HIGGS BOSON MASS MEASURMENT

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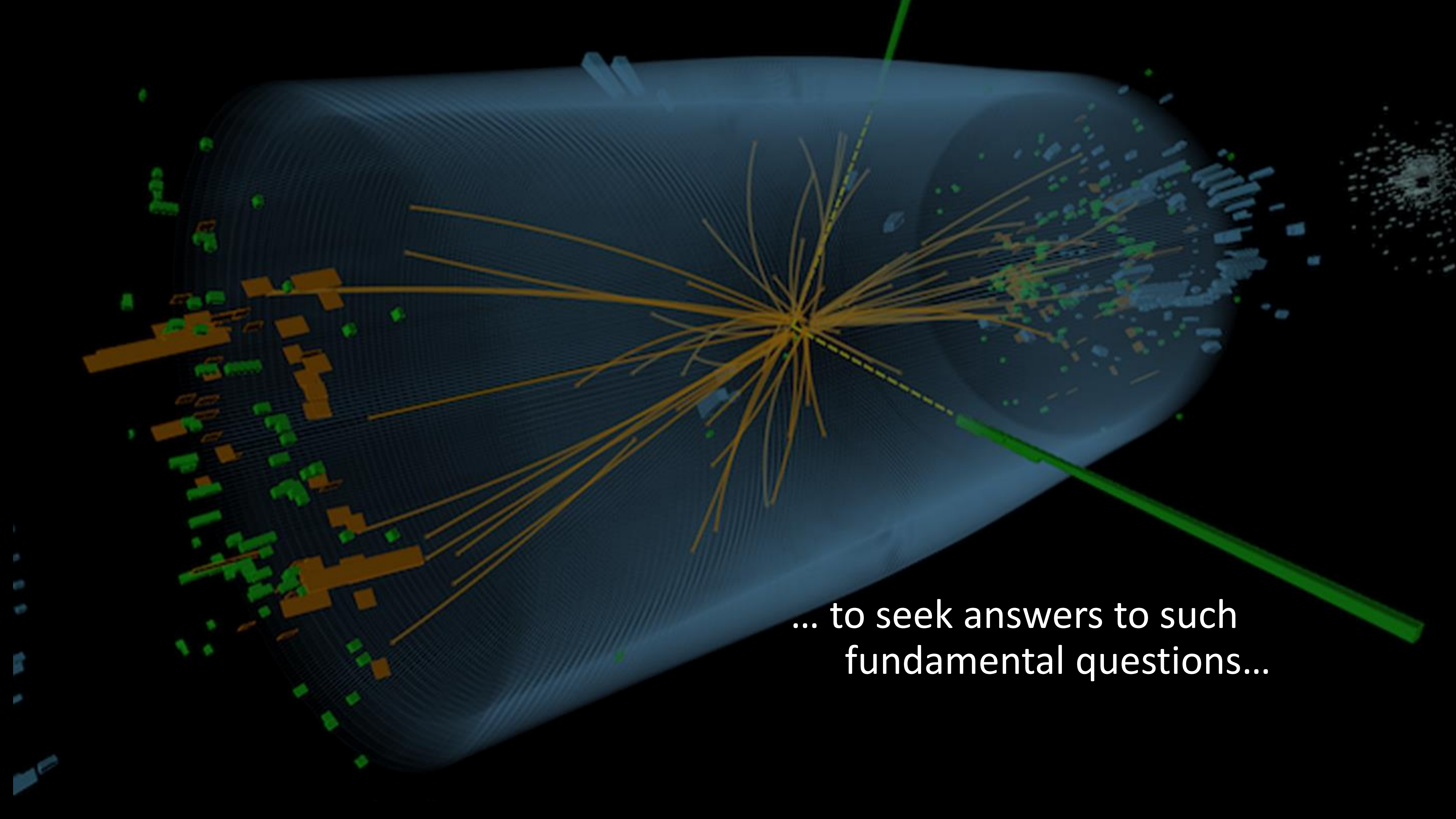
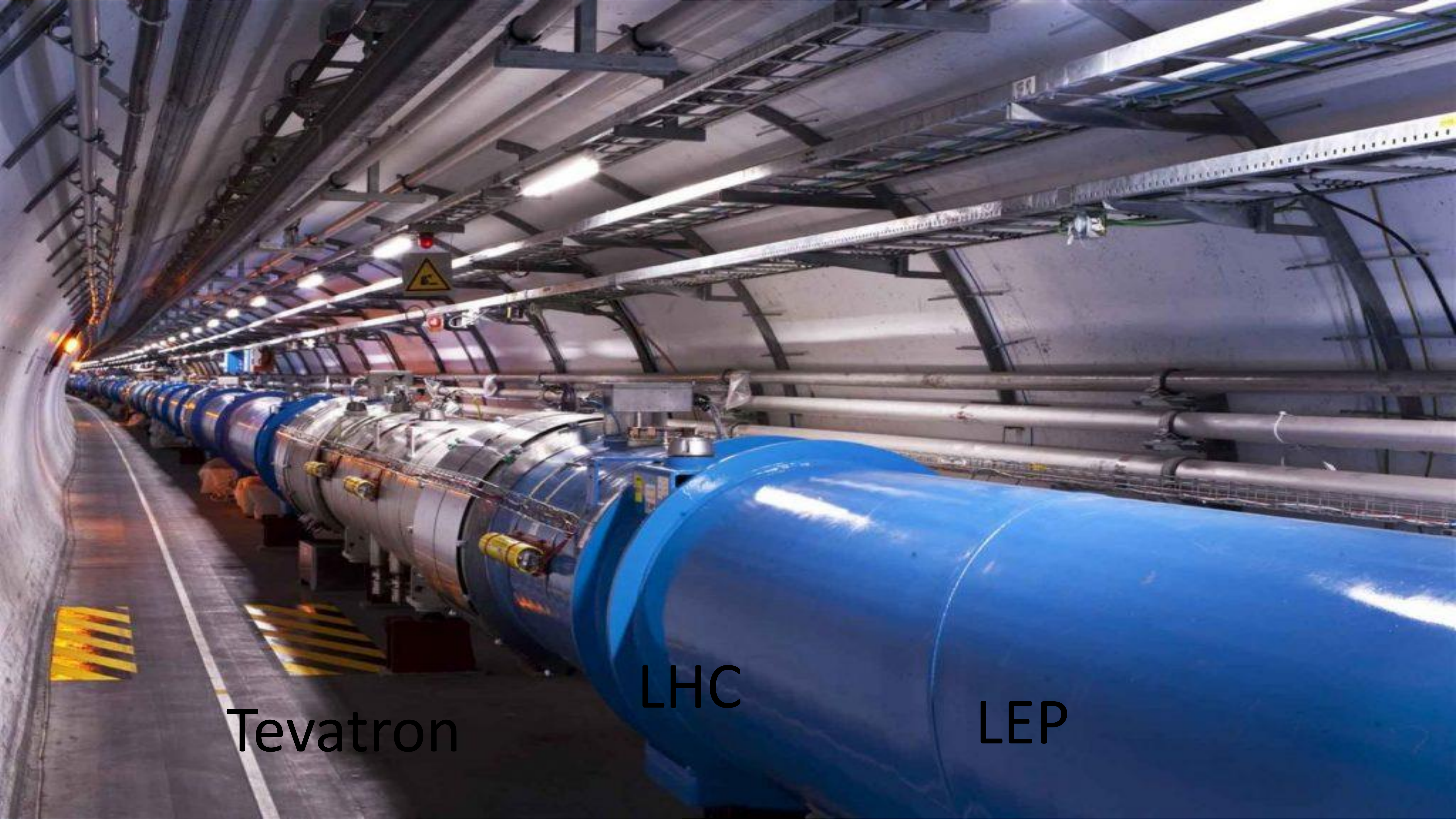
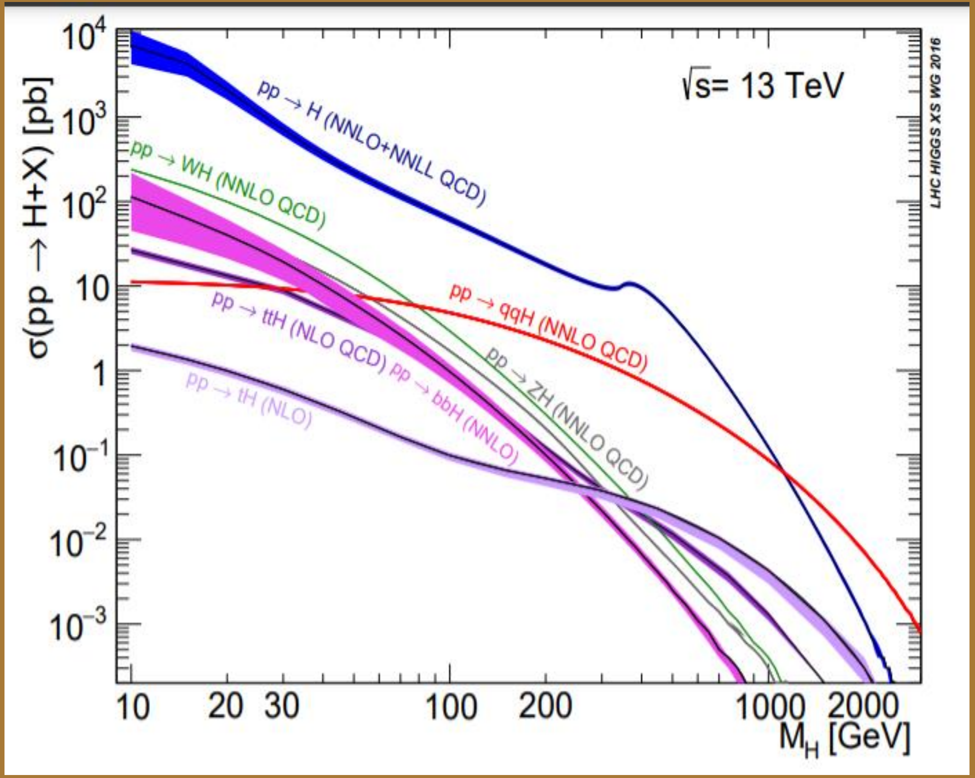
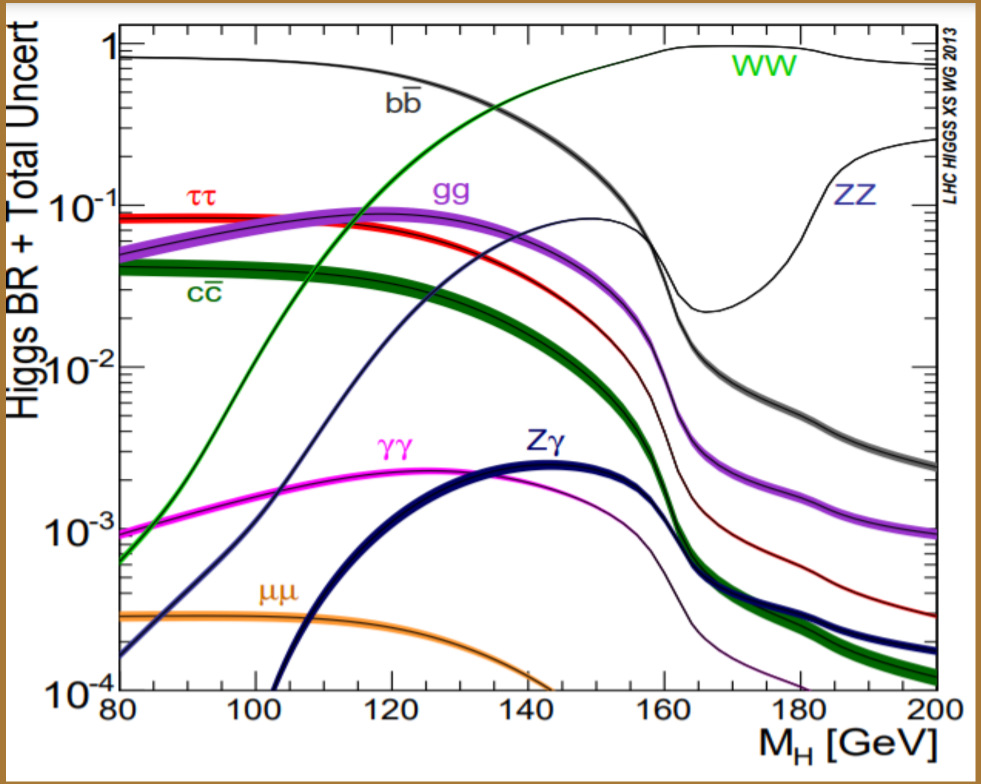

… to seek answers to such
fundamental questions…


LHC
LEP
Tevatron

Different ways to produce the Higgs Boson



The products of the decay of the Higgs Boson



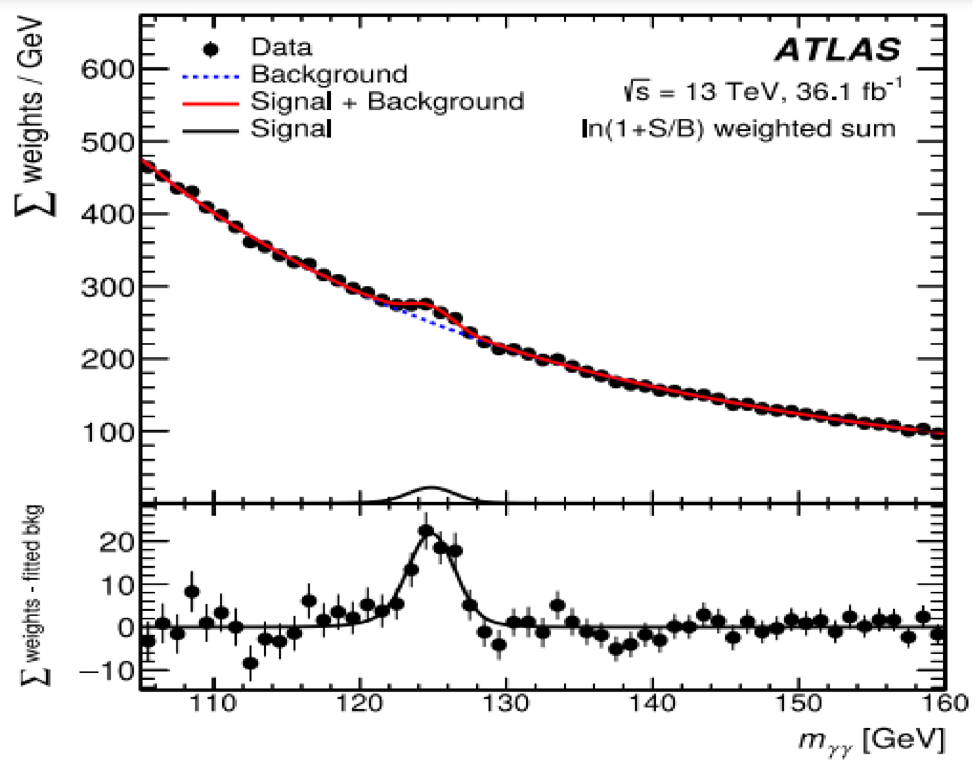
We need to measure the higgs boson mass in order to predict its proprieties

Depending on the Higgs boson mass → we expect to see more or less events at LHC

→ we expect to see different decay rates

How do we measure the mass?

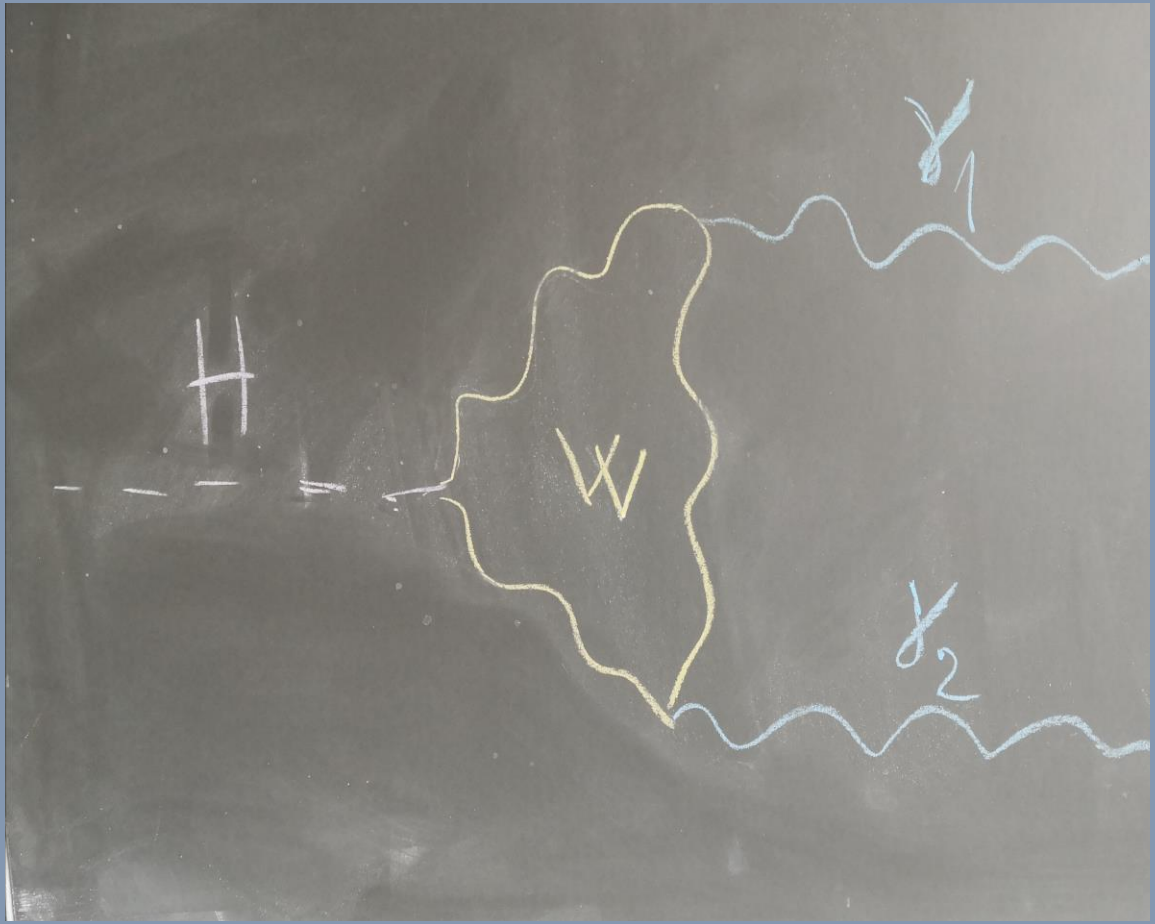
...We can use di-photon events



We need to know how to model the signal peak and the background to obtain the mass of the Higgs Boson

We can observe Higgs Bosons events as a Very Nice peak over a smoothly falling background.

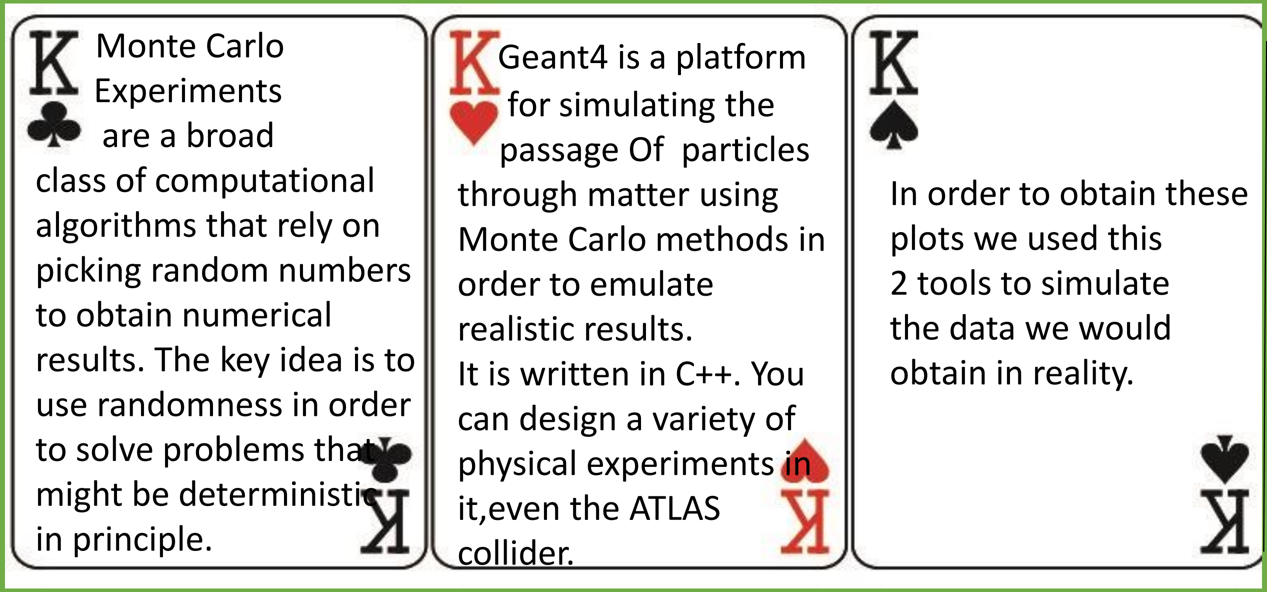
The decay of a Higgs Boson



The Higgs cannot decay directly into 2 photons because it only interacts with particles that have mass however, the photons have zero mass.

It does so through some other particles in between.

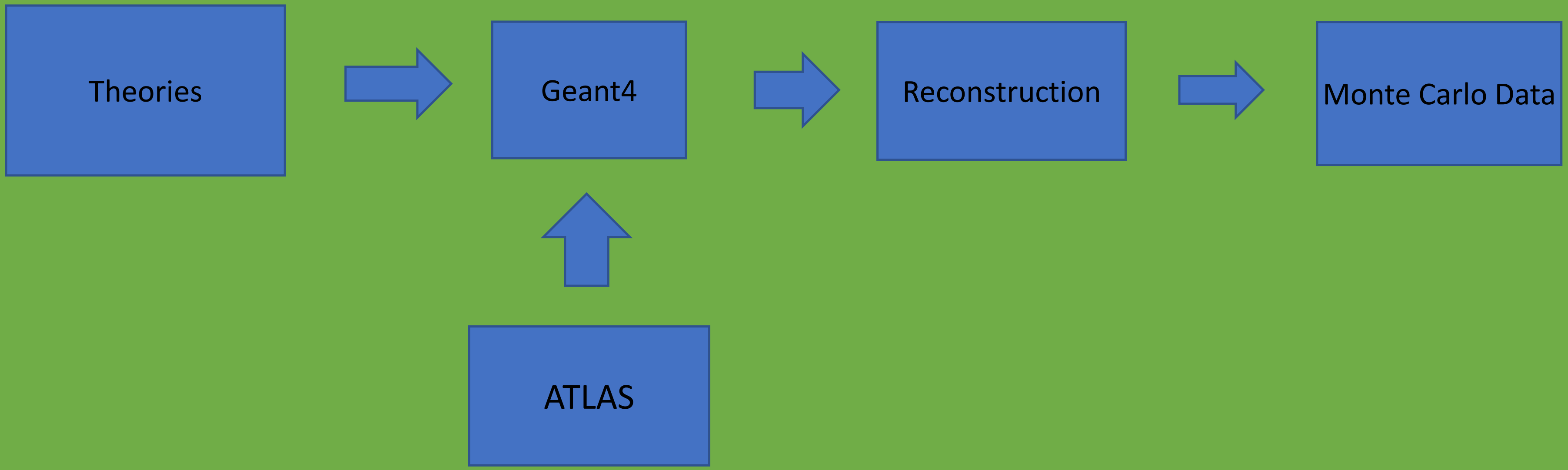
Monte Carlo and Geant 4



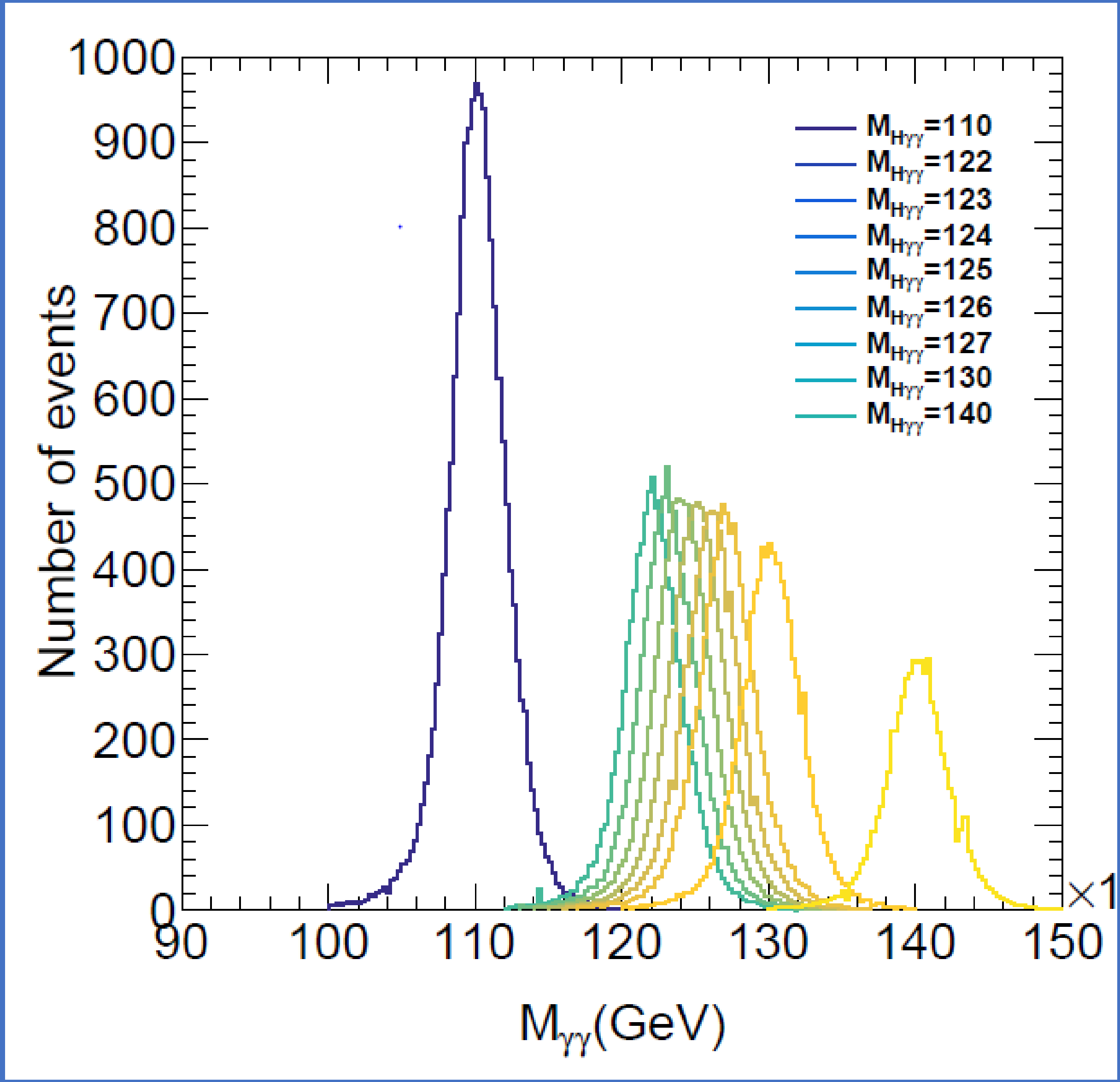
Monte Carlo Experiments are a broad class of computational algorithms that rely on picking random numbers to obtain numerical results. The key idea is to use randomness in order to solve problems that might be deterministic in principle.

Geant4 is a platform for simulating the passage Of particles through matter using Monte Carlo methods in order to emulate realistic results.
It is written in C++. You can design a variety of physical experiments in it,even the ATLAS collider.

In order to obtain these plots we used this 2 tools to simulate the data we would obtain in reality.

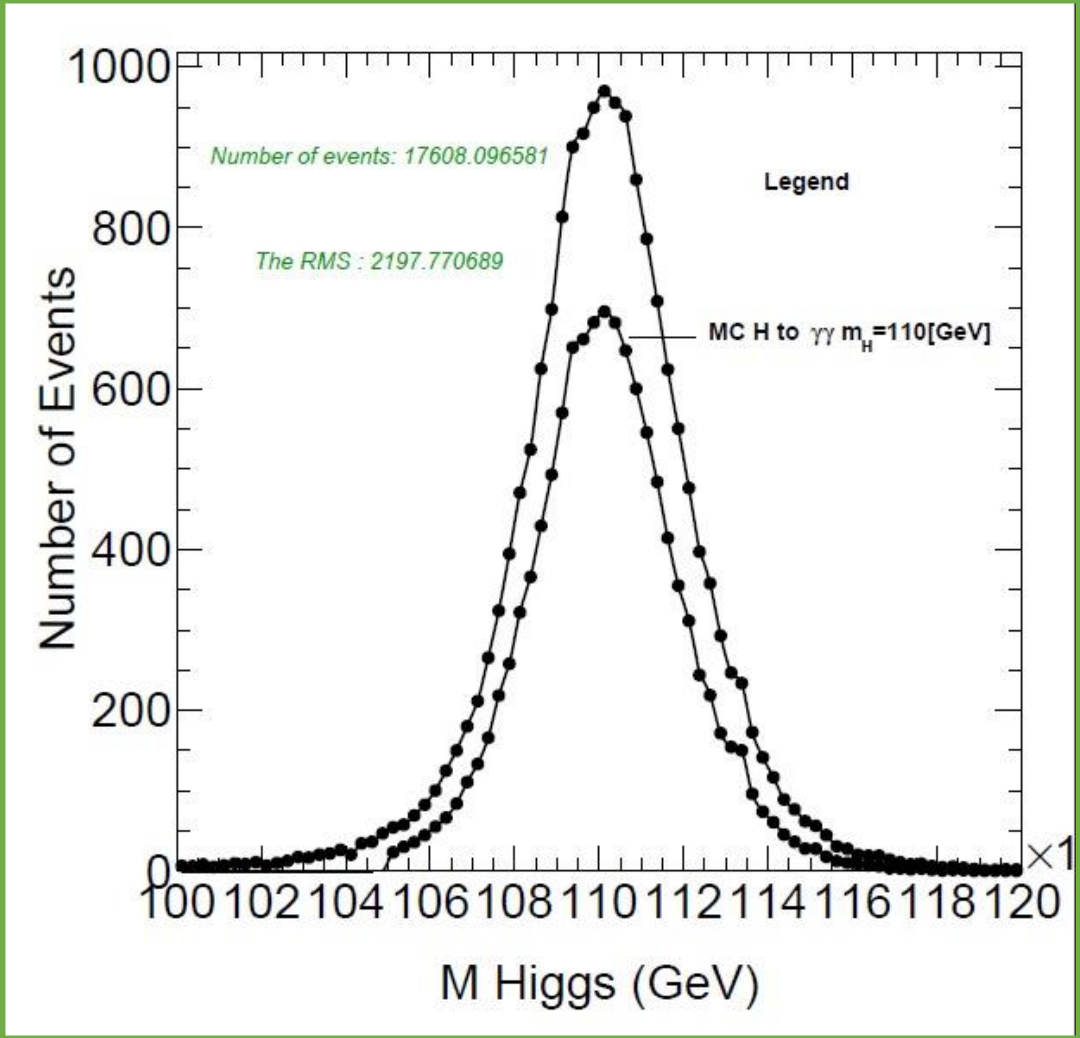


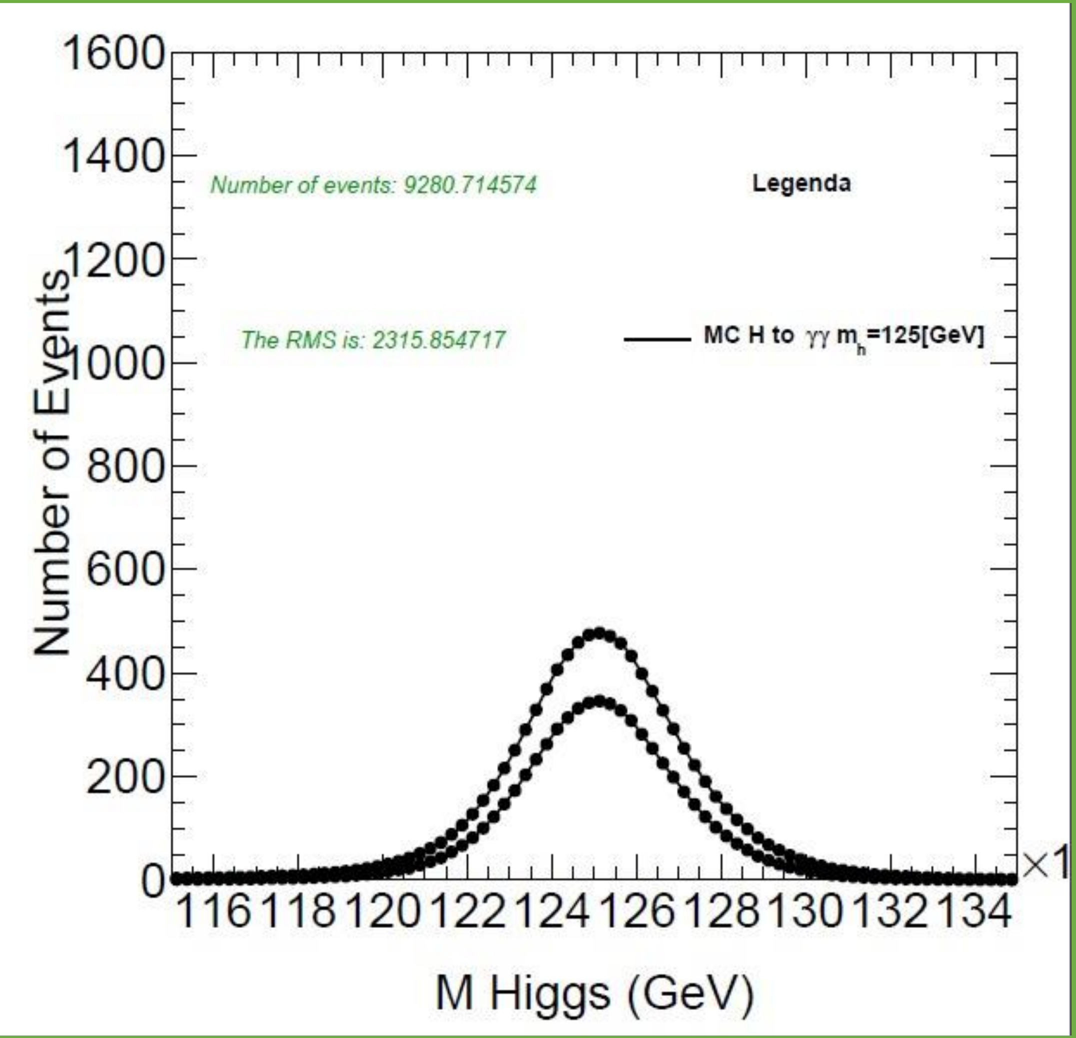
Mass distribution of the two photons for Monte Carlo samples generated with different mass of the Higgs Boson



How do we measure the mass?

To calculate the mass of the Higgs Boson with precision we need to get rid of the background events that affect our data. After that, we estimate the energy of the photon shower detected in the collider's calorimeter and determine the invariant mass of the Higgs Boson.

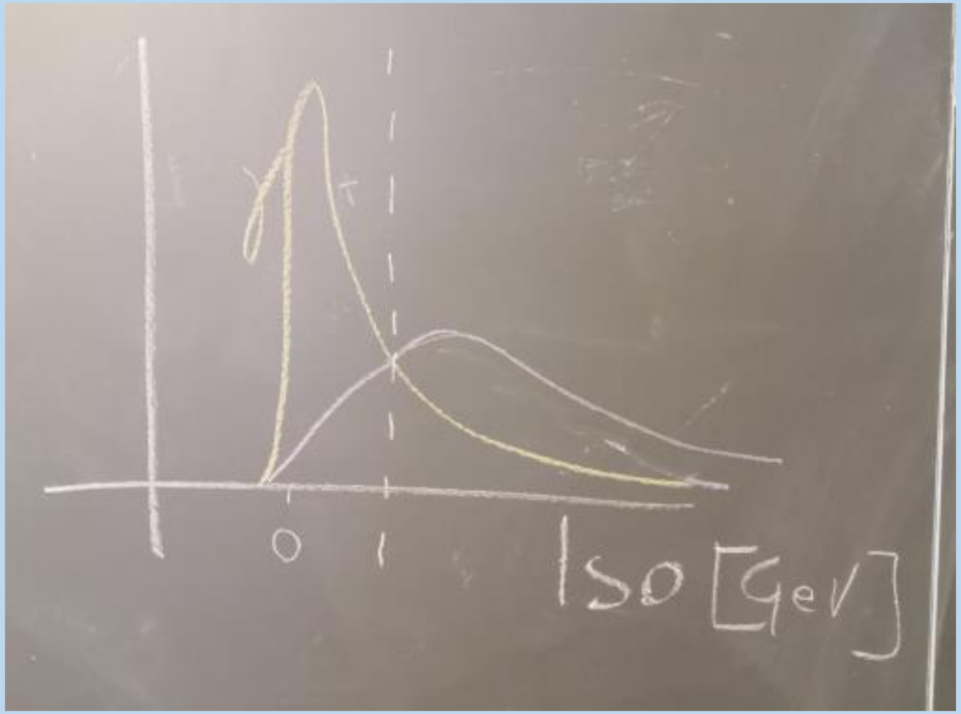




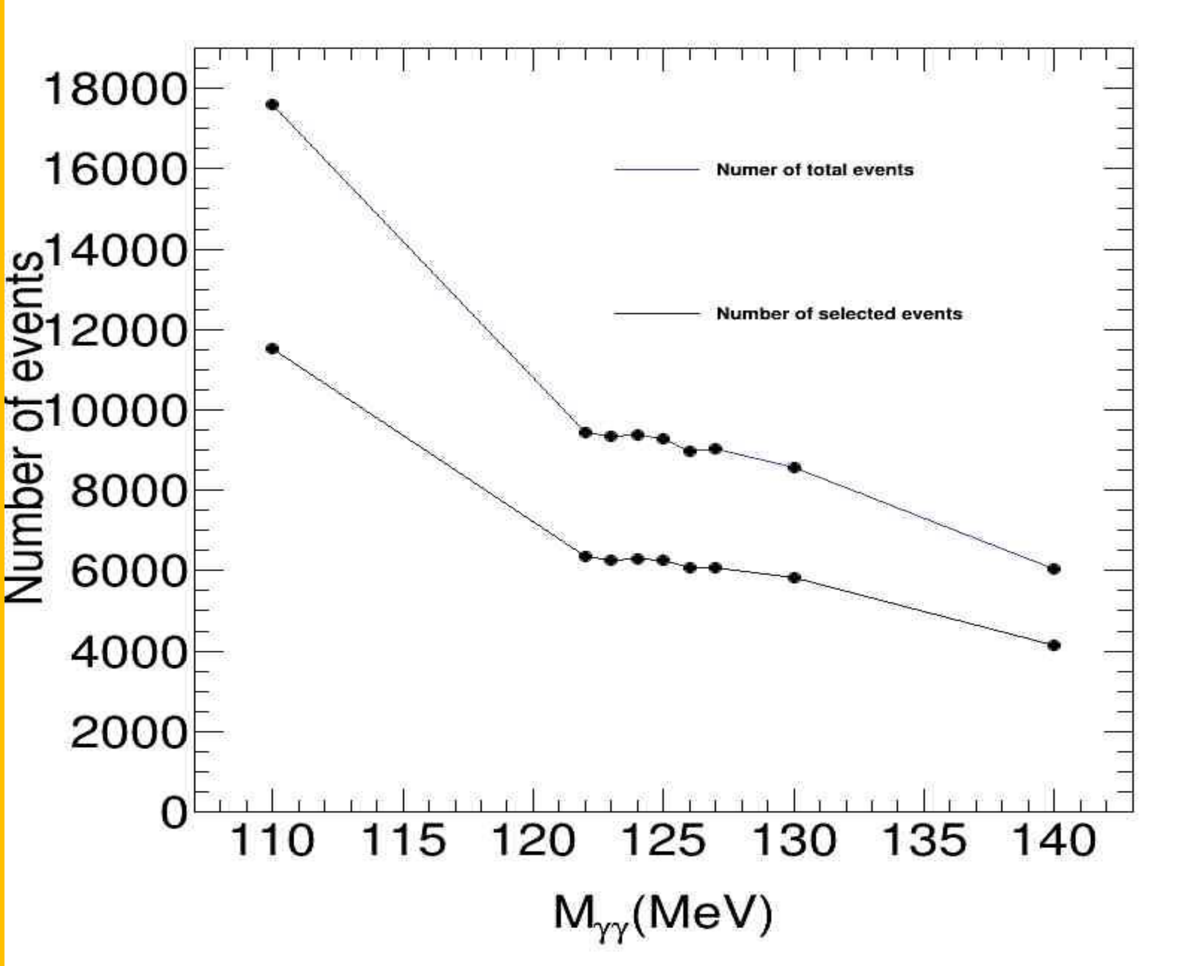
An exemplary selection cut: Isolation

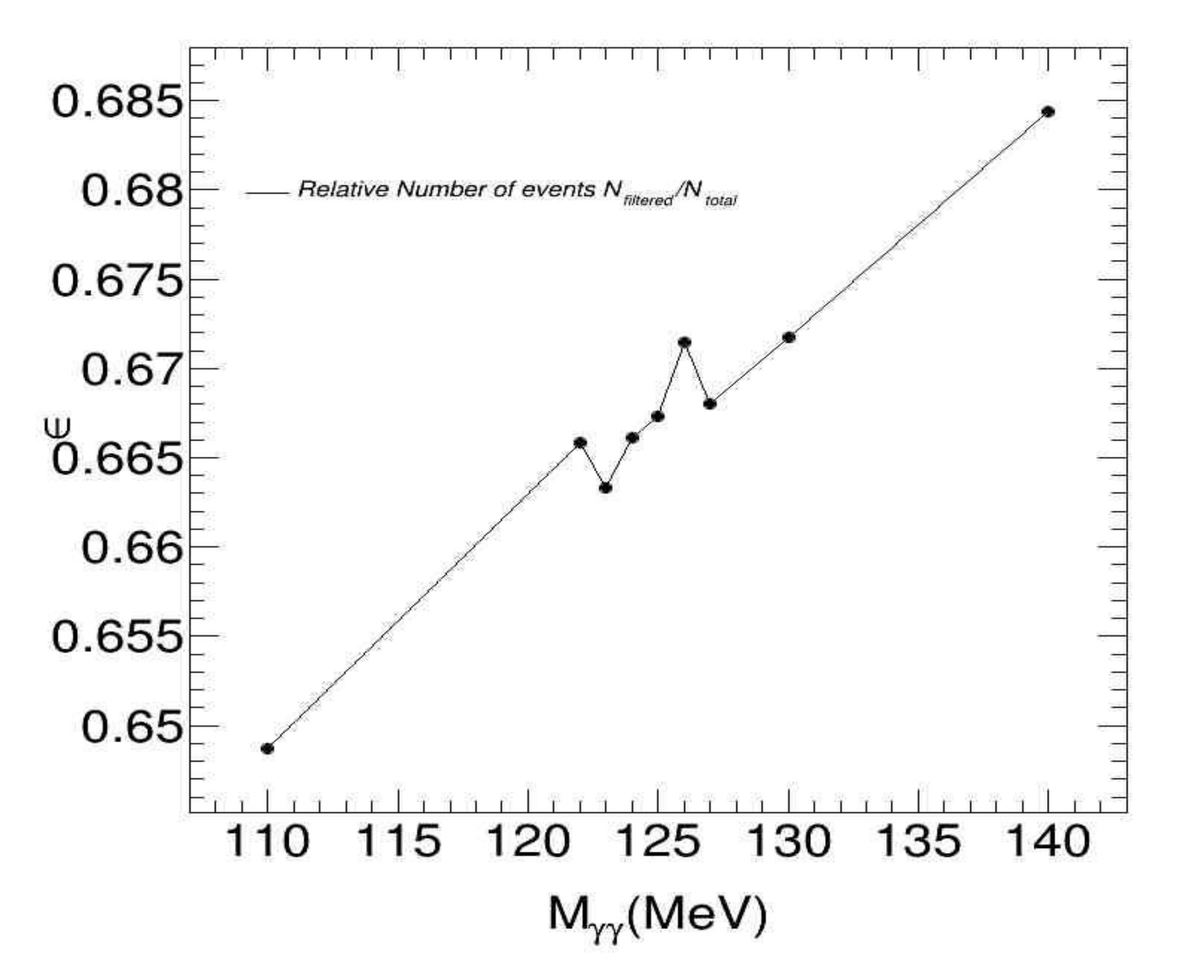
We can distinguish good photons from bad phtons measuring the energy in a cone around them:

- A true photon has almost no energy around it
- A background photon from a jet has a lot of energy in the cone around it because there are a a lot of other particles inside the jets



Comparing the number of total events to the number of the selected events:



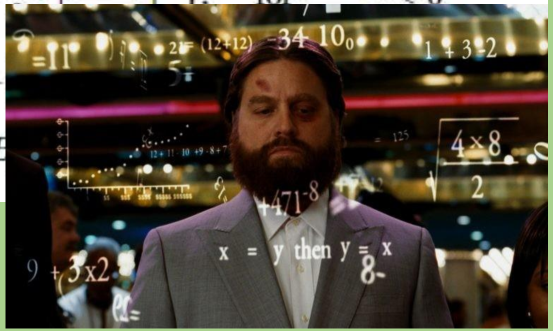


- Unfortunately, we notice that about ~34% of the signal events are removed when applied the selection.
- **However**, we reduce the background by 99%

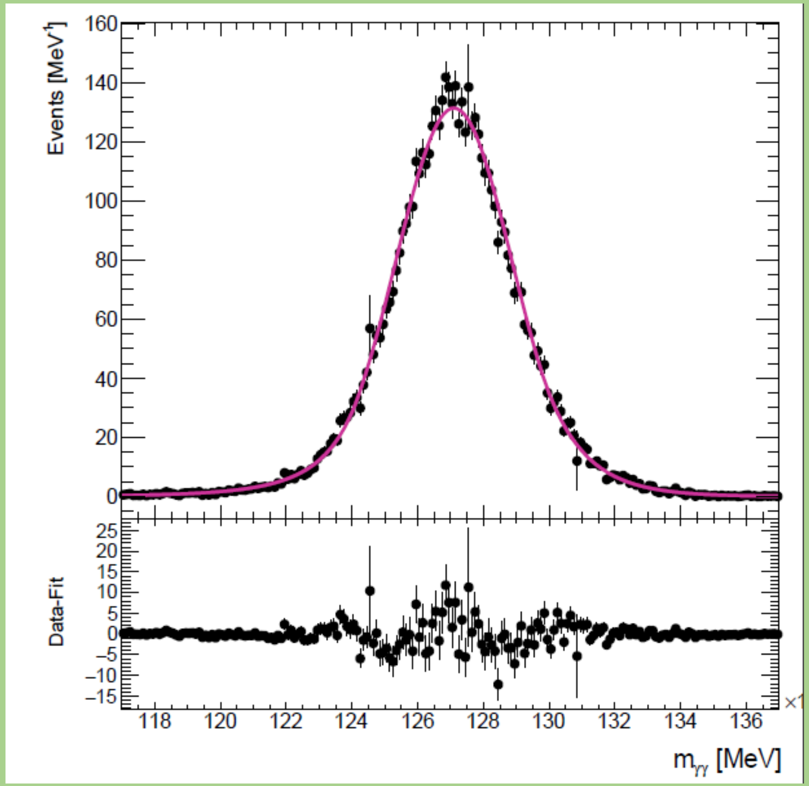
How do we model the signal?

With a very complicated function : a Double Sided Crystall Ball

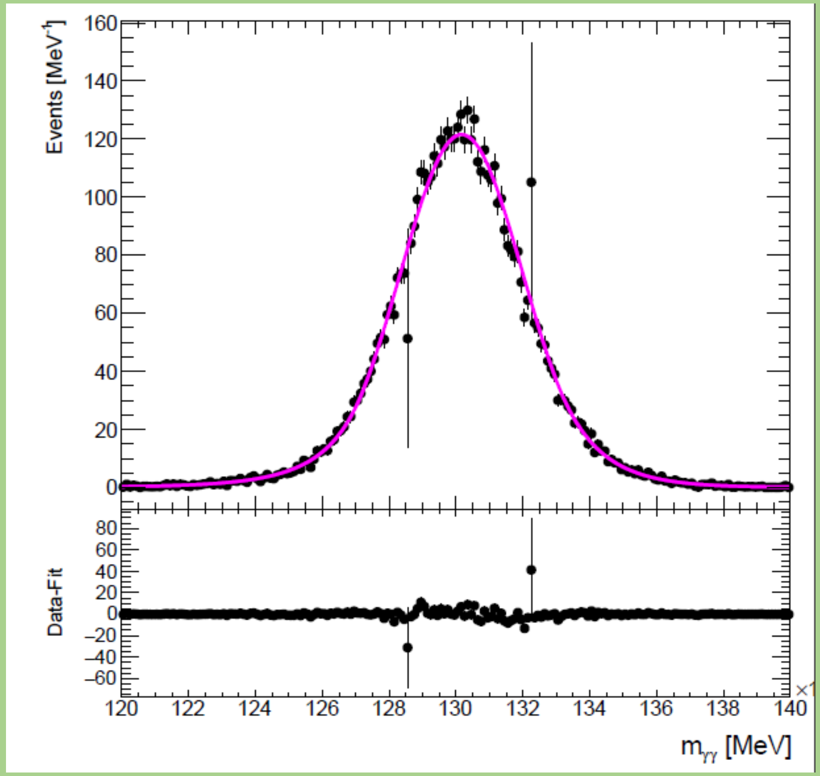
$$f(m; m_0, \sigma, \alpha_L, n_L, \alpha_R, n_R) = \begin{cases} A_L \cdot \left(B_L - \frac{m-m_0}{\sigma_L}\right)^{-n_L}, & \text{for } \frac{m-m_0}{\sigma_L} < -\alpha_L \\ \exp\left(-\frac{1}{2} \cdot \left[\frac{m-m_0}{\sigma_L}\right]^2\right), & \text{for } \frac{m-m_0}{\sigma_L} \le 0 \\ \exp\left(- \ldots\right. \\ A_R \cdot (\ldots \end{cases}$$



We fit the invariant mass distribution for the Higgs: 110, 122, 123, 124, 125, 126, 127, 130, 140 [GeV]



M_H = 127 [GeV]

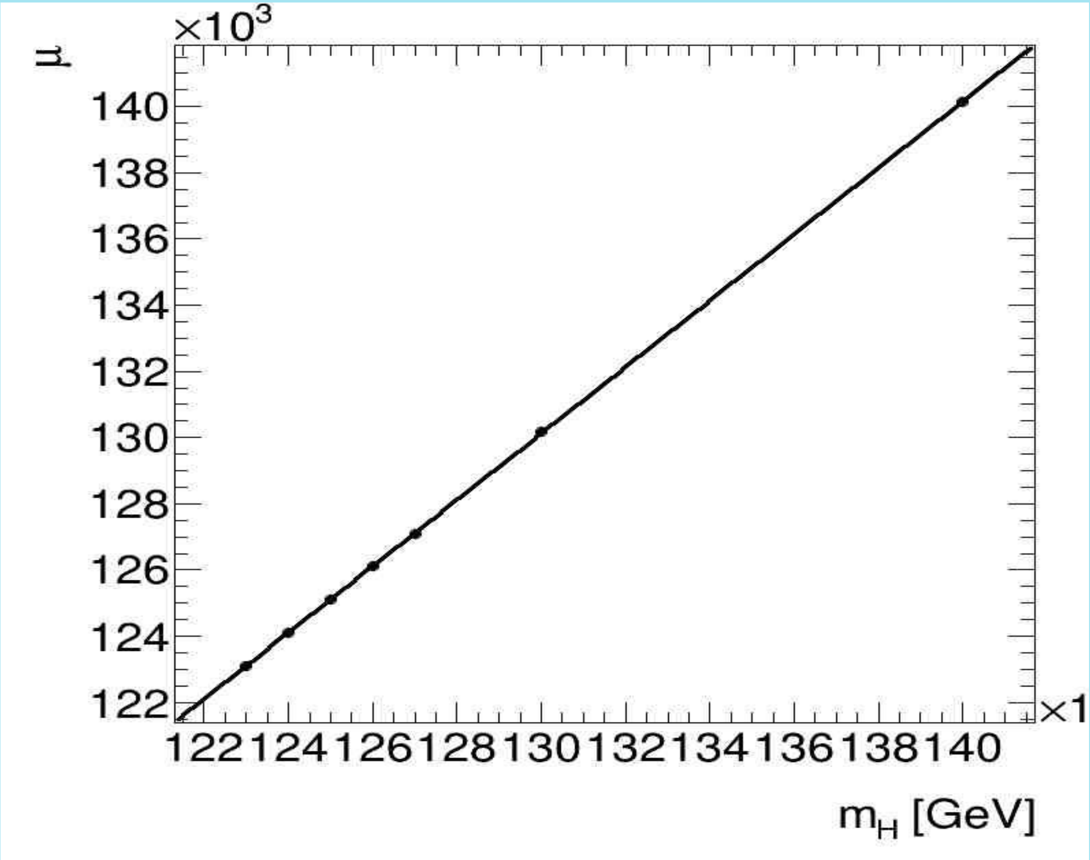


M_H =130[GeV]

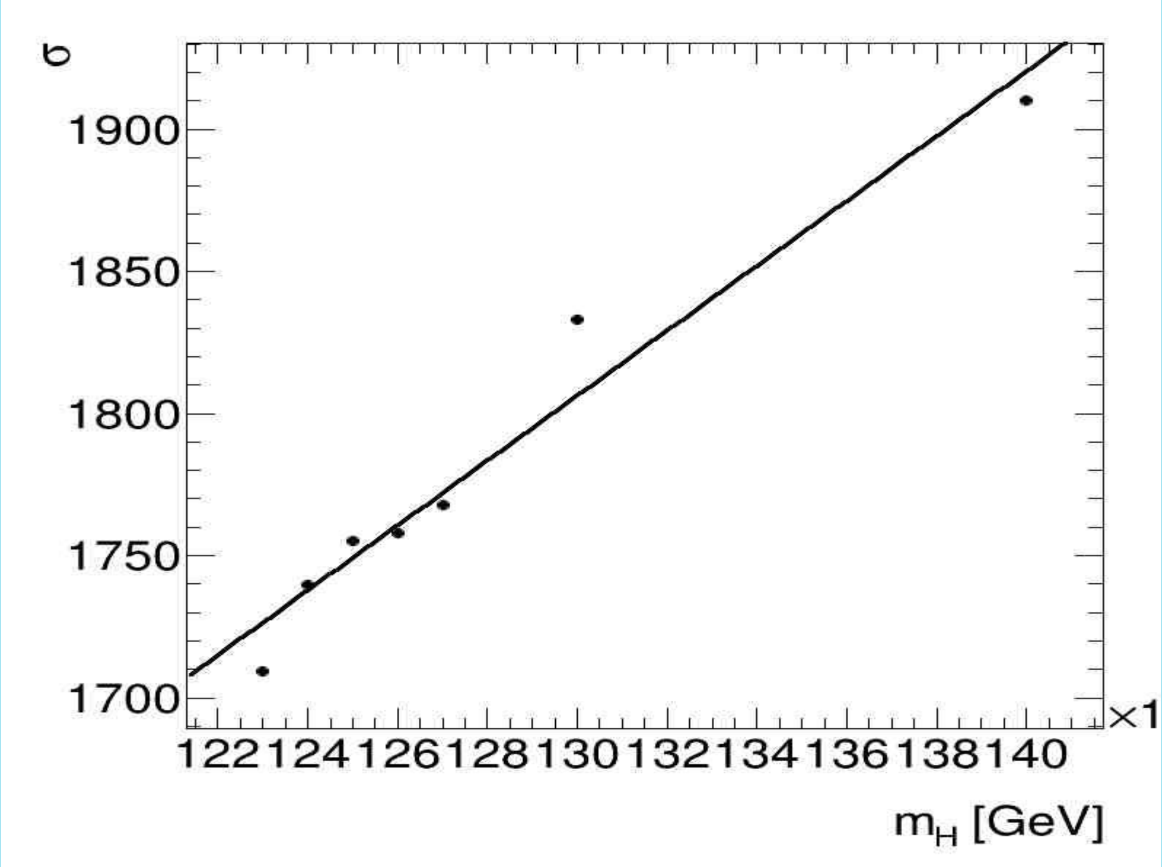
Parametrizing the function

Instead of using a lot of functions, we want to have a general function that only depends on the Higgs Boson mass

→ So we define the parameter of the DSCB as a function of M_H



This is the position where the function peaks with respect to the simulated mass. We notice that the mass of the peak is never exactly equal to the simulated mass.

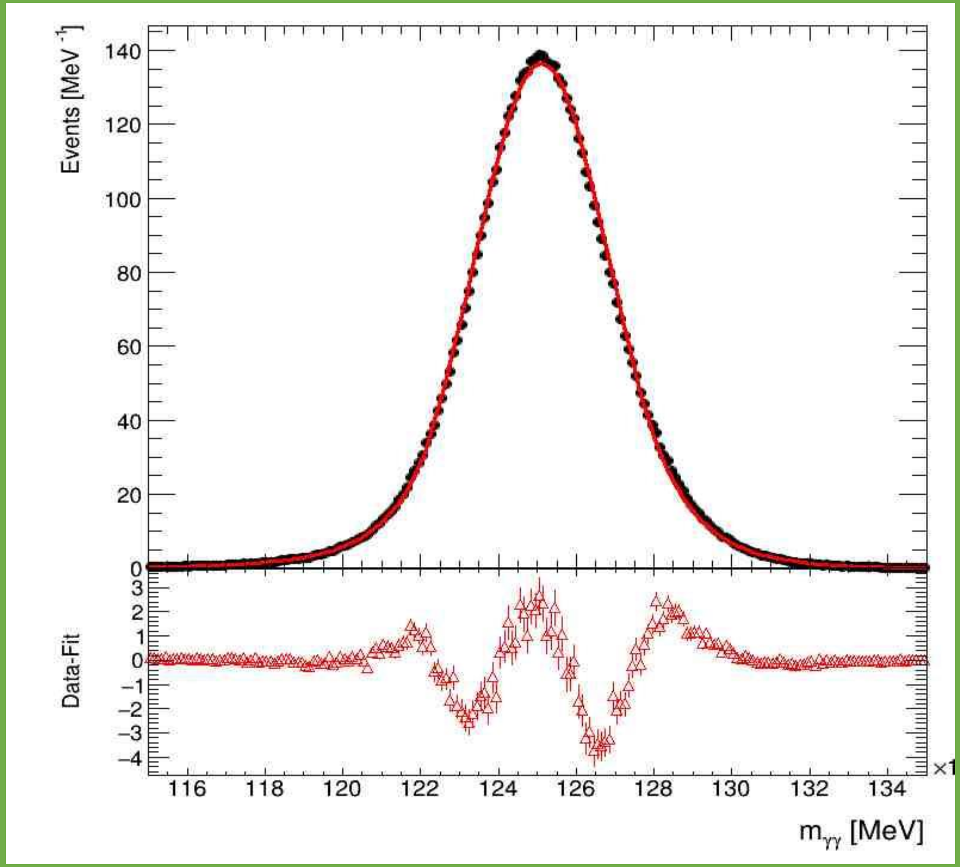


This is called the resolution of the function and we notice that it increases with the mass of the boson, this means that the graphs will get wider with the increase of the simulated mass.

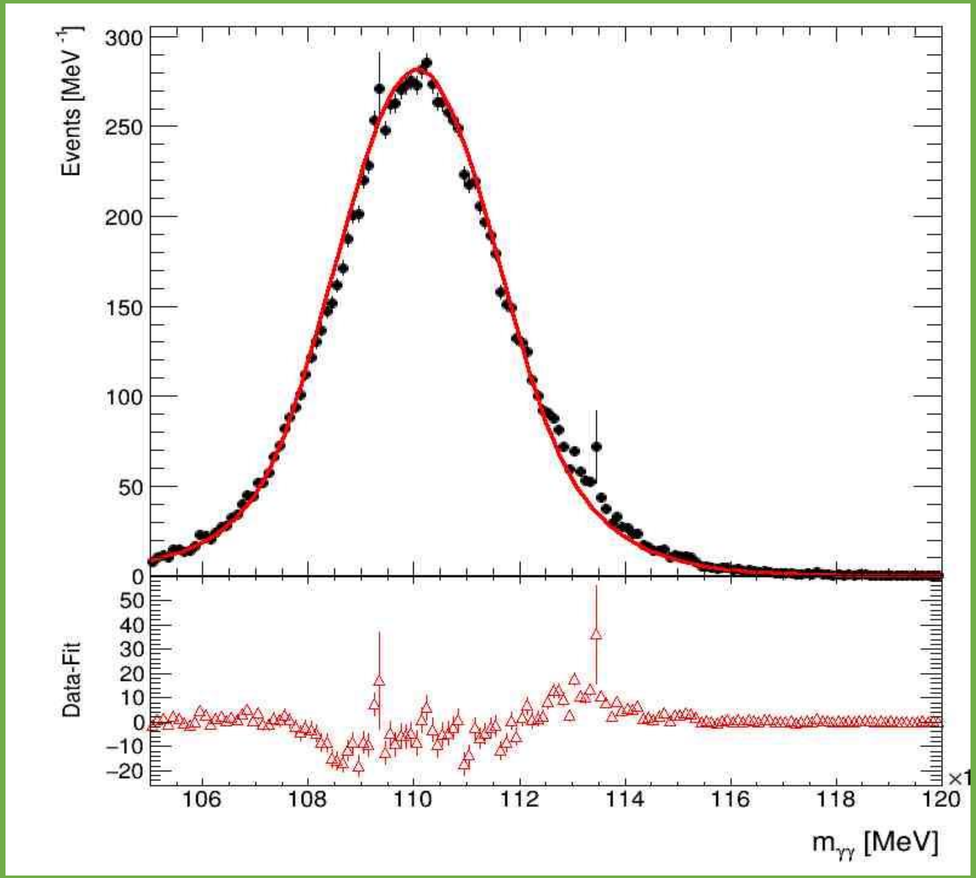
Cross-check for the new function

The parameters of the DCSB function were calculated for the simulated mass of the boson of M_H ={122,123,124,125,127,130 ,140}[GeV]. But we will see that the graph applies to other masses as well.

This is plotted for the simulated mass of 125 GeV. We can see how nicely it the curve fits the points.



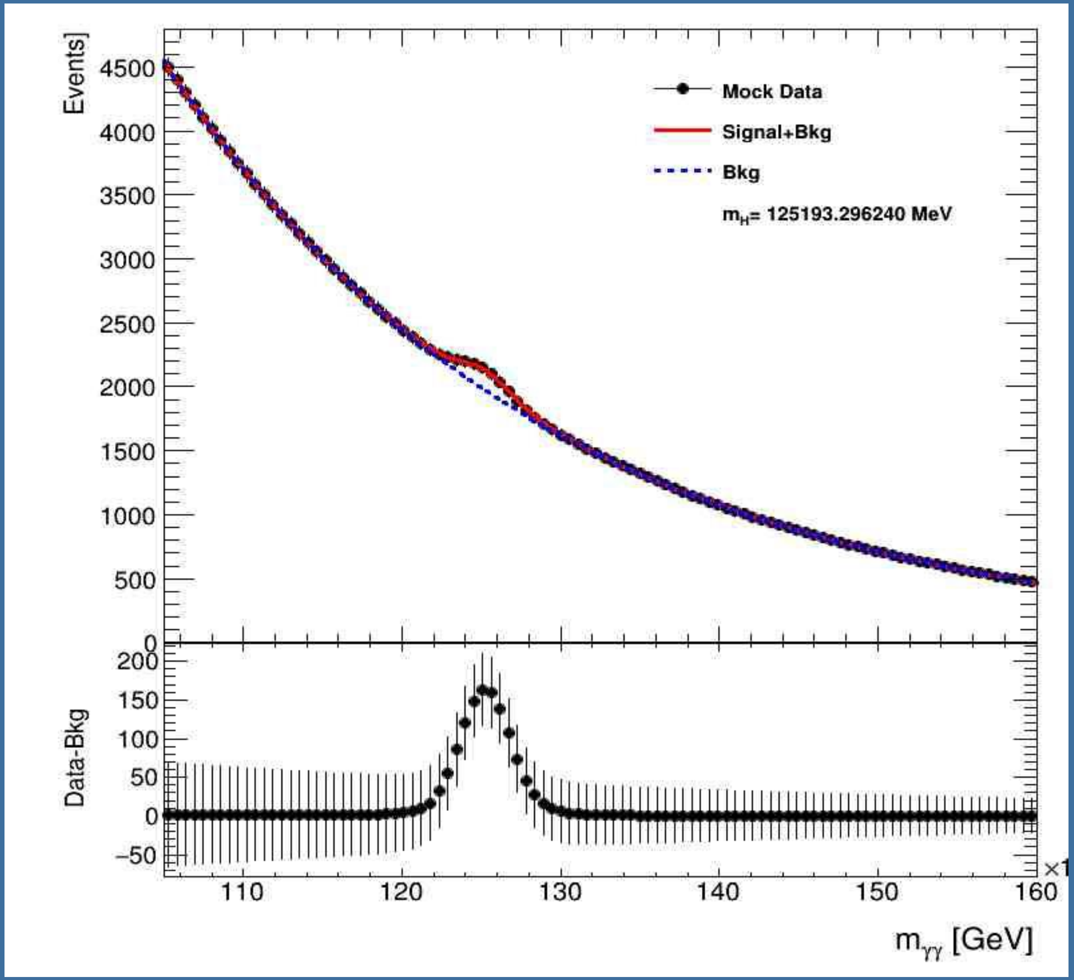
This is plotted for the simulated graph of 110GeV. We can see that even if the parameters were not calculated for this Higgs mass, the curve still fits nicely the points.



Using the photon's peak to determine the mass of the Higgs

Now we have all the ingredients to measure the Higgs Boson mass!

We fit our final function that models the signal and the background



Input (MeV)	Measurment (MeV)
125090	125193 ± 252
124150	124218 ± 239
126052	126039 ± 330
123880	123846 ± 389

To check that everything was correct we determined the mass over mock-data-samples that Stefano has generated with different HIGGS boson mass.

$$F(M_{\gamma\gamma}, N_{sig}, N_{bkg}, M_H) = N_{sig} * DSCB(M_H, M_{\gamma\gamma}) + N_{bkg} * e^{-\alpha * M_{\gamma\gamma}}$$


Thank you!
Va multumim!