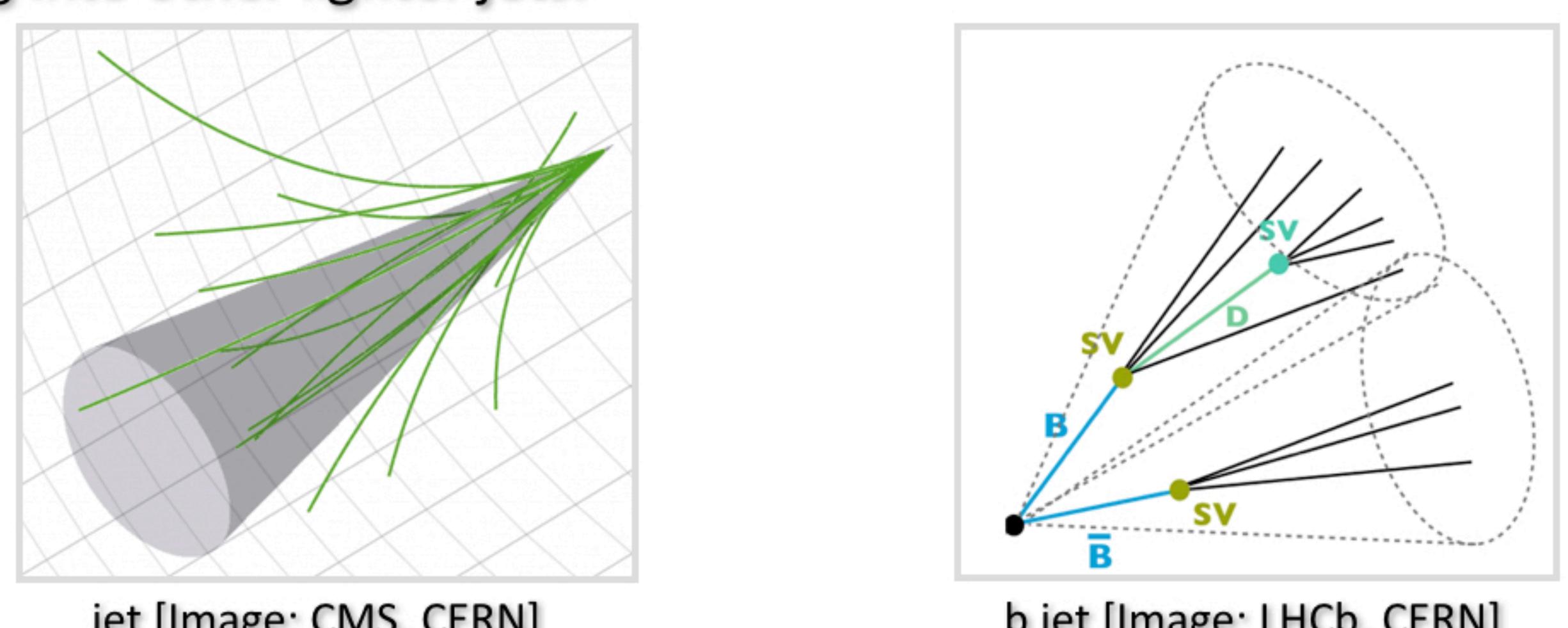


typical baryons [Image: profmattstrassler.com]

typical meson [Image: [wikipedia.com](https://en.wikipedia.org)]

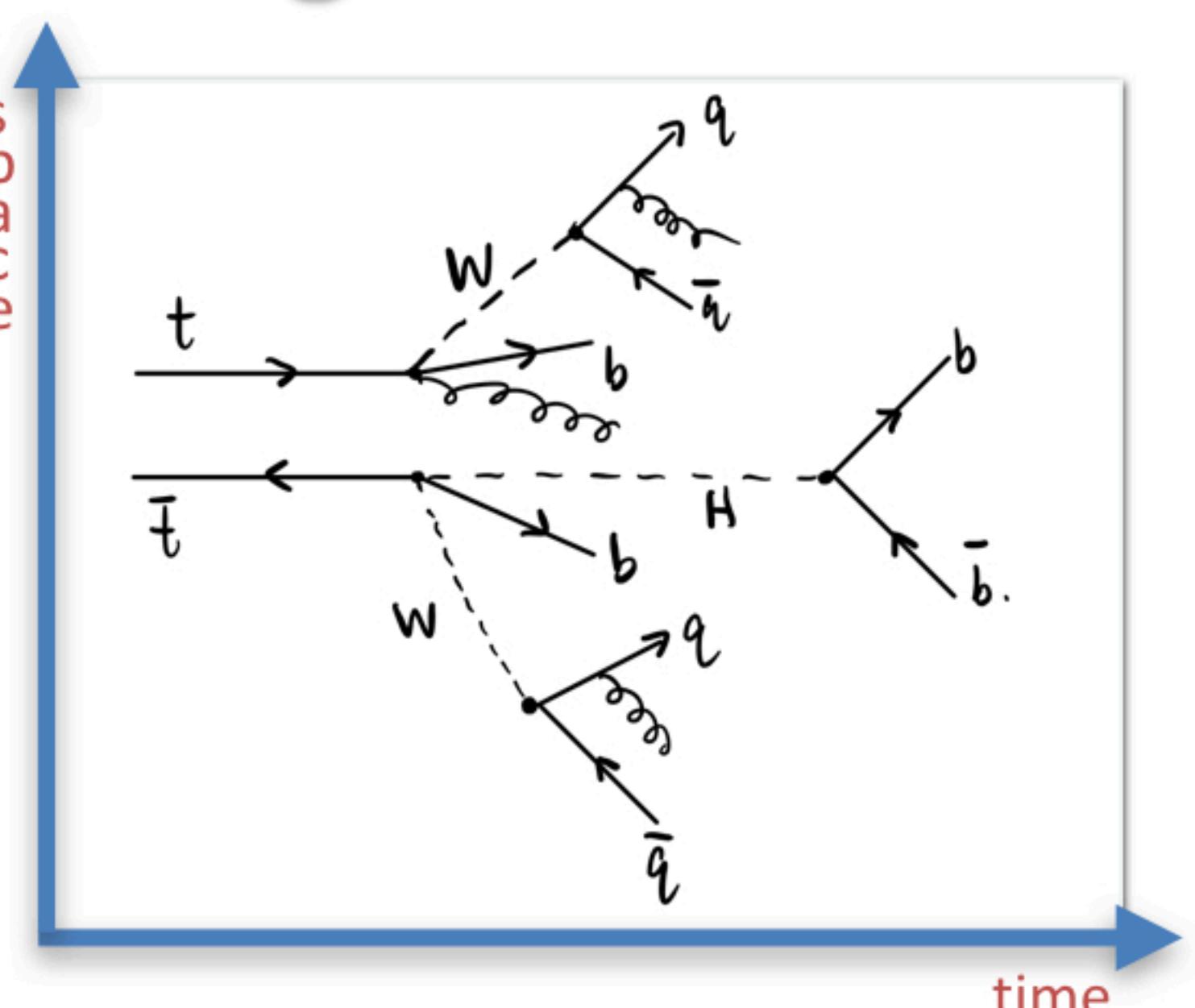
b jet

A **jet** is a narrow cone of hadrons and other particles produced by the hadronization of a quark, anti-quark or gluon. By measuring the energy and the momentum of the lighter jets decayed from a heavier and more energetic jet, we can reconstruct an original jet. **b jet** arises from the bottom quark hadronization. It travels a distance of a few millimeters before decaying into other lighter jets.

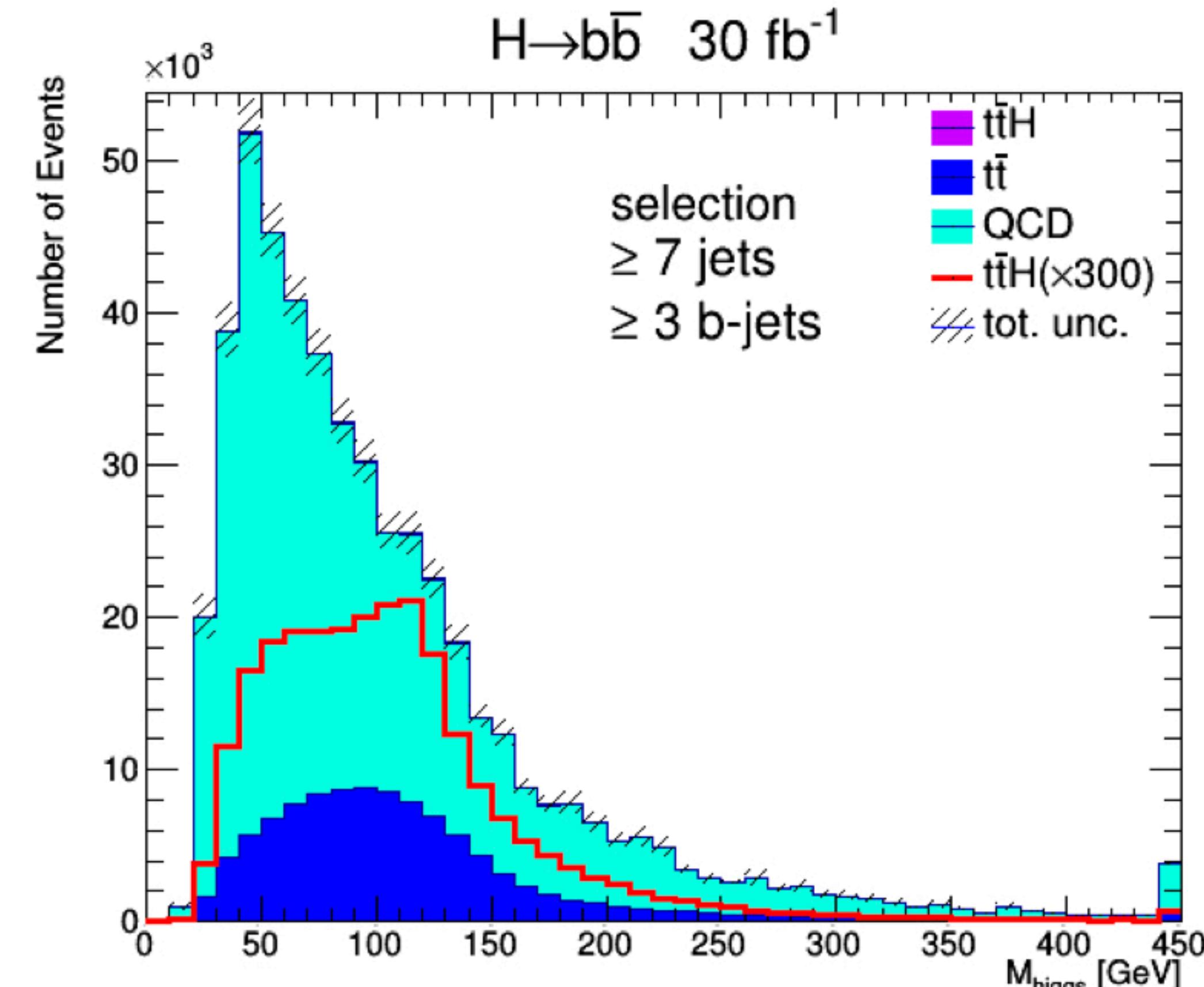


Fully Hadronic ttH Categorization

Prof. Florencia Canelli's research group is studying the properties of the **Higgs boson**, especially how it interacts with the **top quarks**. Daniel and I were doing data analysis on the fully hadronic decay channel, based on the theoretical model of b quarks and other light quarks as the decay products.



Methods and Results



All the data for the fully hadronic ttH are collected from the CMS Experiment. The goal is to optimize the signal significance (S/VB). To accomplish this, we have to reconstruct the particles from the decay products, and look into the distribution of the mass of each reconstructed particle we want to investigate. For example, to reconstruct a Higgs boson, we have to find the two closest b jets from an event.

Range	$\geq 0 \text{ GeV}$	$\geq 32 \text{ GeV}$	$\geq 39 \text{ GeV}$	$\geq 80 \text{ GeV}$	$\geq 120 \text{ GeV}$
ttH	820	802	773	526	256
ttbar	102791	100490	97466	68403	34561
QCD MC	391926	365198	341630	191388	111356
S/VB	1.166σ	1.175σ	1.167σ	1.032σ	0.669σ

From the distribution we get a rough idea of where signal might appear optimized and then we apply **selection cuts** on various mass regions. However, this is far from enough to obtain a 3σ strong evidence signal. I had spent most of my research time doing data training. If you are interested in how it works please don't hesitate to contact me at n_ding@coloradocollege.edu.

Acknowledgments

Special thanks to Prof. Florencia Canelli, and Daniel Salerno at the University of Zurich, and Prof. Shane Burns at Colorado College. Particle Physics is fun!

Image Credits:

1. Standard Model - Physik Institut, UZH
2. LHC - cern.ch
3. Baryons - profmattstrassler.com
4. Meson - [wikipedia.com](https://en.wikipedia.org)
5. jet & b jet - cern.ch

Reference:

1. Standard Model, <https://home.cern/about/physics/standard-model>
2. Large Hadron Collider, <https://home.cern/topics/large-hadron-collider>