A few word about Higgs bosons and other things...

Andres Tiko

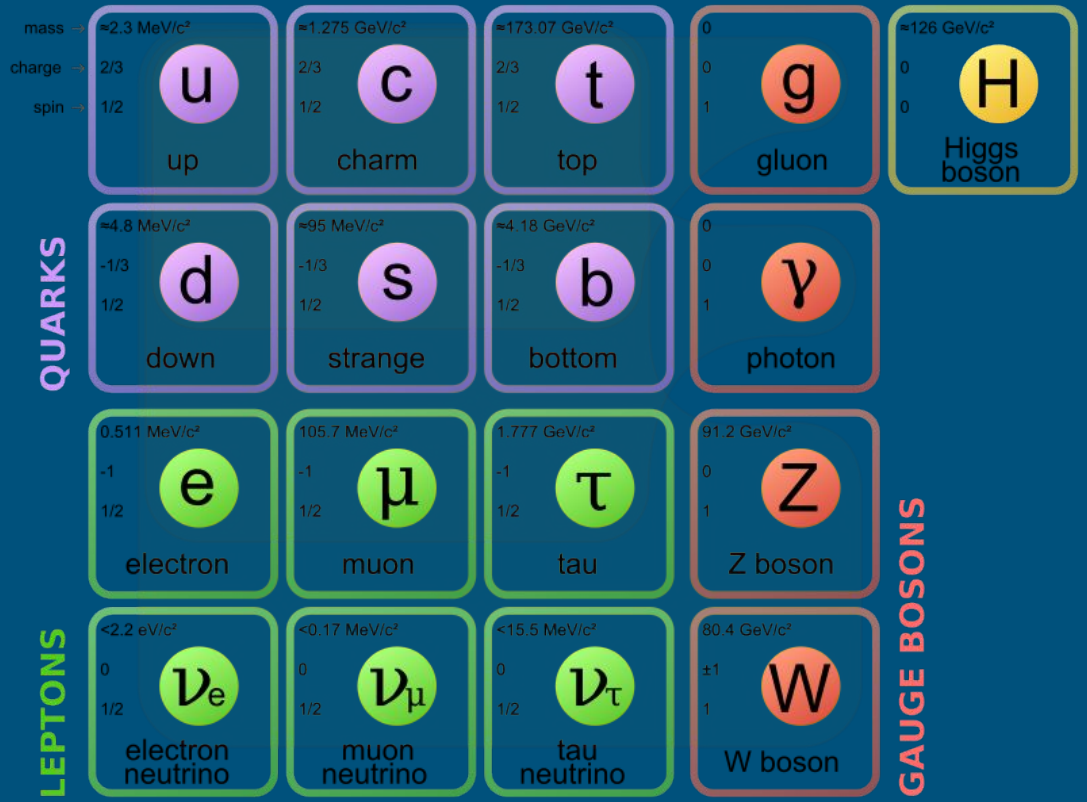
How I ended up here

- Studied physics 2003-2007
- Worked as a programmer 2006-2007
- Did a masters in computer science, 2007-2009
- CERN summer student 2008
- Worked as a programmer in India, 2009-2010
- Somehow ended up doing a PhD in physics, 2010-2016 (University of Tartu / National Institute of Chemical Physics and Biophysics), joined the CMS experiment
- Currently postdoctoral researcher at INFN Padova, 2017-2019

Standard model of particle physics

What are the particles that exist?

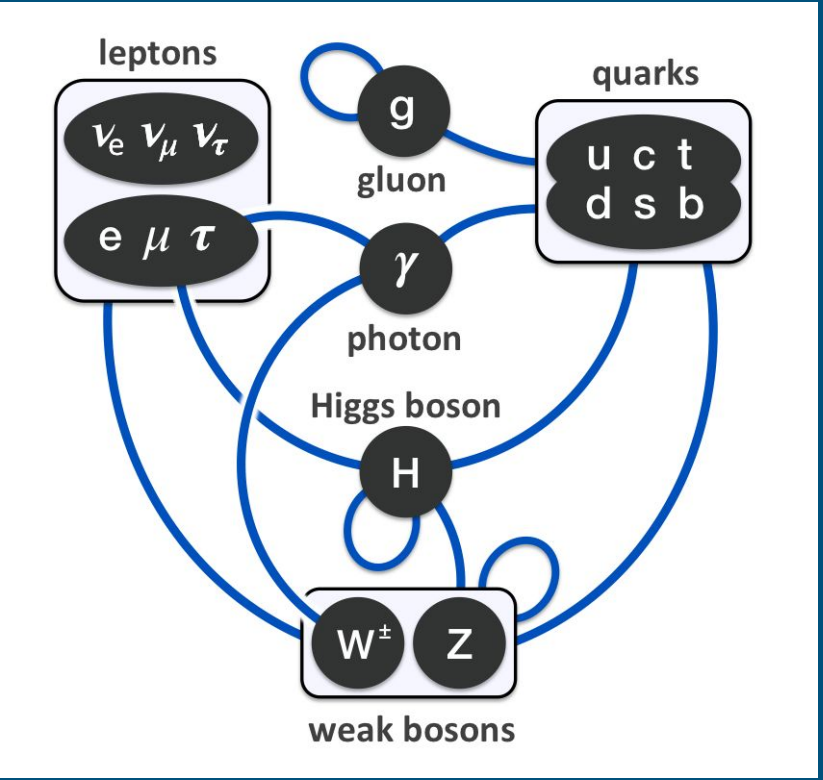
How do the interact?



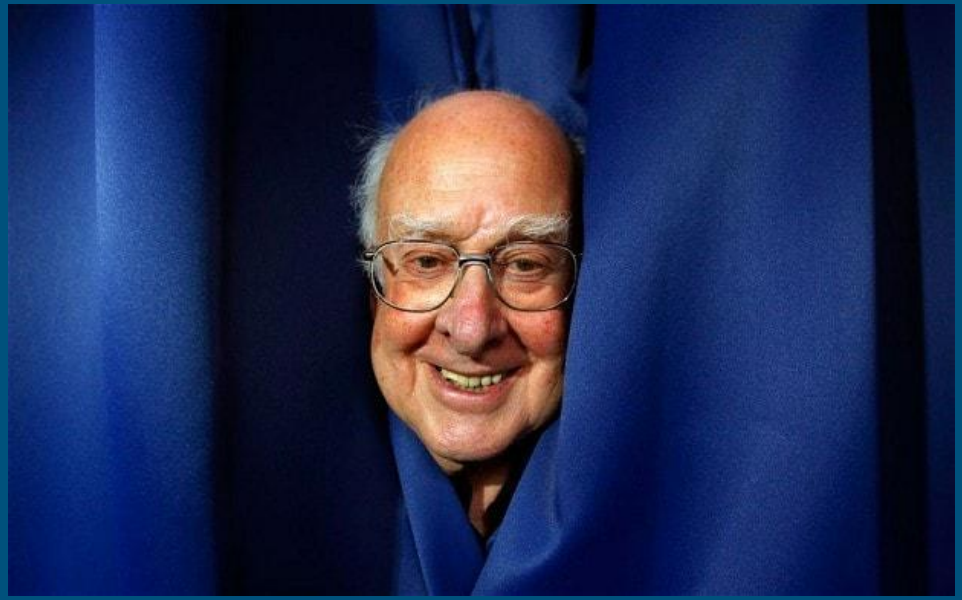
Standard model of particle physics

What are the particles that exist?

How do they interact?



So we found the Higgs boson. Are we done?



SM is a very successful theory, but…

All measurements so far compatible with SM

But many reasons why it cannot be the final theory

- Does not describe dark matter or dark energy
- Does not explain why there is more matter than antimatter
- Does not include gravity
- Does not include neutrino masses
- Has 19 numeric parameters that we cannot predict, only measure
- …

So we look for any deviations from SM predictions for a hint of new physics

$$E = mc^2$$

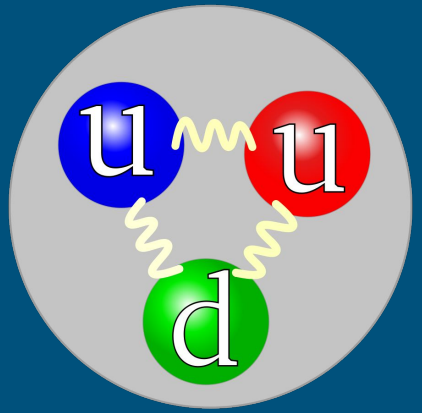
We want to find new particles (with big masses) and collide protons to do that

(Or produce more of the heavy particles we already know to study them)

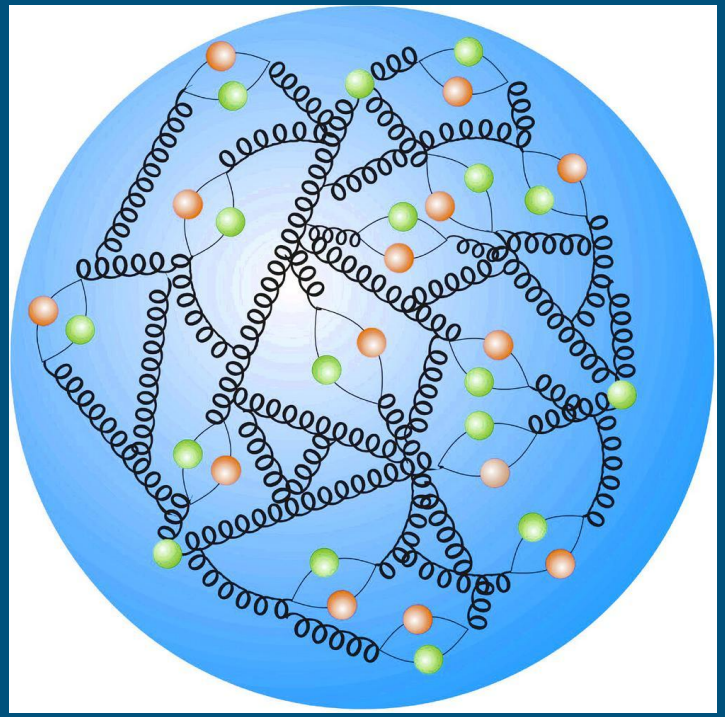
Steps in a physical measurement

1. Reconstructing measured particles and their properties (types, trajectories, energies etc.)
2. Reconstructing the original particles (Higgs, top, tau, heavy bosons etc.) - a lot of the work done by applying conservation laws
3. Separating signal and background
4. Measuring a variable of interest or setting a limit on its value
5. Calculating the uncertainty

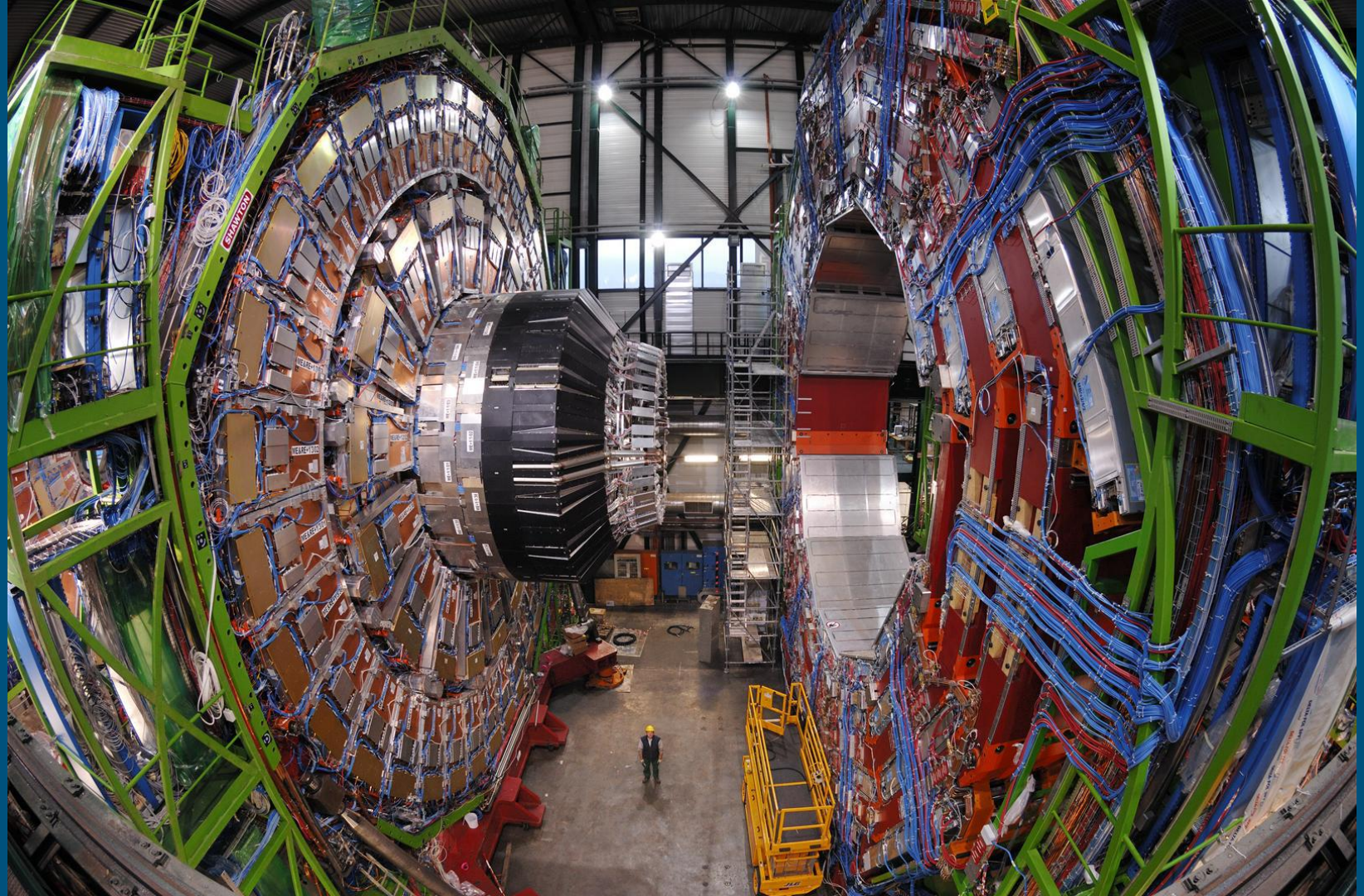
We collide protons, but what are they?



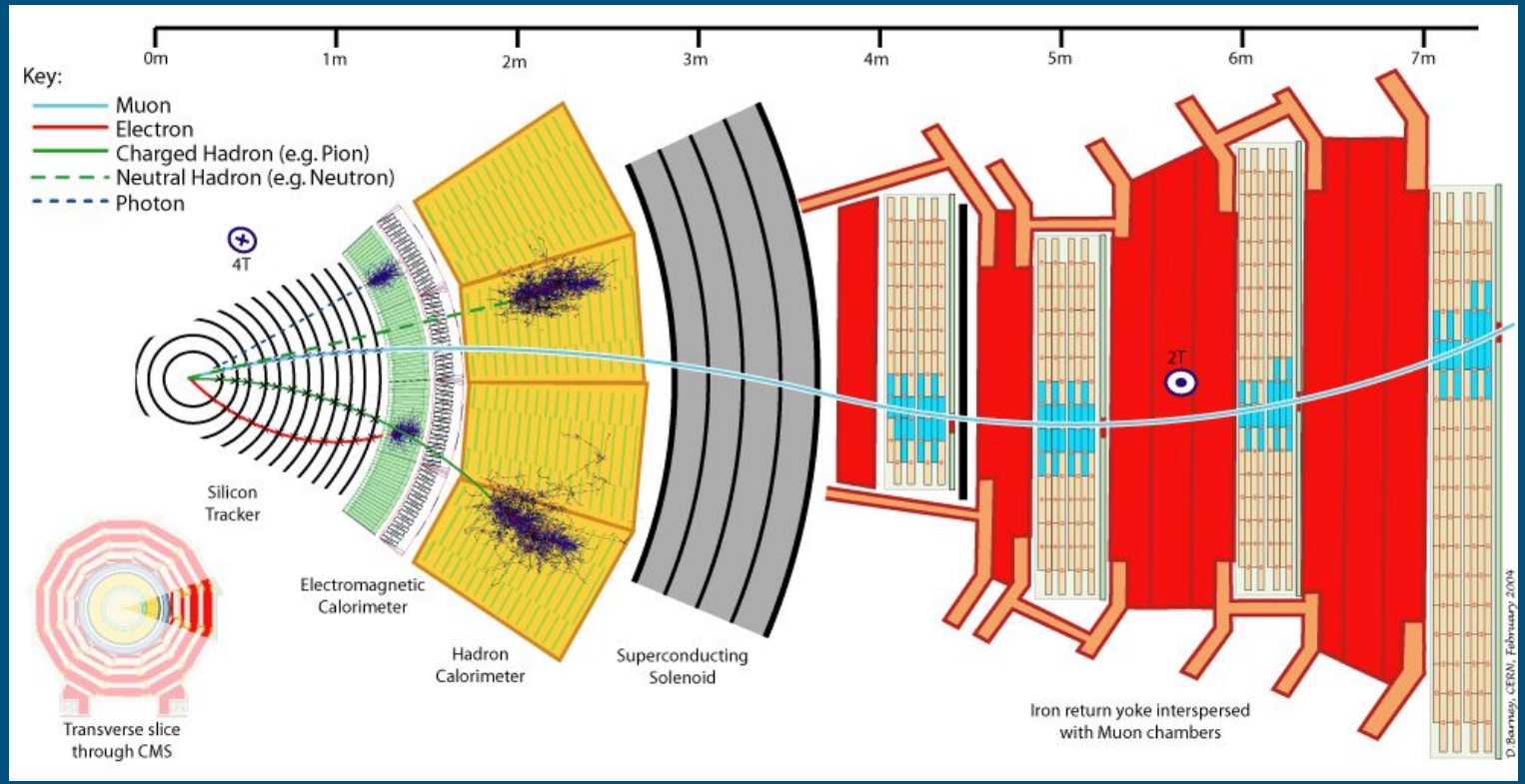
Wikipedia



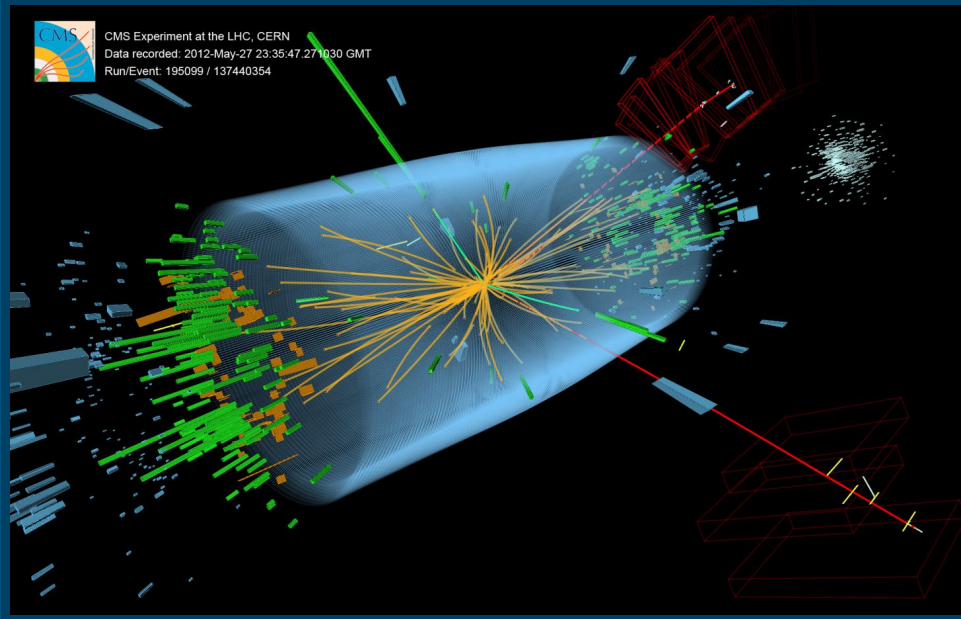
LHC more like this


CHAMPION

Detecting particles

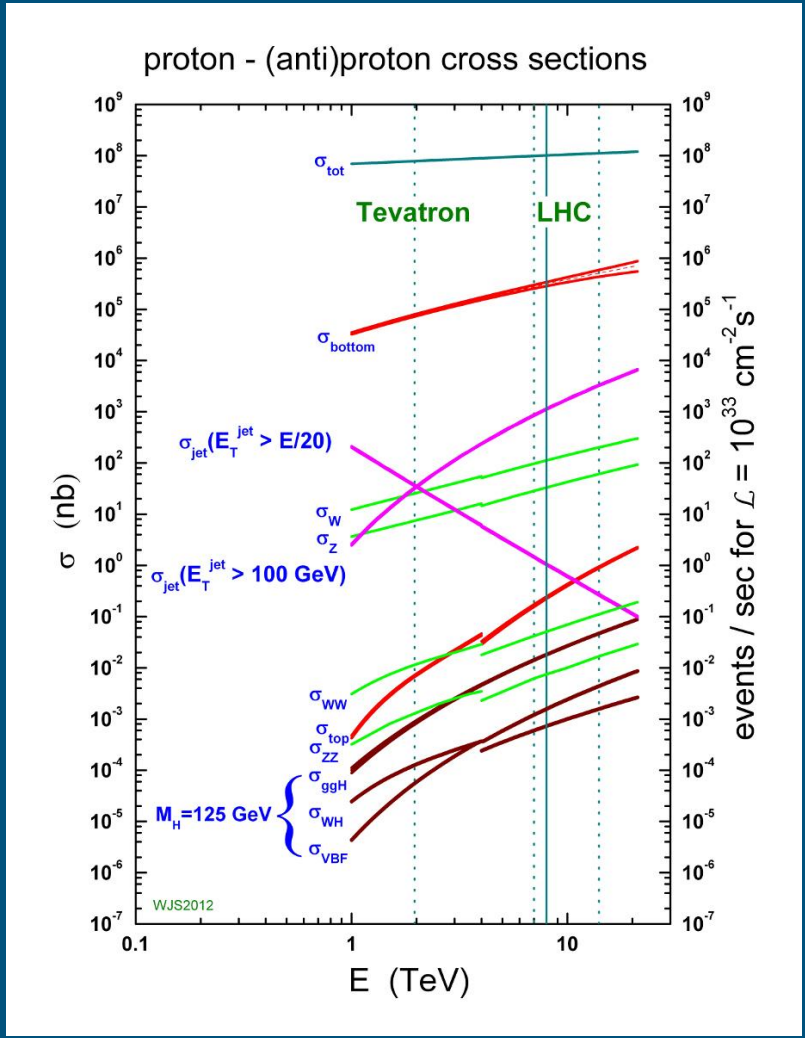


Reconstructing a collision



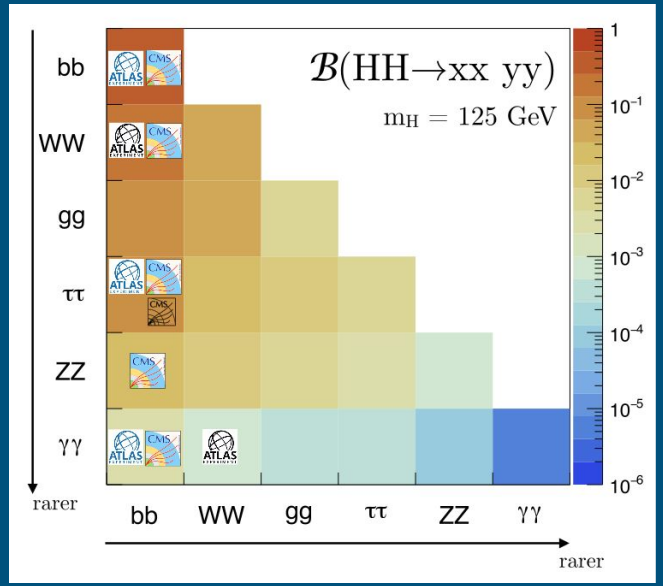
Looking for a needle in a haystack

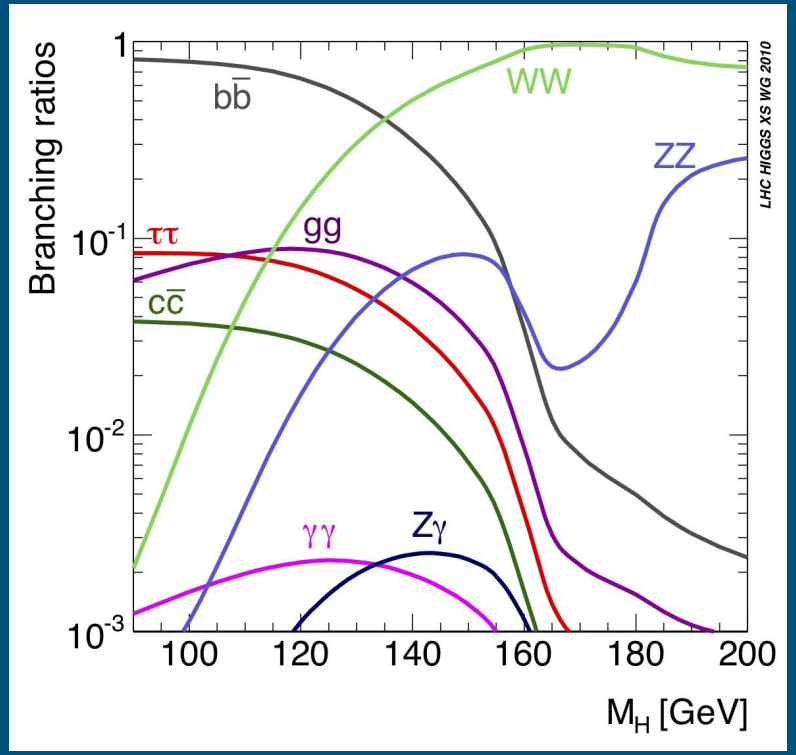
- To discover the Higgs boson we collected ≈ 10^{15} proton-proton collisions
- In them ≈ 10^5 Higgs bosons
- Reconstructed of them ≈ 1000
- A Higgs pair is much rarer



Higgs boson decay products

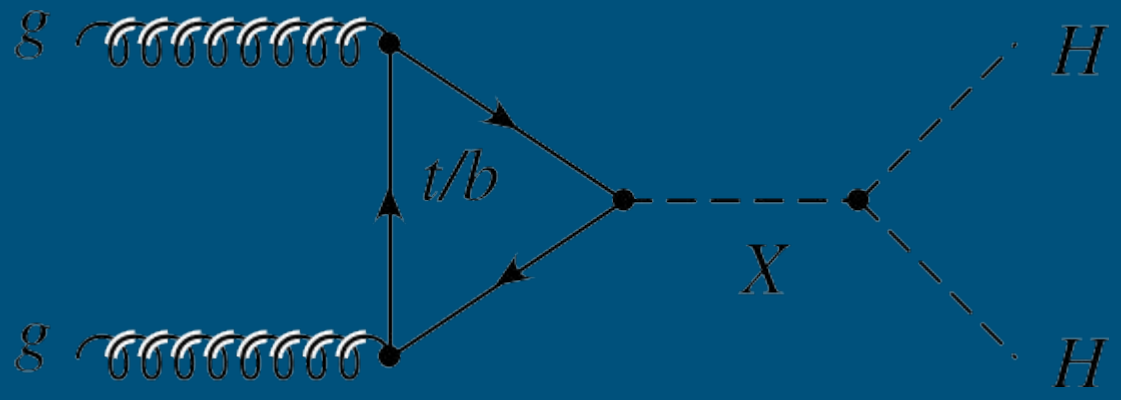
- Higgs→bb the most frequent for SM Higgs boson, but with a lot of background



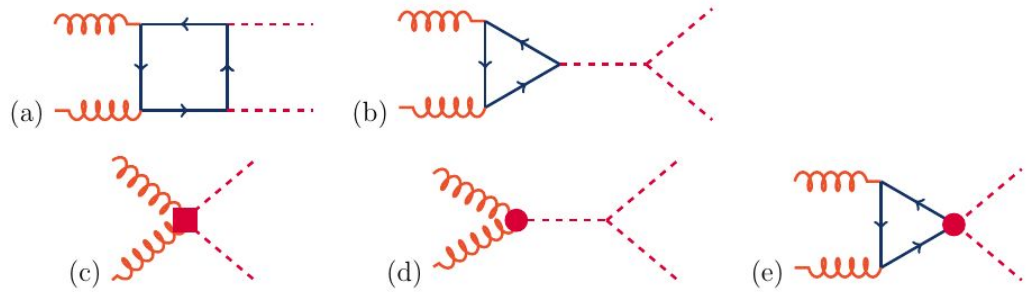


Resonant and non-resonant production

Higgs boson pairs can be created when some new particle decays into them - resonant production

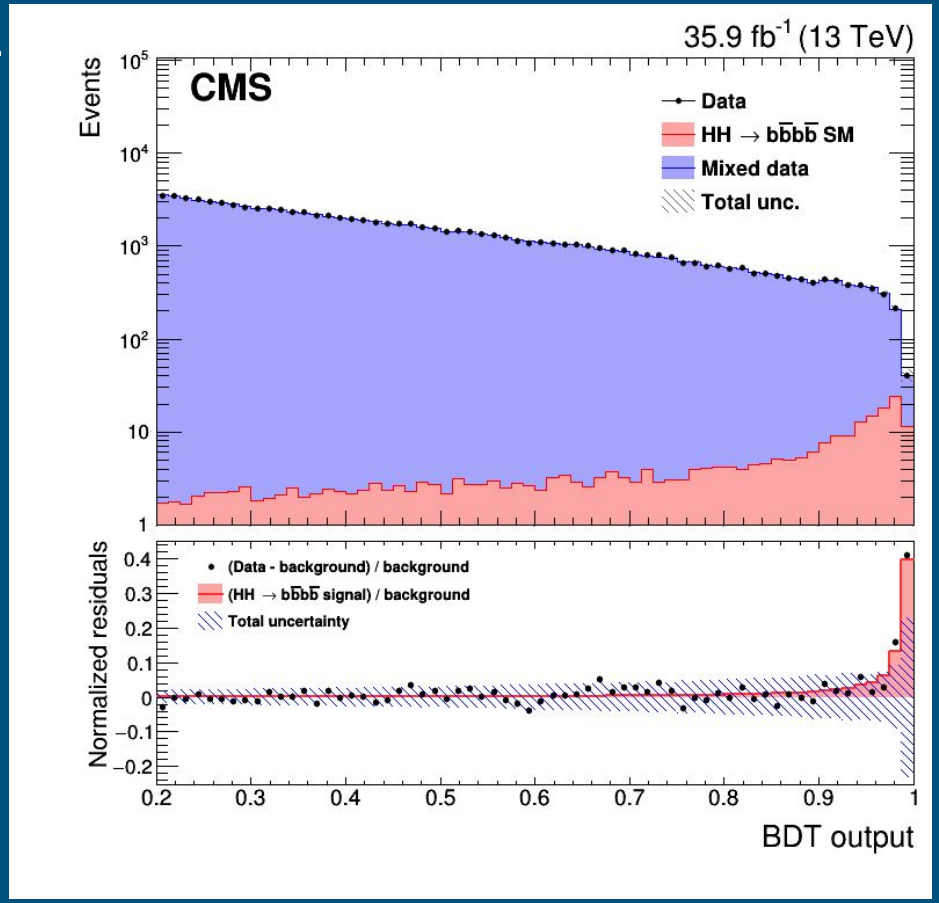


Or non-resonant production - without such a new particle



Signal and background

- We use machine learning to try to separate our Higgs pairs from background
- Still a lot of it remains
- We measure a limit of ≈75 times the SM HH production cross section times the square of the branching fraction for the H → bb decay (expected ≈37)
- The best combination of all decay channels at the moment gives us limits of ≈8*SM



Questions?