# The study of *ZH*, $H \rightarrow b\bar{b}$ production using different event generators

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# Outline

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- **Signal and background processes**
- **Determination of some useful variables**
- **Event generators**
- **Event selection**
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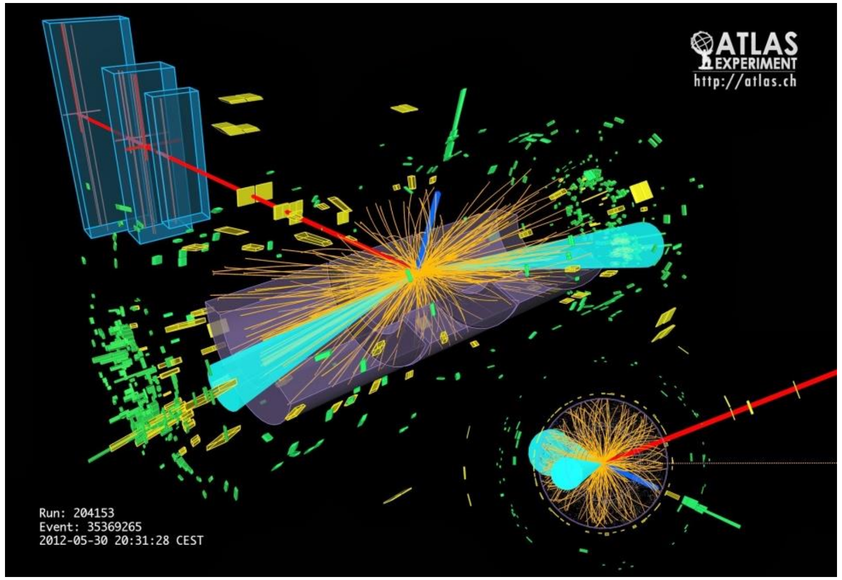
# Introduction

- Observation of a new particle by the ATLAS and CMS experiments in 2012;
- The mass of the observed new particle is about 125 GeV and has the properties of the Higgs boson;
- The first observed decay channels: *$H \rightarrow \gamma\gamma$, $H \rightarrow ZZ$ & $H \rightarrow WW$*;
- Observation of the *ggF, VBF, ttH* production and *$\gamma\gamma$, ZZ, WW, $\tau\tau$* decay channels;
- Decay into b-quarks is the dominant decay mode for a given mass (BR($H \rightarrow bb$) ≈ 58%).



# July 4$^{th}$ 2012

Official announcement of the discovery of a Higgs-like particle with mass of 125-126 GeV by CMS and ATLAS.

Historic seminar at CERN with simultaneous transmission and live link at the large particle physics conference of 2012 in Melbourne, Australia

CERN

Melbourne

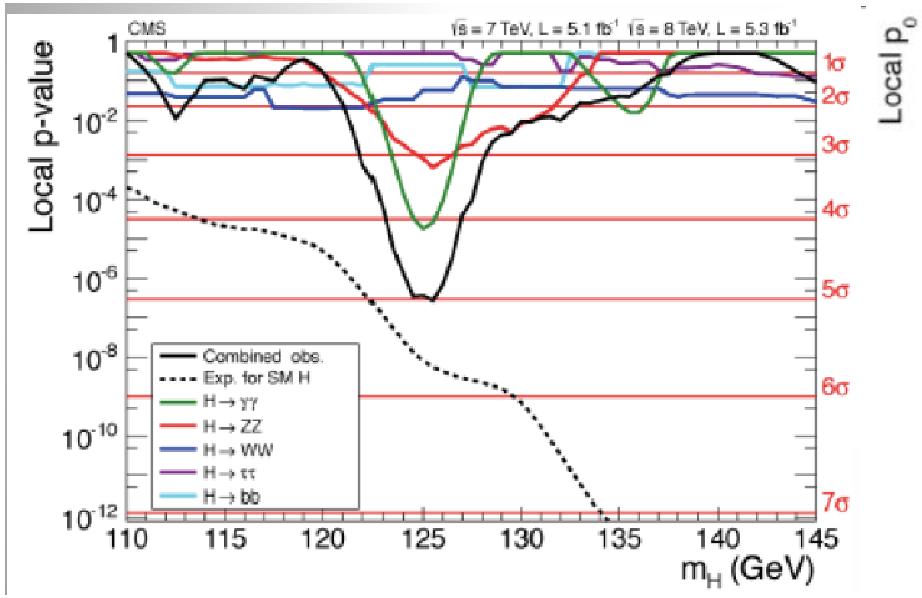
Followed live around the world…

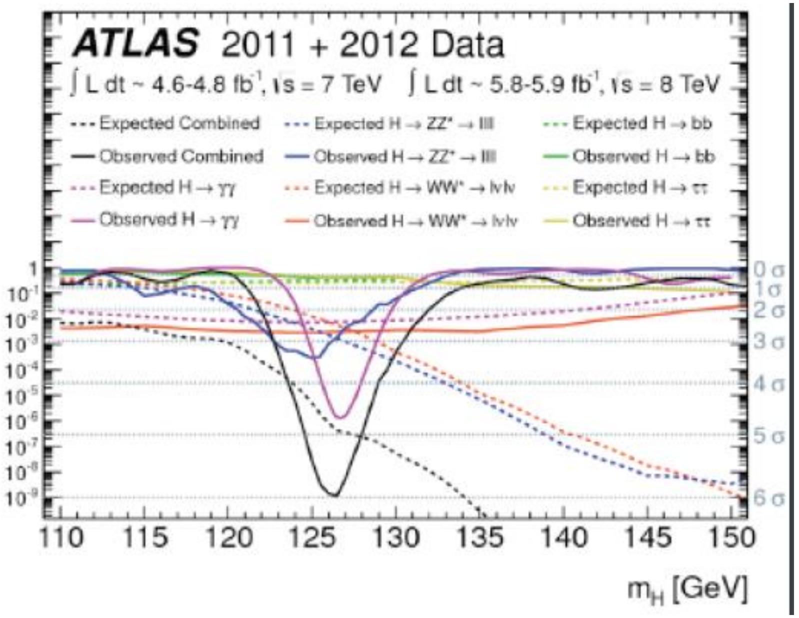
# Results 2012

Both experiments see an excess ~125 GeV in the γγ, ZZ and WW channel

Adding up al the channels gives the following combination Shown is the compatibility with a “background only hypothesis”

$5fb^{-1}$ /2011 and $5fb^{-1}$/2012



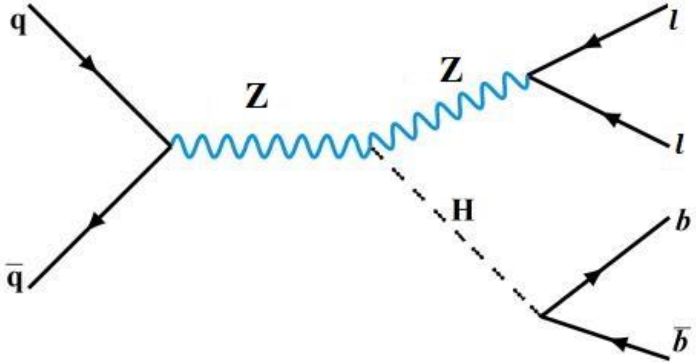




**CMS and ATLAS observe a new boson with a significance of about 5 sigma**

# Motivation

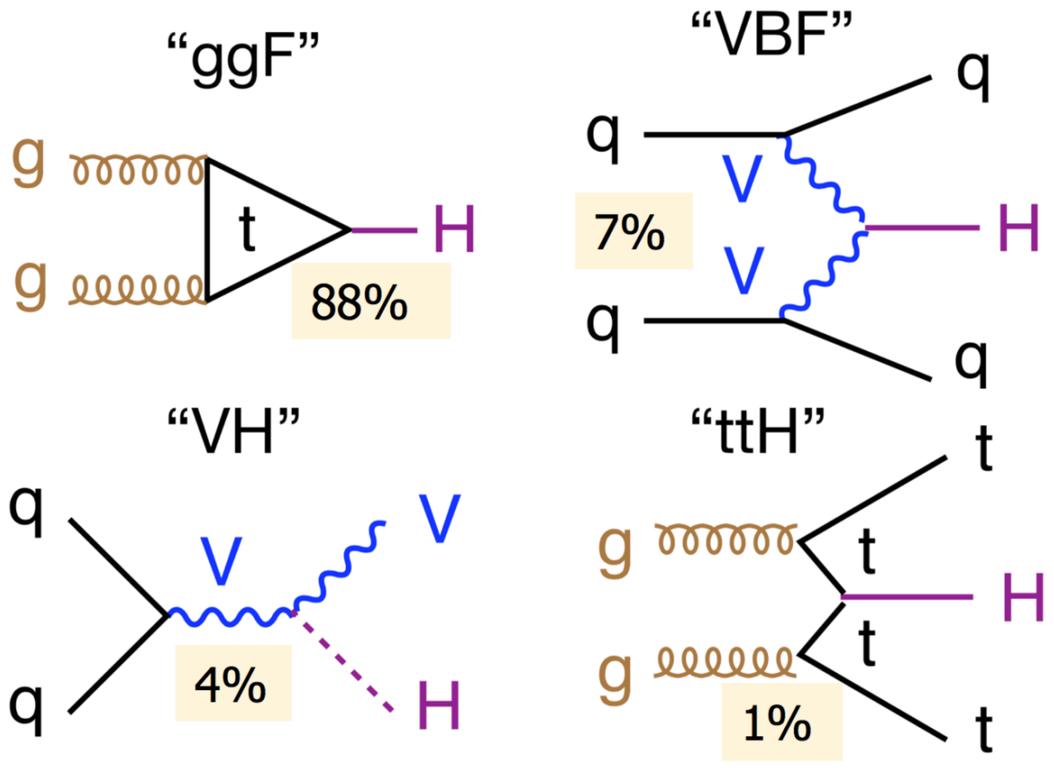
The associative Higgs boson production with the $Z$ boson is a more promising way of detecting the $H \to b\bar{b}$ decay. The use of certain variables to improve the signal-to-background ratio is one of the main objectives of this work.

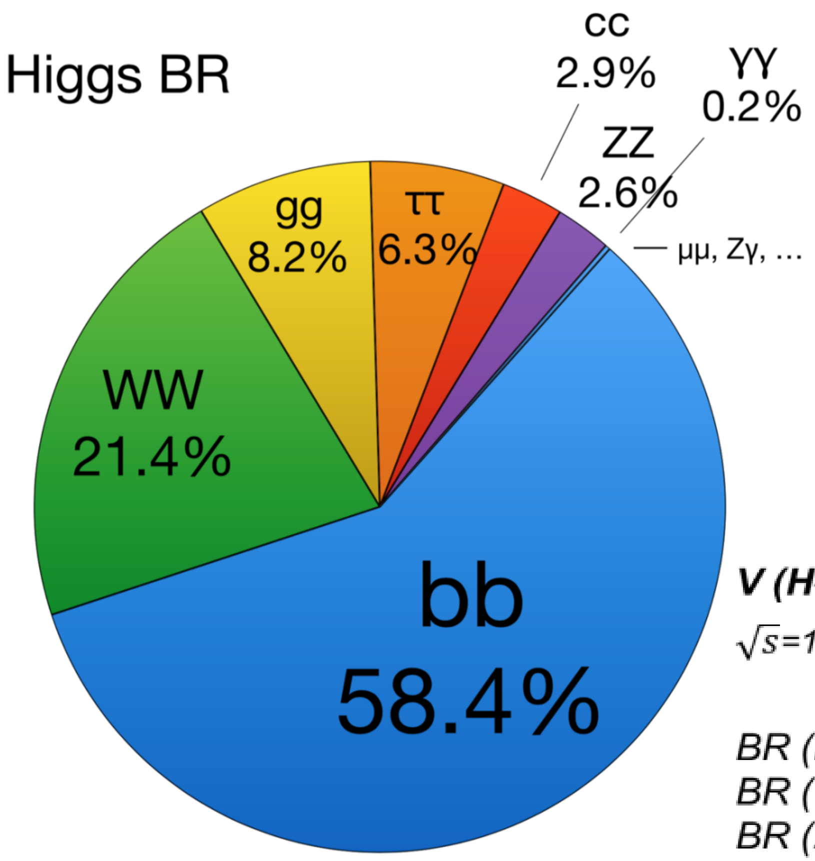
For particle physics and for the study of fundamental interactions, the observation of the decay of the Higgs boson into a pair of $b\bar{b}$ quarks is an important discovery, which determines the relevance of this work.




- Signal and background processes were generated using the CompHEP, POWHEG and PYTHIA8 generators.
- Monte Carlo data were processed in the ROOT software.

# Higgs boson production and decay




*V (H→bb); V=W or Z*

*$\sqrt{s}$=13TeV, $m_H$=125 GeV*

*BR (H→bb) ~ 58%*
*BR (W→lν) ~ 33%*
*BR (Z→ll+νν) ~ 30%*

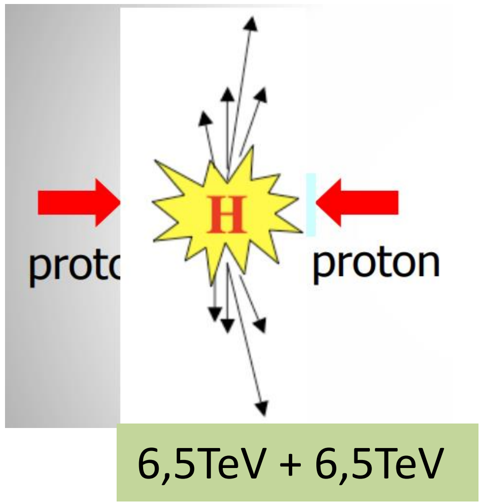
**The leptonic decays of the vector boson, W or Z can be used for triggering and background reduction purposes.**

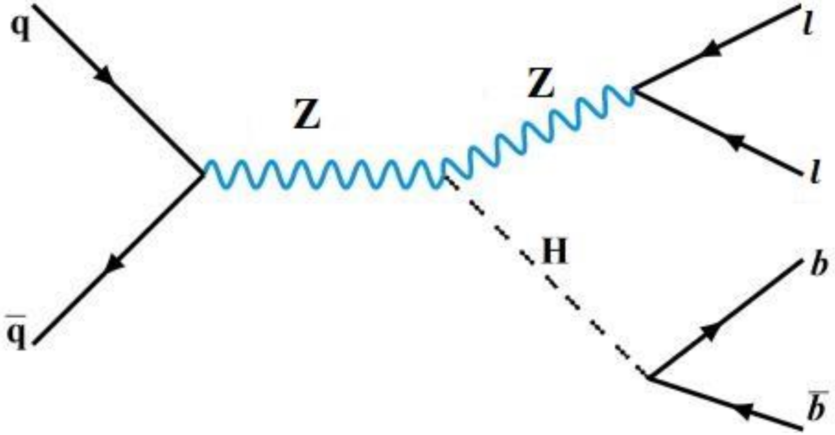
# Signal and background processes

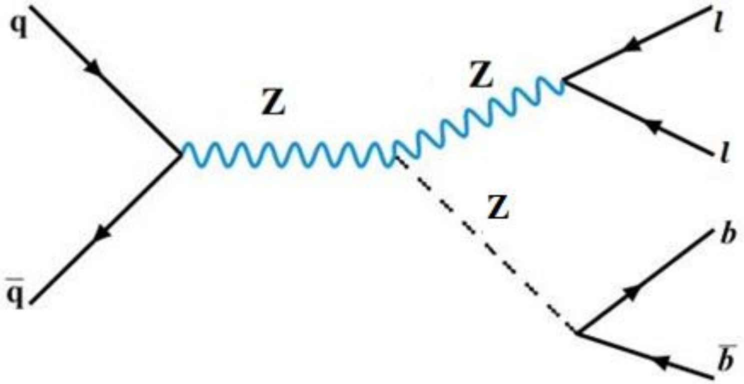
$ZH \to llb\bar{b}$ **is signal process**

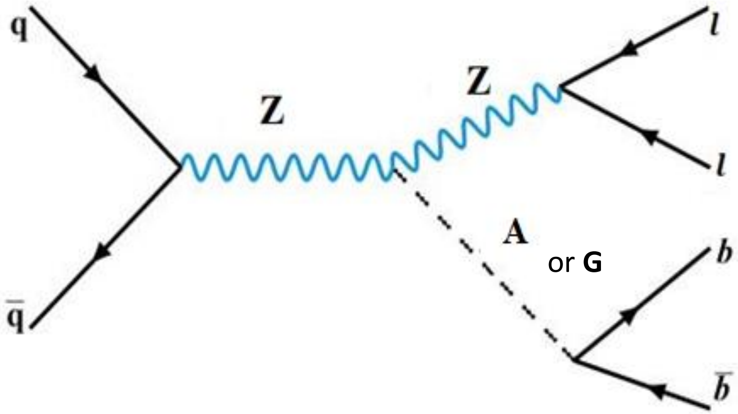
$pp \to ZZ \to llb\bar{b}$ **are irreducible backgrounds**

$pp \to Zbb \to llb\bar{b}$ **are the main backgrounds** where $l = e^{\pm}$ or $\mu^{\pm}$.



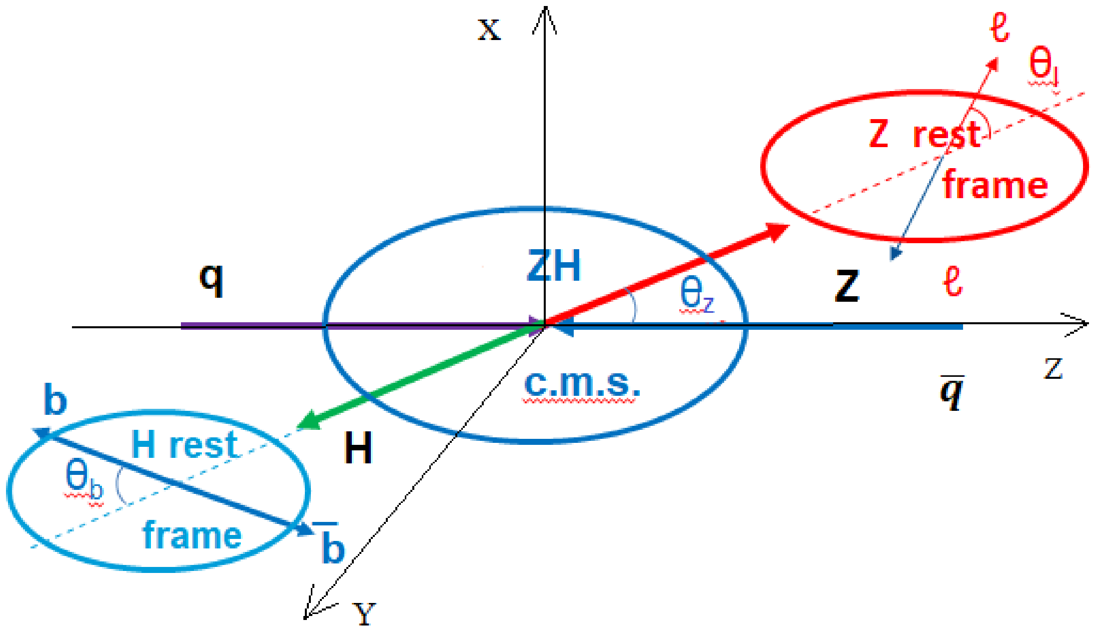



# Determination of some useful variables

To determine angle of the charged lepton for the signal and background:

- convert all momenta from the laboratory system to the ZH center of mass system.
- Rotate the direction of the Z-boson so that it coincides with the direction of z.
- convert the momentum of the Z-boson along the z-axis to the rest frame of the Z-boson.



# Event generators

- **CompHEP** https://arxiv.org/abs/hep-ph/9908288v2

*Matrix Element Monte Carlo Generator, produces parton- level events in tree-level approximation.*

- **PYTHIA** https://pythia.org/download/pdf/worksheet8200.pdf

*The program can be used to generate high-energy-physics 'events', i.e. sets of outgoing particles produced in the interactions of two incoming particles.*

- **POWHEG** https://arxiv.org/abs/0709.2092

*The method that uses the POWHEG BOX computing environment to perform NLO calculations in Monte Carlo programs.*

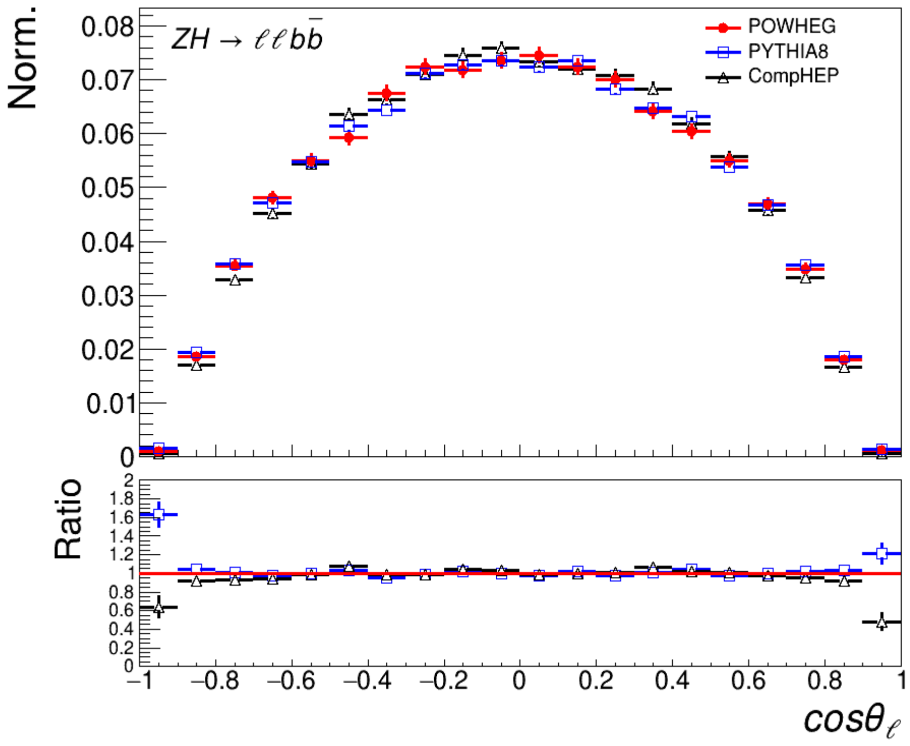
# Event selection

- The transverse momentum of a charged lepton, $b$- and $\bar{b}$-quarks are required to be greater than 25 GeV;

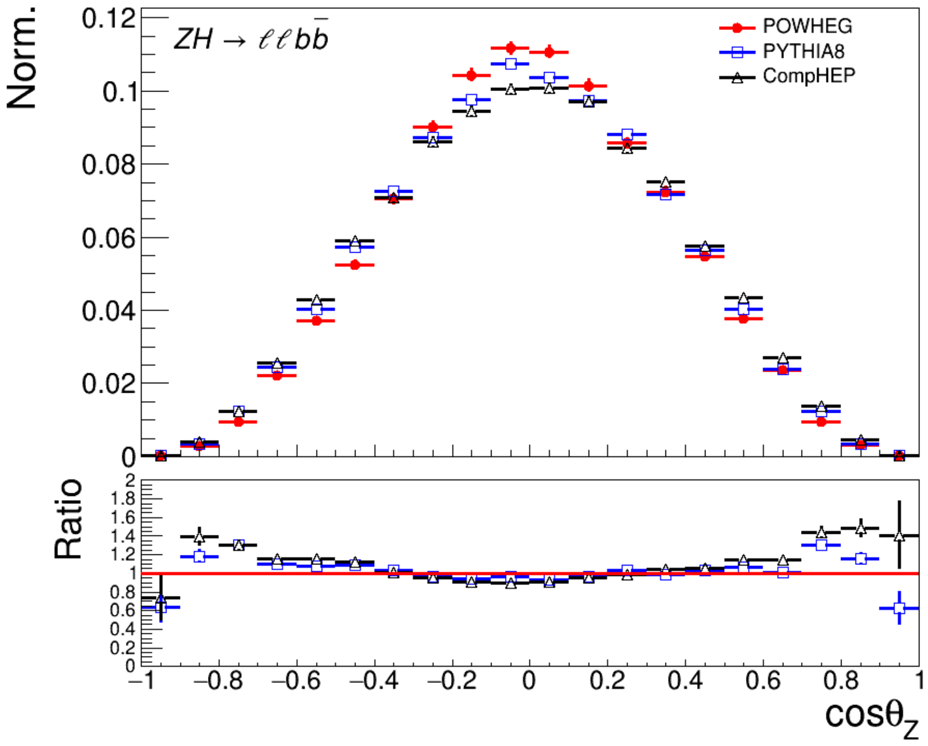
- The pseudorapidity of the lepton, $b$- and $\bar{b}$- quarks should be within [-2.5, +2.5];

- The transverse momentum of the $Z$ boson must be greater than 150 GeV.

# Comparison of generators

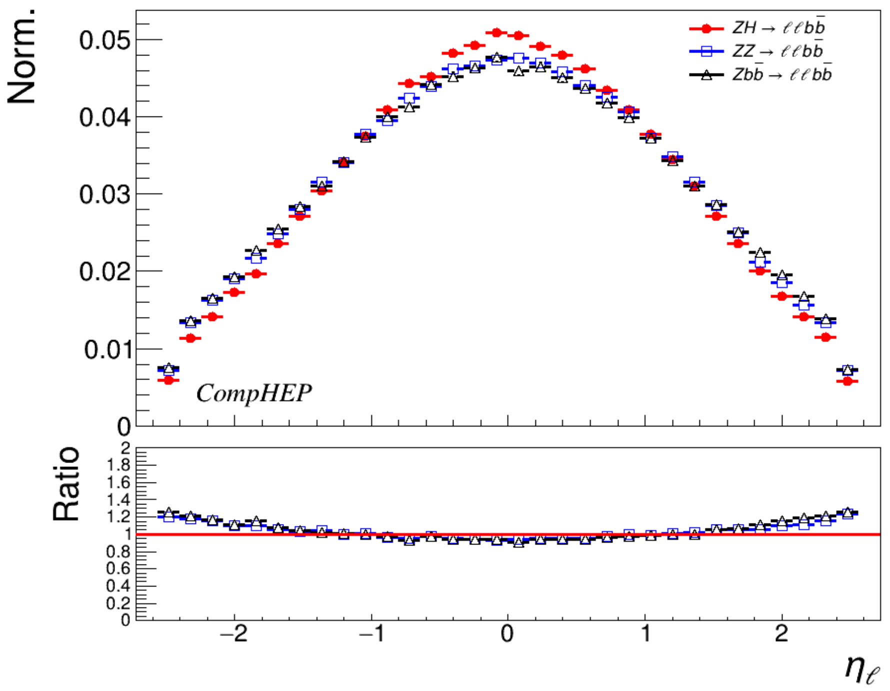



Distributions of the cosine of the negatively charged lepton angle for different event generators.

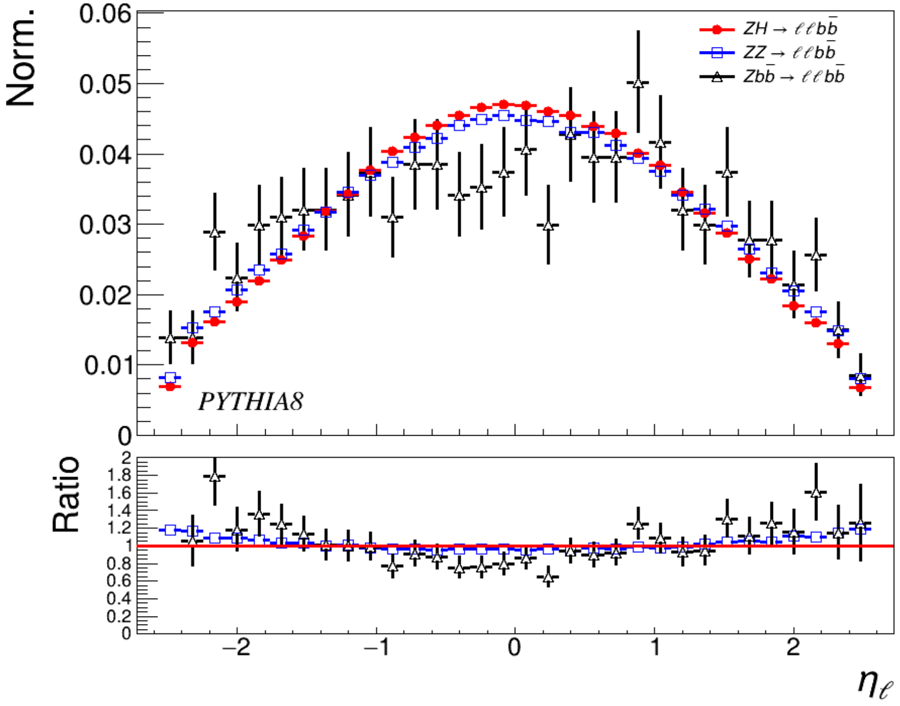



Distributions of the cosine of the Z-boson polar angle for different event generators.

# Pseudorapidity distribution



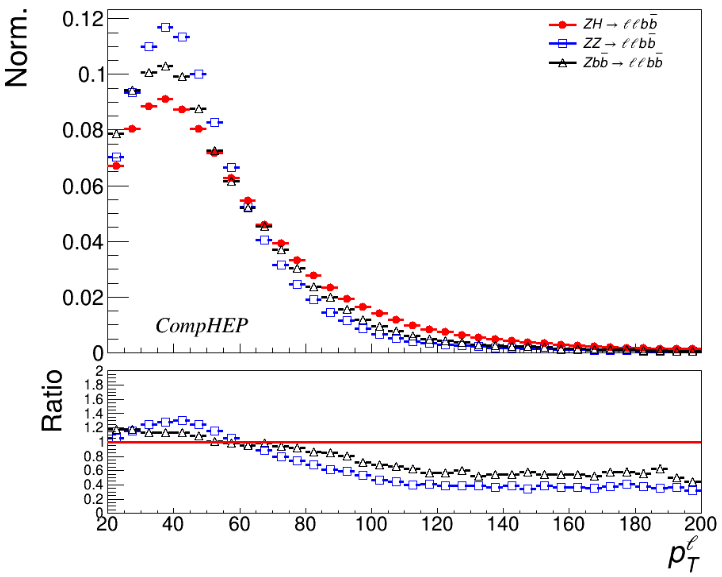

Distribution of pseudorapidity of the negatively charged lepton obtained from CompHEP.



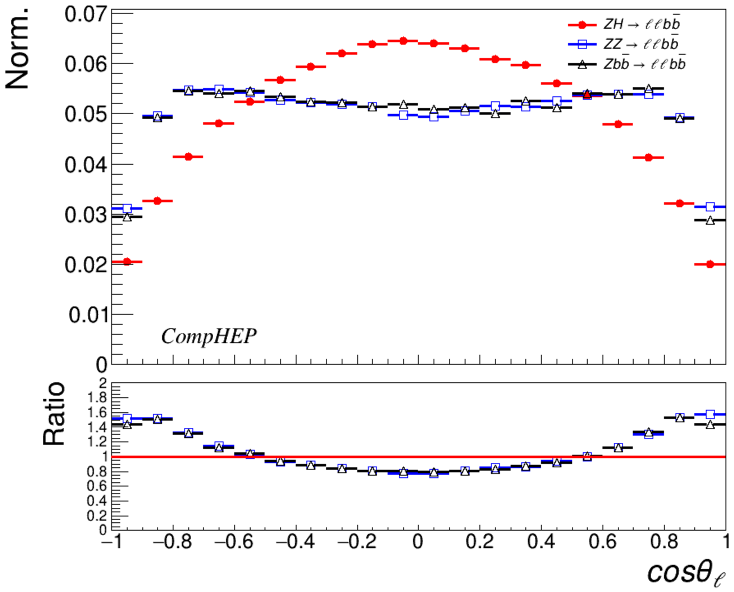

Distribution of pseudorapidity of the negatively charged lepton obtained from PYTHIA8.

**It can be seen that the signal and the background do not differ much from each other**

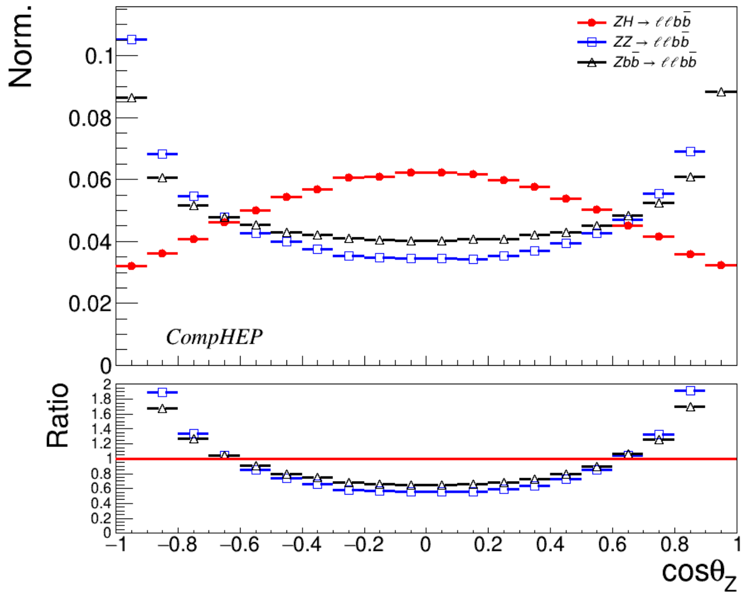
# CompHEP results




Distributions of the transverse momentum of the negatively charged lepton.

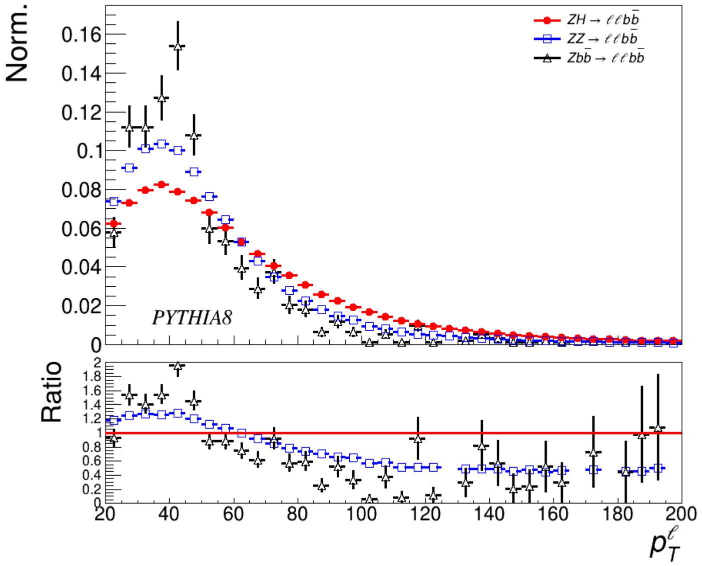



Distributions of the cosine of the negatively charged lepton emission angle.

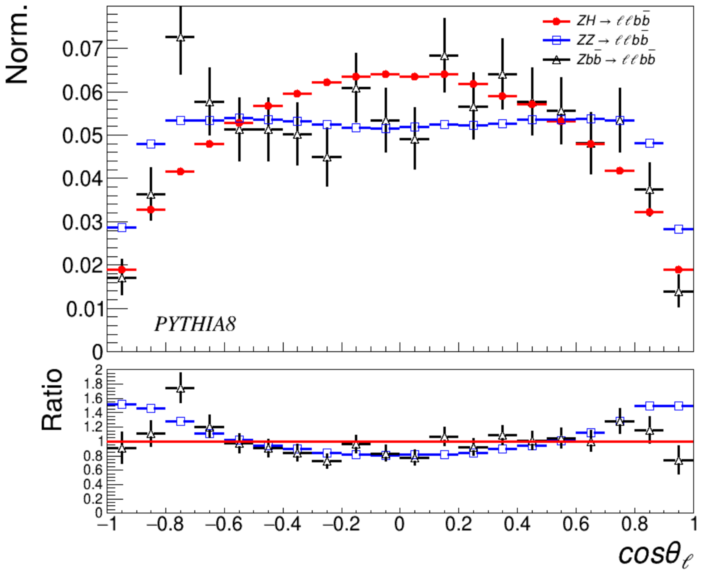



Distributions of the cosine of the Z-boson polar angle.

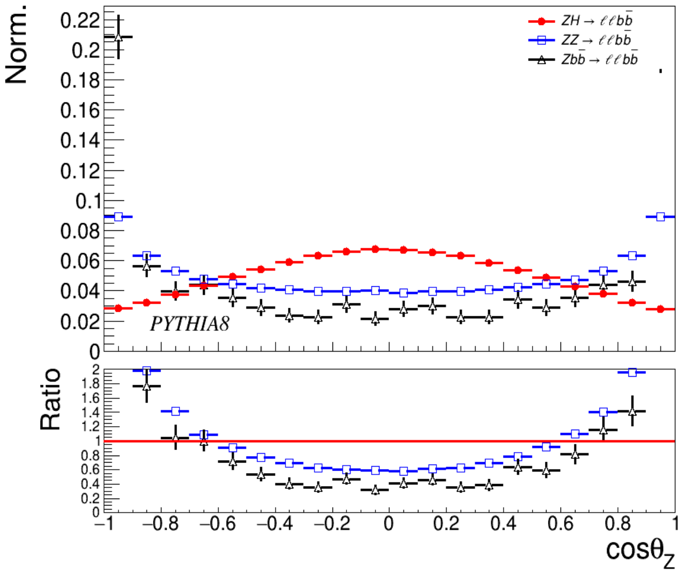
# PYTHIA8 results




Distributions of the transverse momentum of the negatively charged lepton obtained from PYTHIA8.




Distributions of the cosine of the negatively charged lepton emission angle obtained from PYTHIA8.




Distributions of the cosine of the Z-boson polar angle obtained from PYTHIA8.

# Conclusion

- Signal and background processes were generated using the CompHEP, POWHEG and PYTHIA generators.
- Monte Carlo data were processed in ROOT software.
- The shape of the distributions of variables for different generators are similar in the same processes .
- The shape of the distributions of variables for signal and background processes is very different. And these differences can be used in future analyses to suppress a large background contribution.