$e^+e^- \rightarrow HZ\ (Z \rightarrow \mu\mu)$
Status of the Recoil Mass Studies with shape analysis

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Introduction

FCCAnalyses Package

- Use **FCCAnalyses** package produces flat ROOT trees using **FCCSW EDM root files** produced with the EventProducer
  - https://github.com/HEP-FCC/FCCAnalyses

- Monte-Carlo samples: **“Spring2021” campaign**
  - Samples correspond to IDEA simulation
  - Beam-energy spread included
  - Pythia and Whizard generators

Monte Carlo Samples

“Spring2021” campaign

- **Signal HZ** events:
  - **PYTHIA - HZ (inclusive decays)**
    - m_H = 125.000 GeV p8_ee_ZH_ecm240 with 10M events
    - m_H = 125.050 GeV p8_ee_ZH_ecm240 with 10M events
    - m_H = 125.100 GeV p8_ee_ZH_ecm240 with 10M events
    - m_H = 124.950 GeV p8_ee_ZH_ecm240 with 10M events
    - m_H = 124.900 GeV p8_ee_ZH_ecm240 with 10M events
    - m_H = 125 GeV p8__noBES_ee_ZH_ecm240 with 10M events
  - **Whizard - HZ(Z→ μμ) (exclusive decays)**
    - m_H = 125 GeV wz_ee_mumuH_ecm240 with 1M events
    - m_H = 125 GeV wz_noBES_ee_mumuH_ecm240 with 1M events

Monte Carlo Samples

“Spring2021” campaign

- **Backgrounds ZZ and WW events** (inclusive):
  - p8_ee_WW_ecm240 with 10M events
  - p8_ee_ZZ_ecm240 with 10M events

Selection

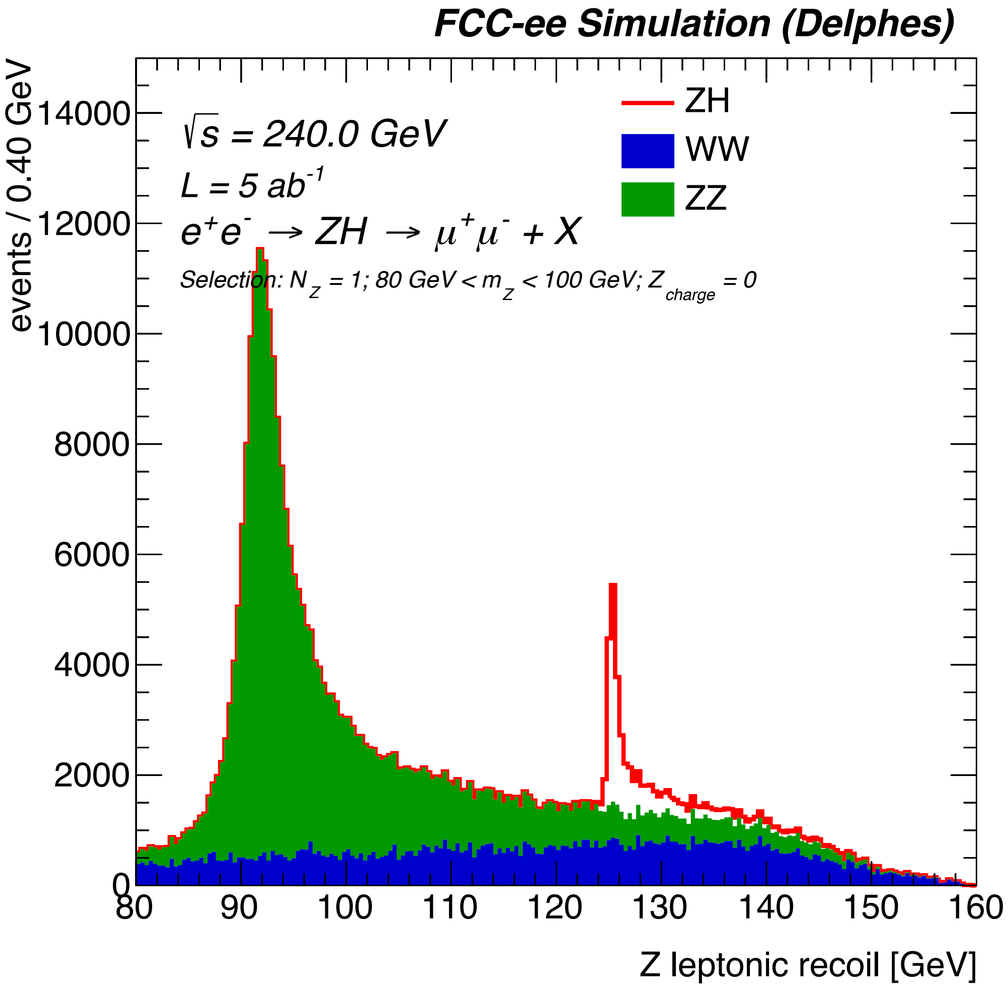
$e^+e^- \rightarrow HZ$ ($Z \rightarrow \mu\mu$)

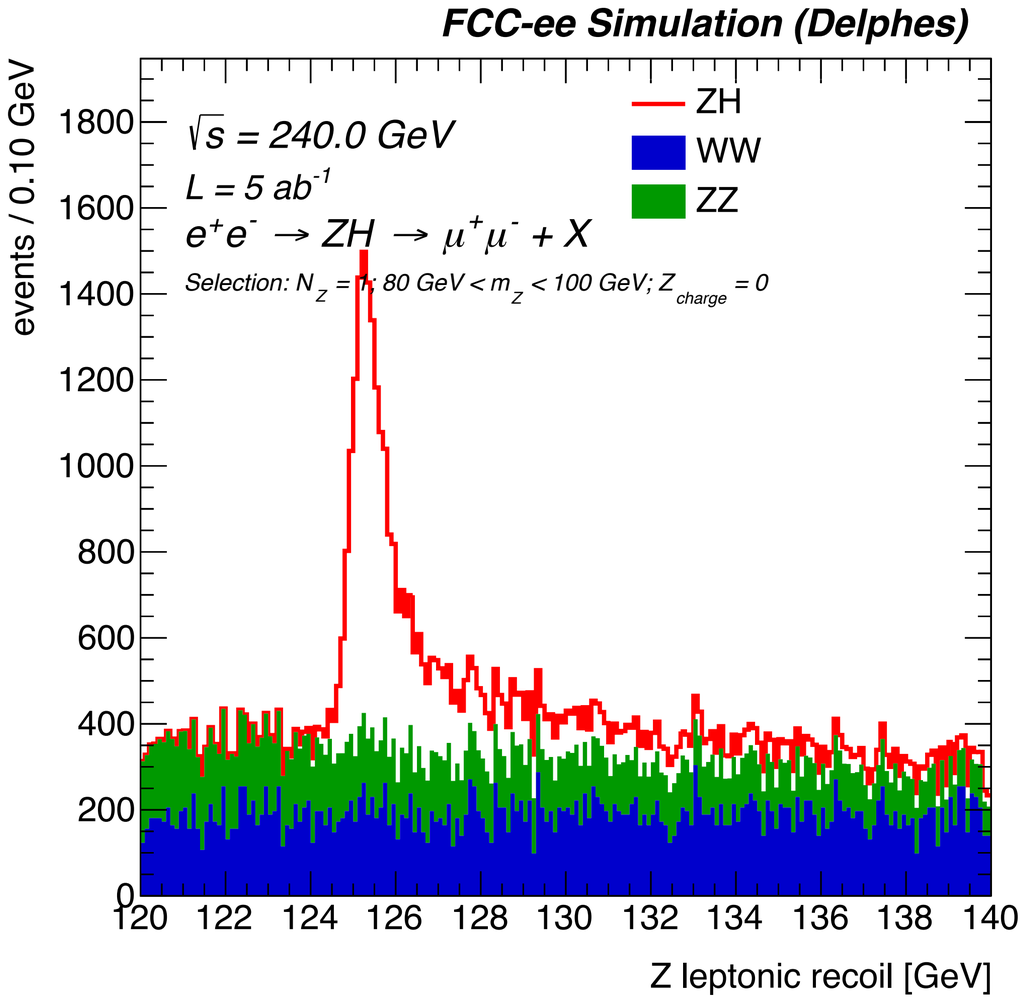
- Select muons with $p_T > 10$ GeV
- Z resonance
  - built with *ResonanceBuilder* with 2 muons from the selected muon list
  - with mass 80 GeV < M_Z < 100 GeV
  - with charge = 0

- Very basic selection that needs to be optimised
  → *see And and Greg analysis studies*

Z Leptonic Recoil Mass

$e^+e^- \rightarrow HZ\ (Z \rightarrow \mu\mu)$

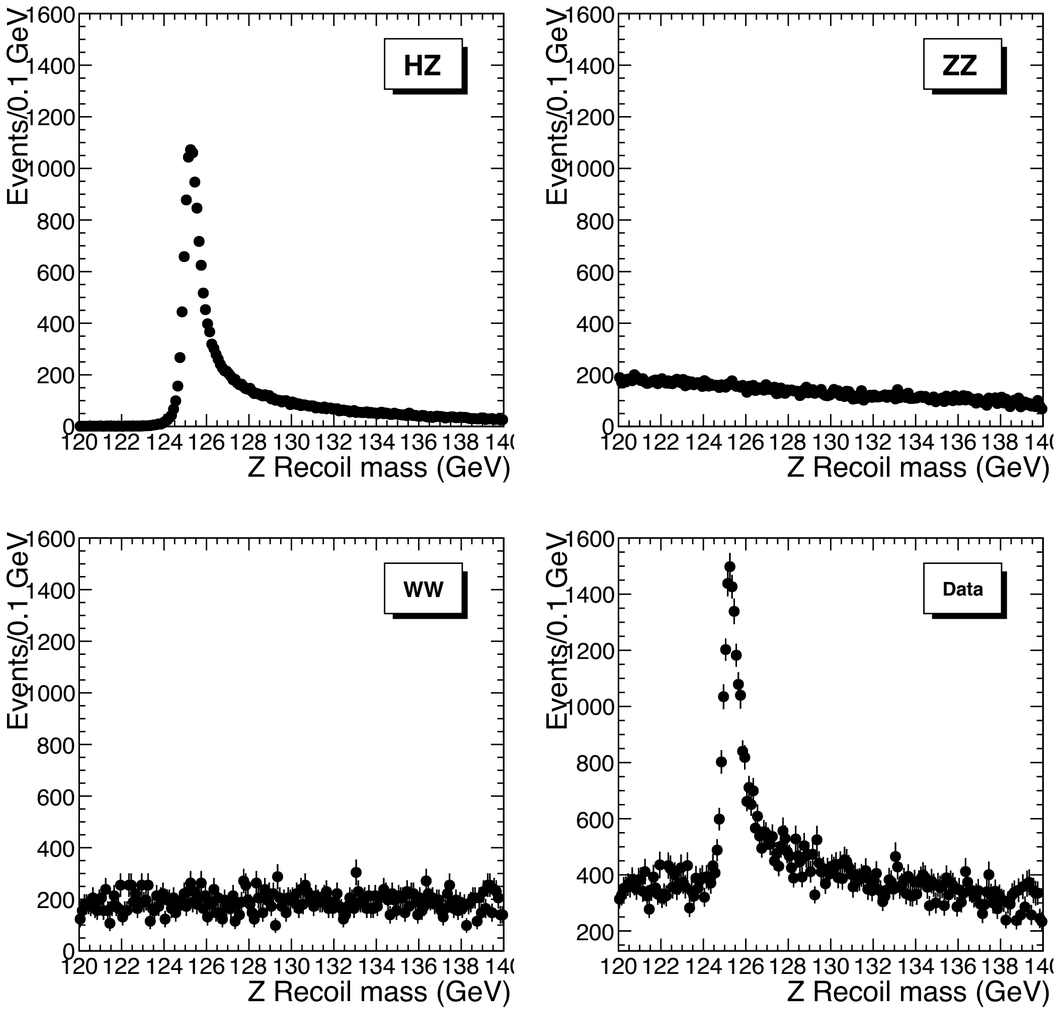




Statistical Analysis

Combine tool

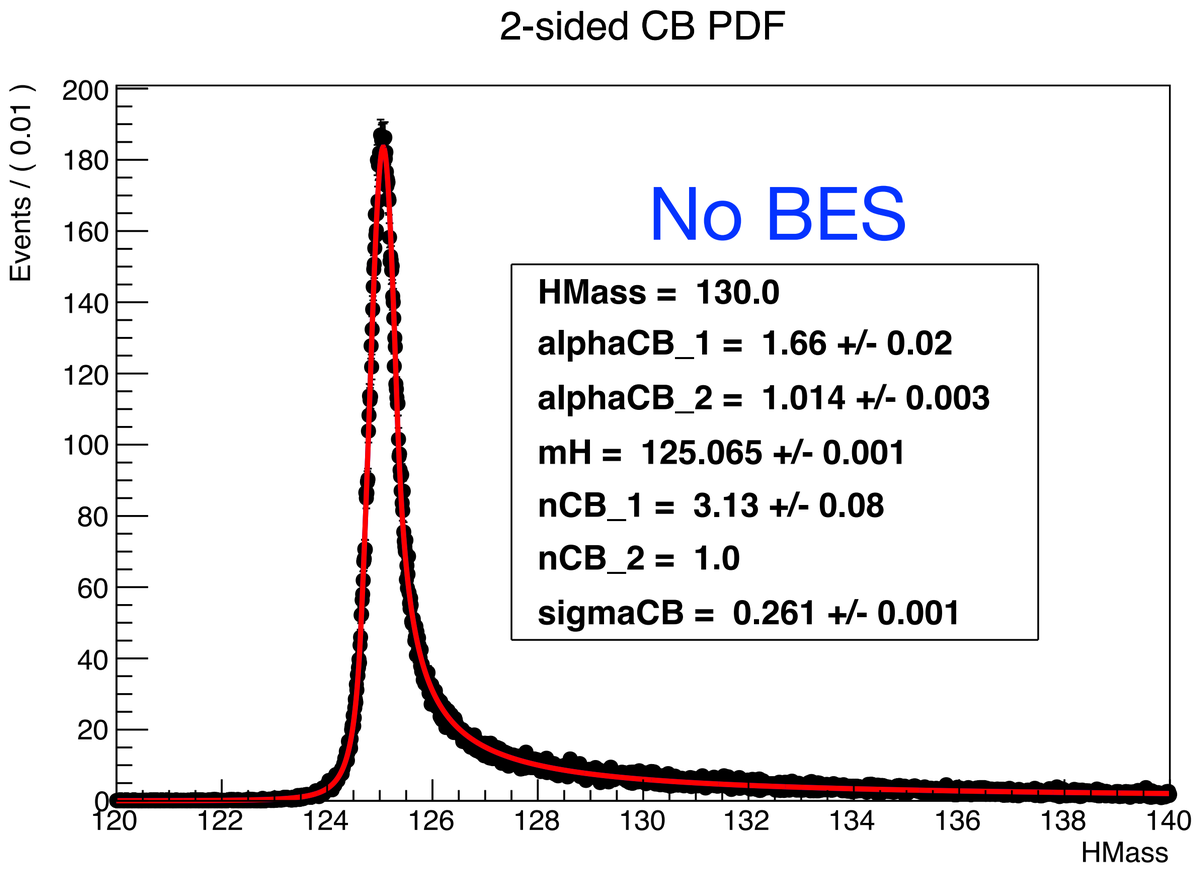
- ***Combine***[1]: RooFit based CMS statistical framework, developed in the context of the Higgs analyses combinations
  - *Available as a standalone tool on lxplus / CERNVM*
  - *Extremely flexible and powerful. Handles any number of POI, bins, channels; can mix shape, normalisation and parametric unc; binned and unbinned distributions. Several statistical methods available (FC, CLs, profiled likelihood…)*
- Template histograms normalised to 5 ab^{-1} are input to *Combine* to perform a binned shape analysis
- Higgs mass is the Parameter Of Interest (POI)

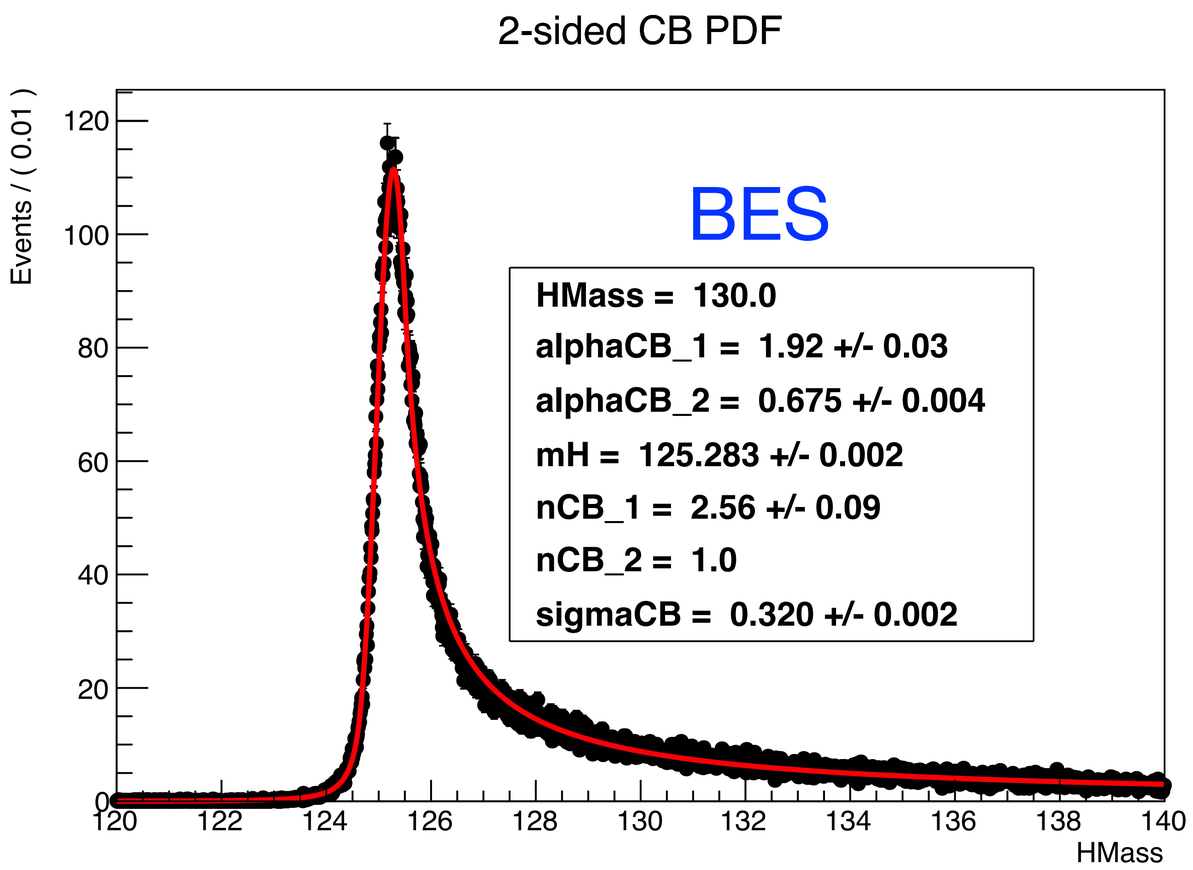


[1]*The ATLAS, CMS Collaborations, and LHC Higgs Combination Group. Procedure for the LHC Higgs boson search combination in Summer 2011. Technical Report CMS-NOTE-2011-005. ATL-PHYS-PUB-2011-11, CERN, Geneva, Aug 2011*

Shape Analysis

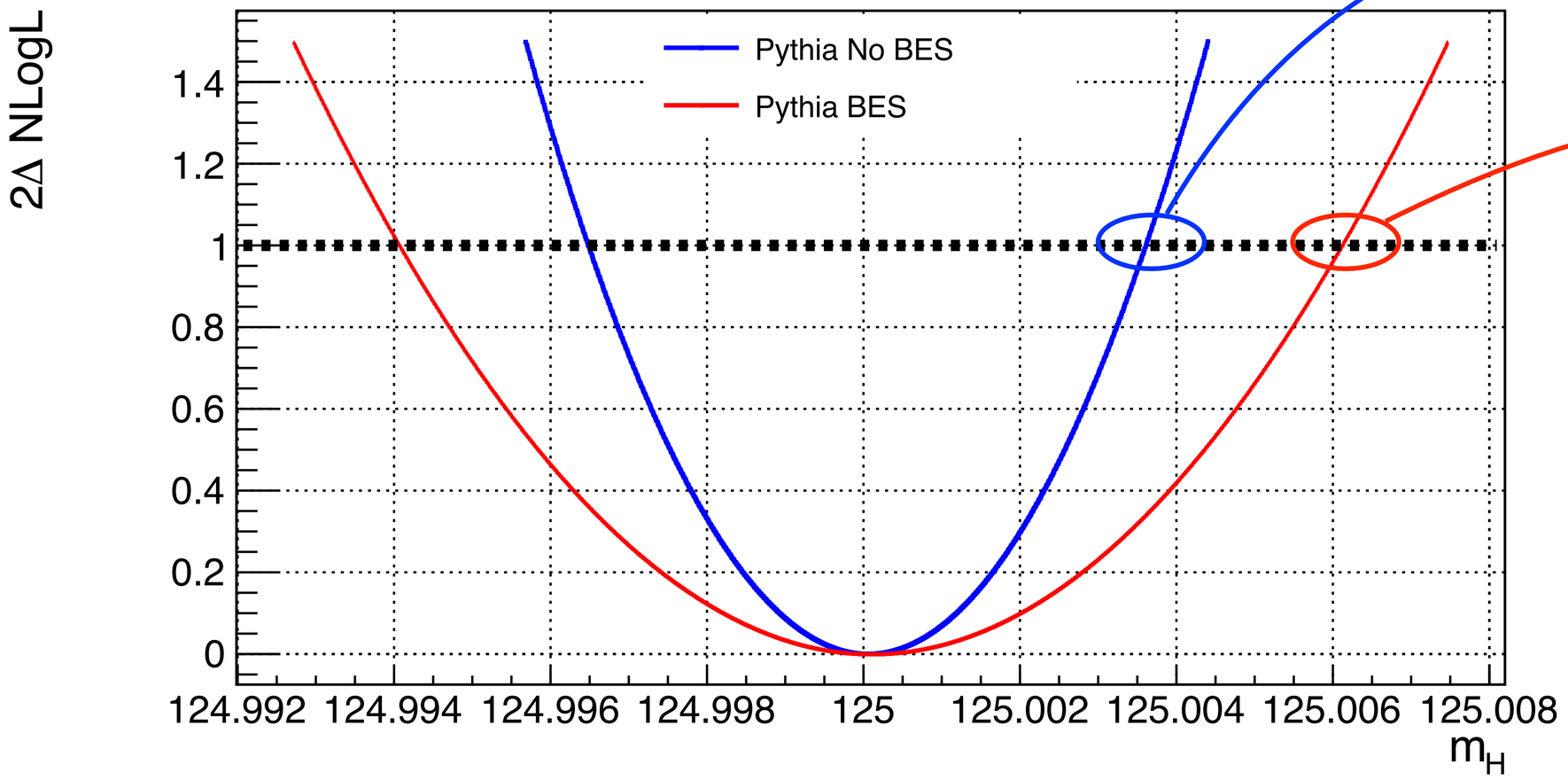
PYTHIA samples with and without BES





Log Likelihood Versus m_H

PYTHIA samples with and without BES



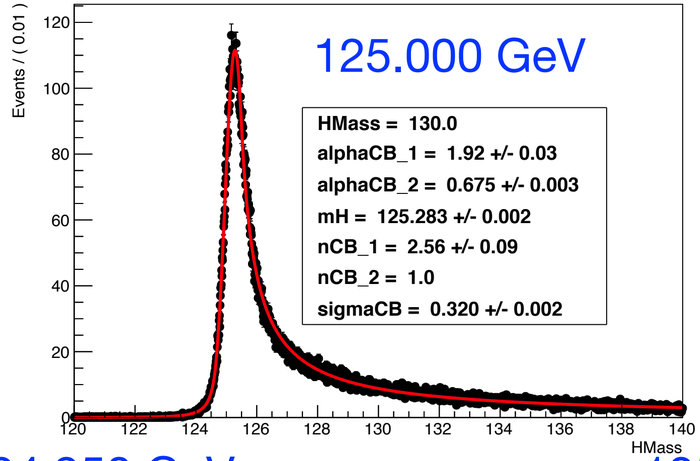
No BES: 3.6 MeV

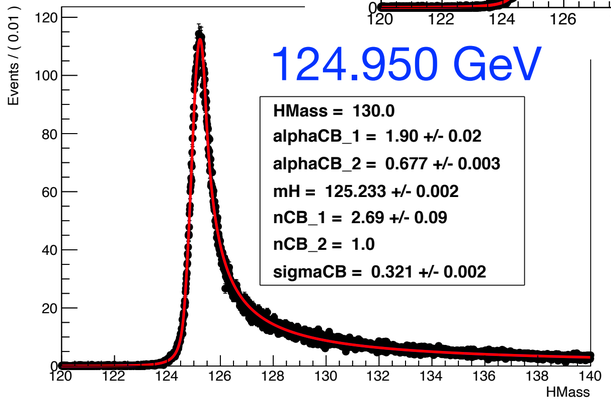
BES: 6.1 MeV

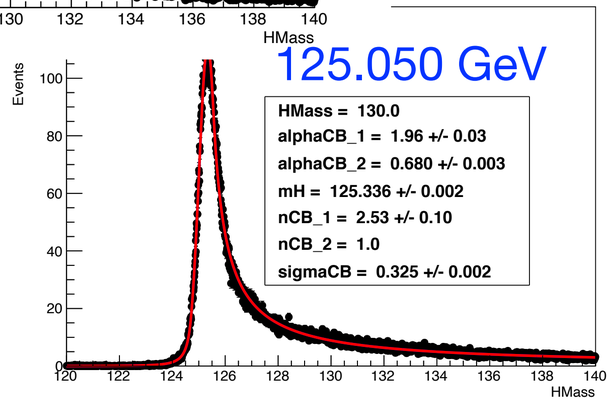
Shape dependency on m_H

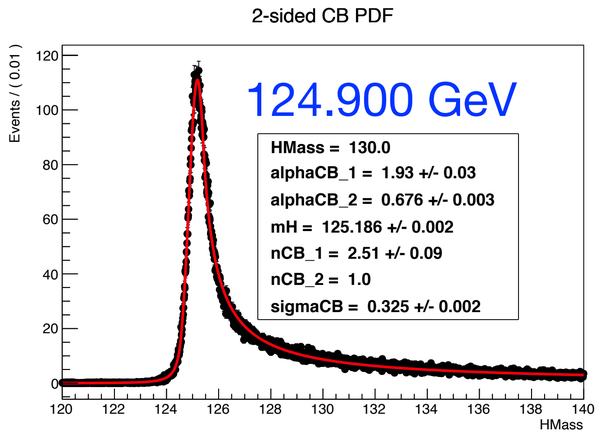
PYTHIA samples with BES

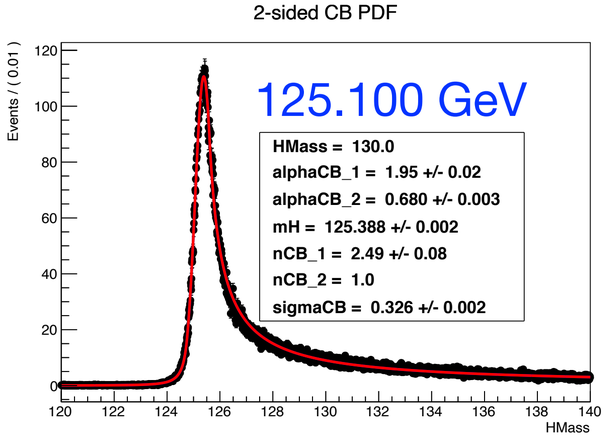
- Double-sided Crystal Ball fit parameters dependency on m_H







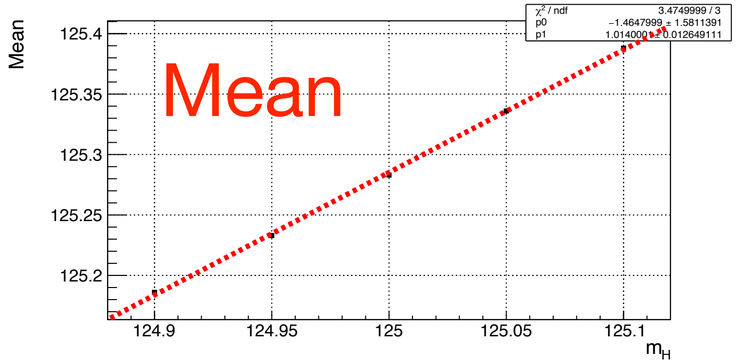


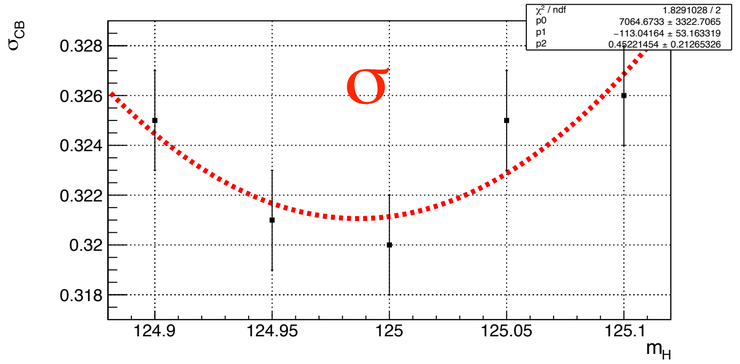


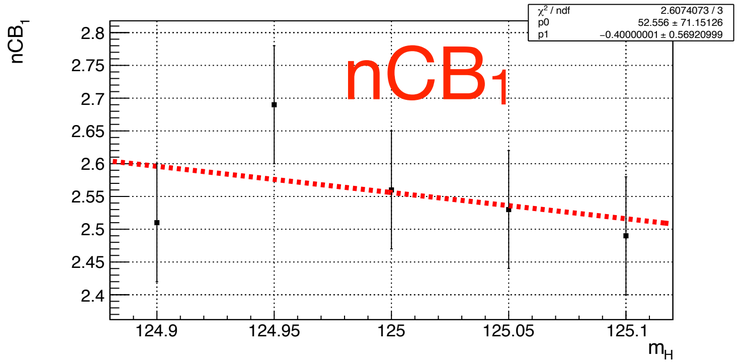
Shape dependency on m_H

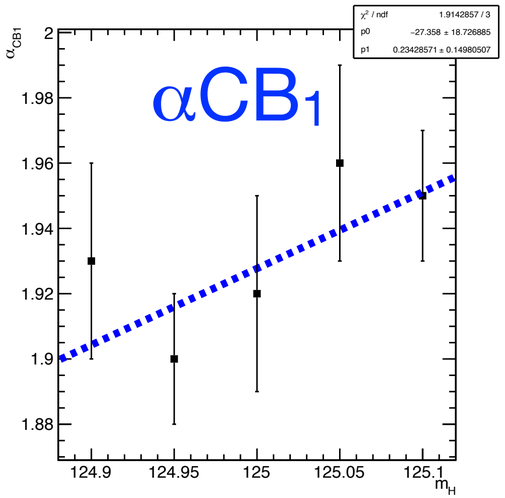
Pythia samples with BES

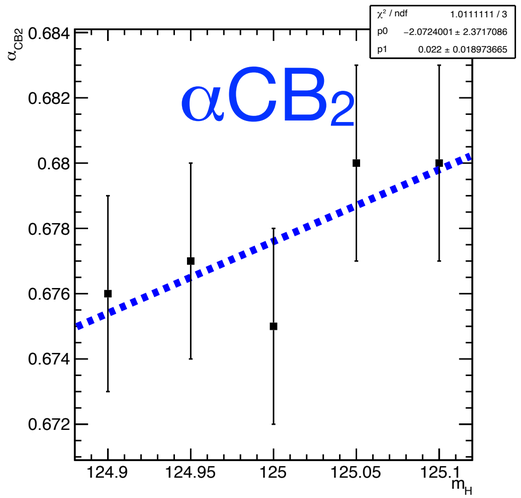
- Double-sided Crystal Ball fit parameters dependency on m_H





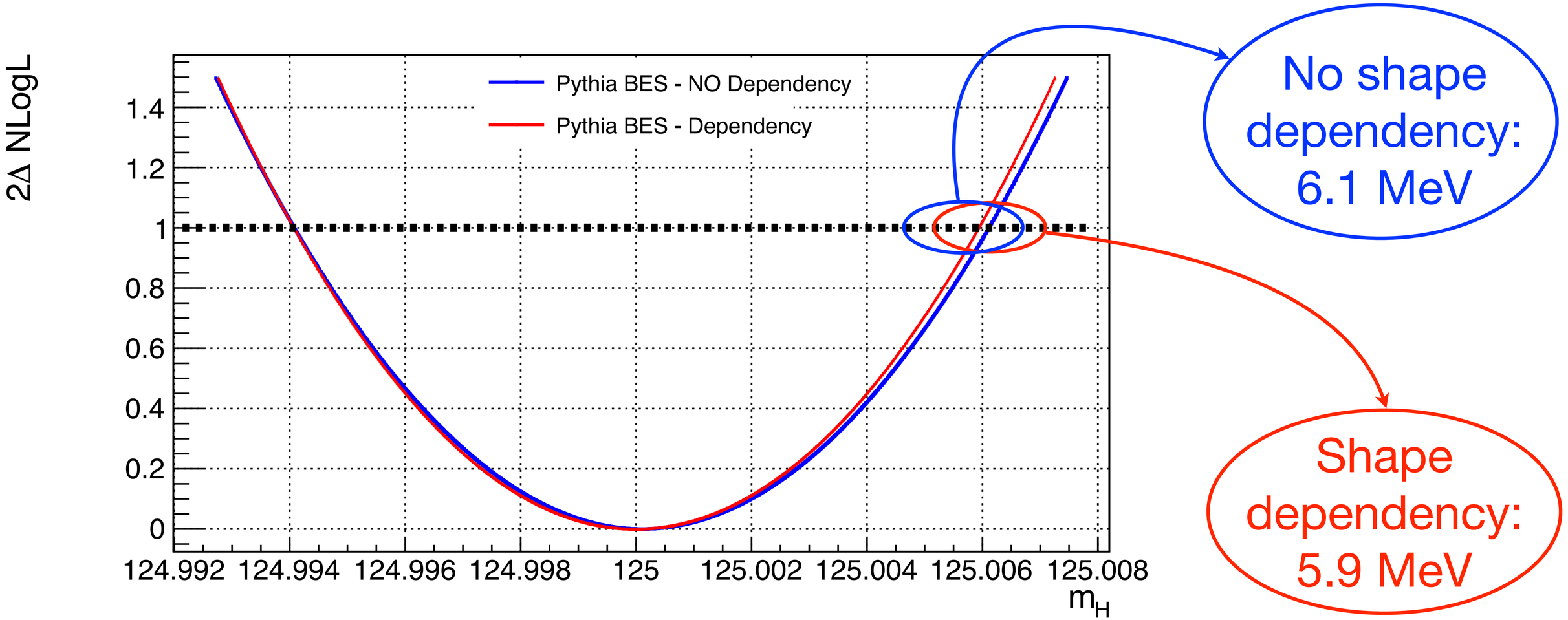






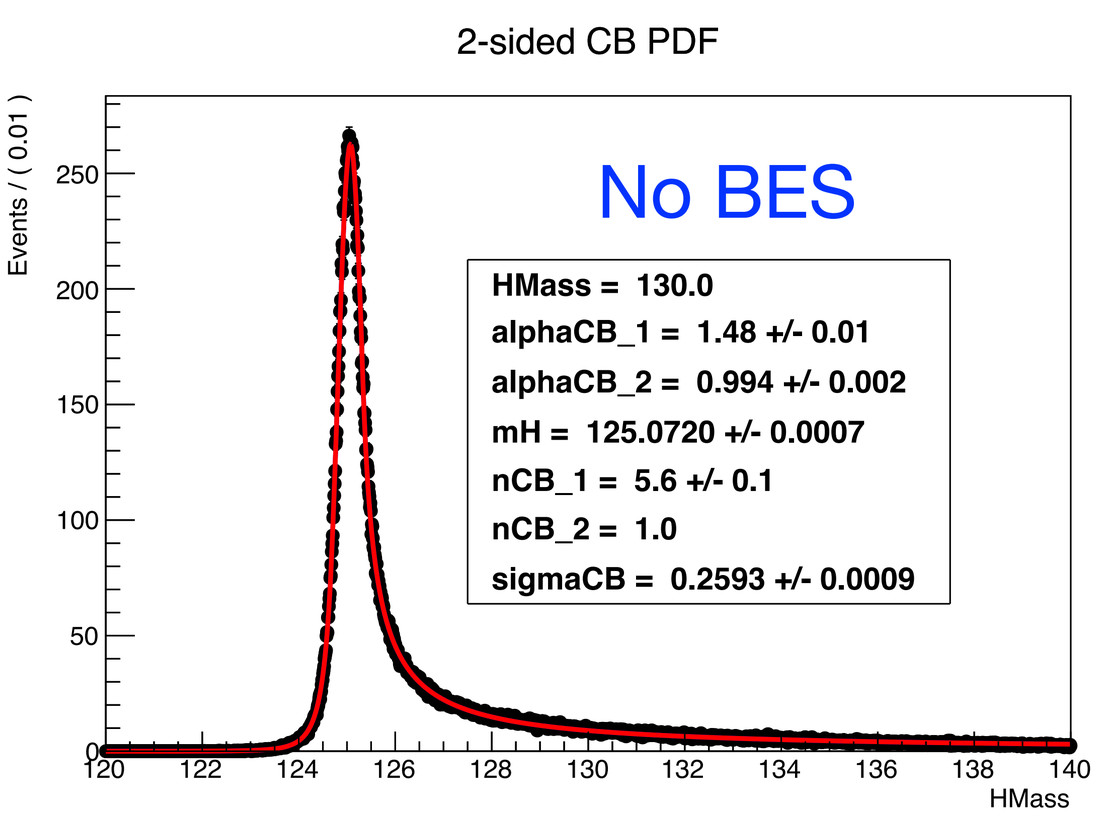
Log Likelihood Versus m_H

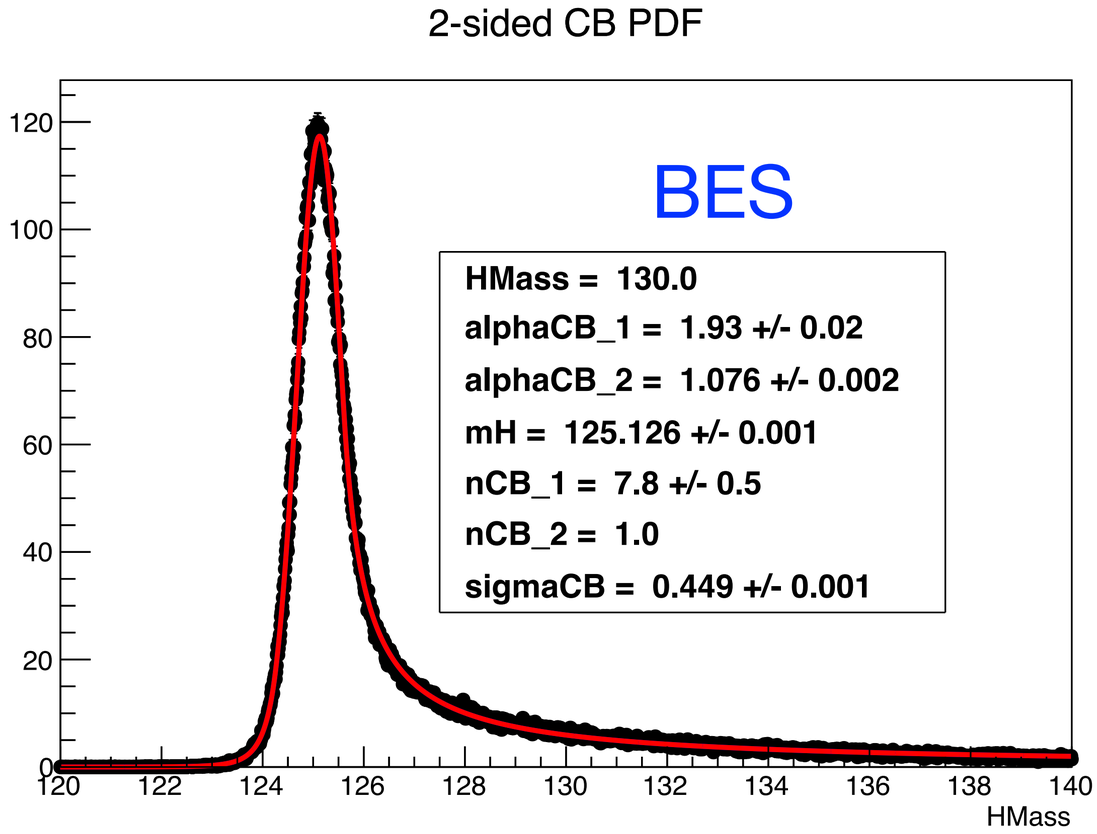
PYTHIA samples with BES and shape dependency



Shape Analysis

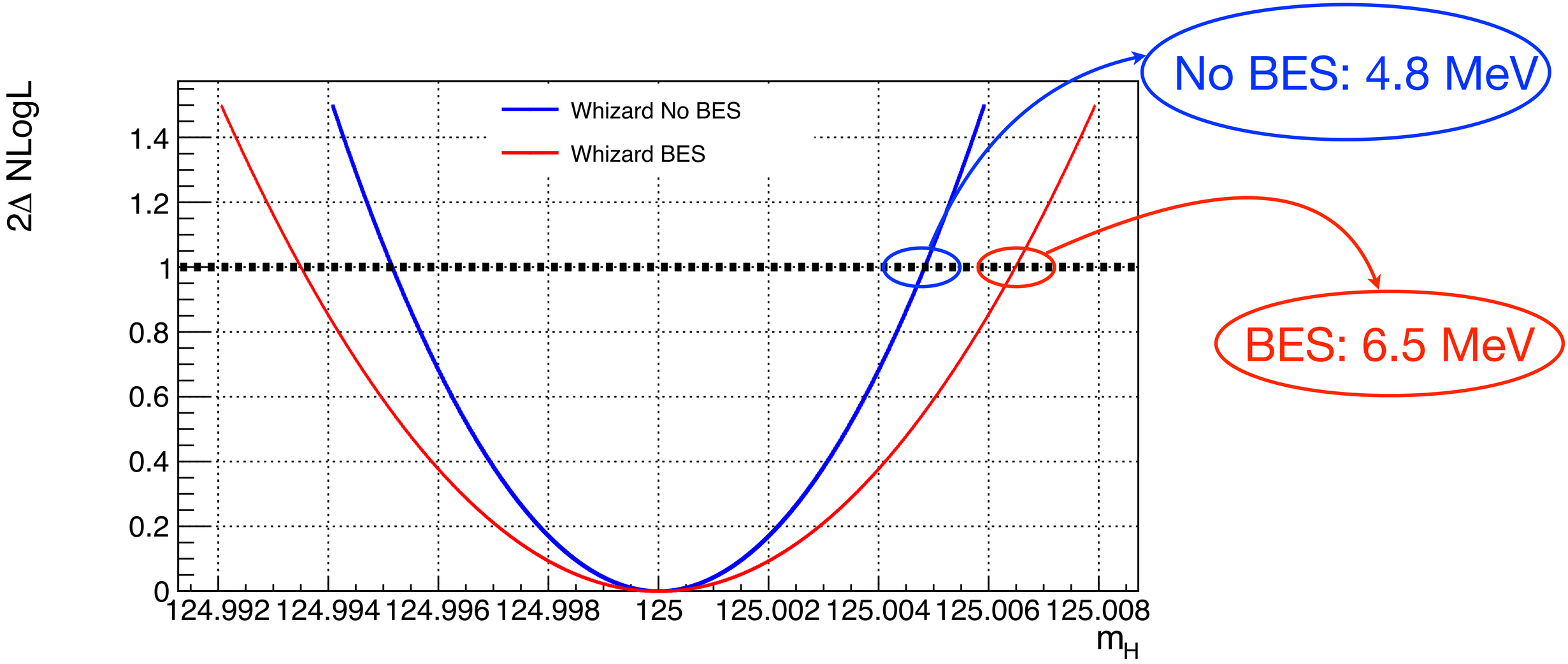
Whizard samples with and without BES





Log Likelihood Versus m_H

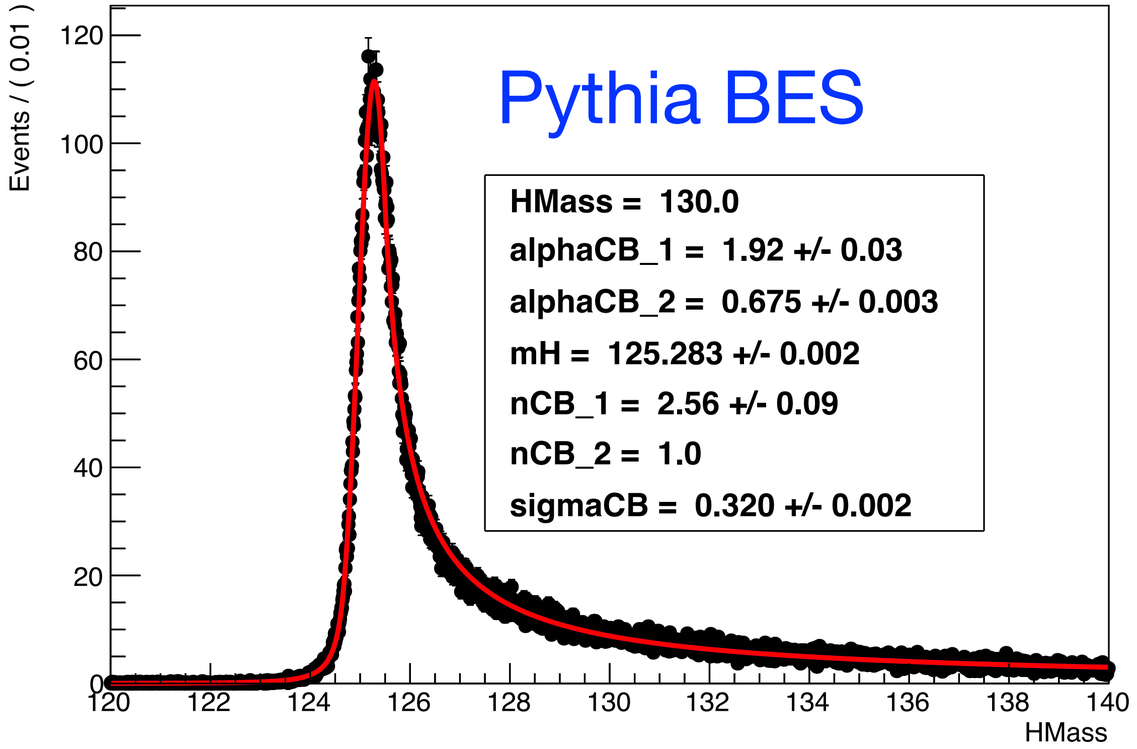
Whizard samples with and without BES

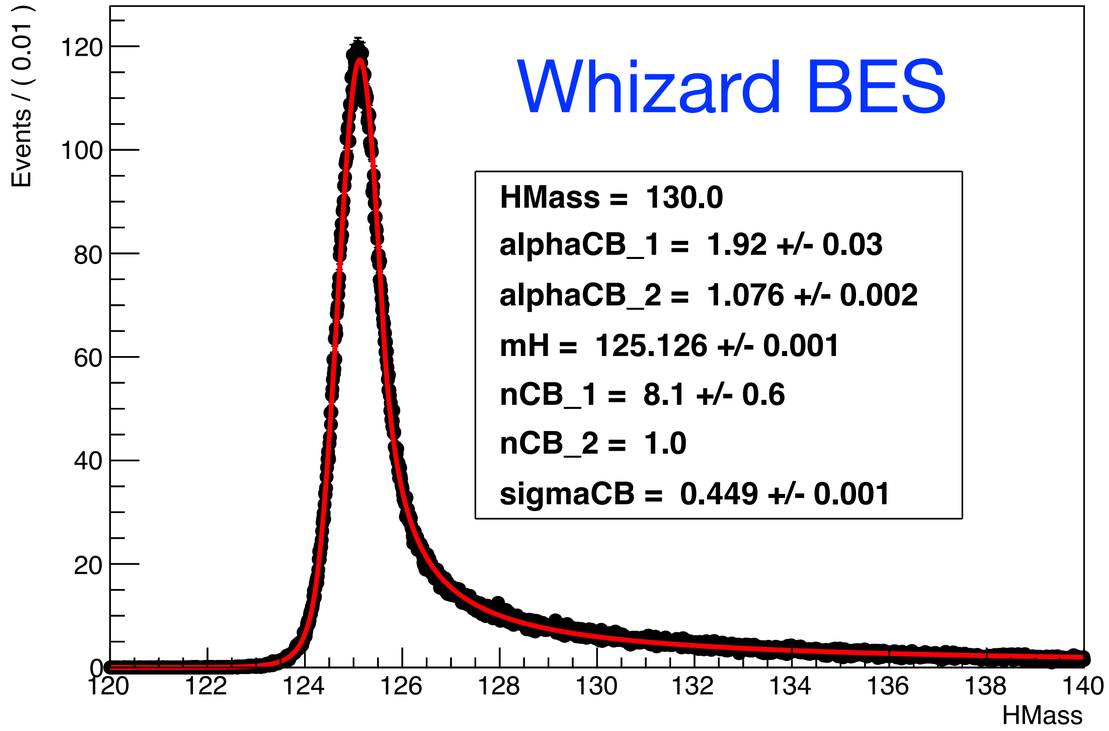


Shape Analysis

Whizard versus Pythia Samples with BES

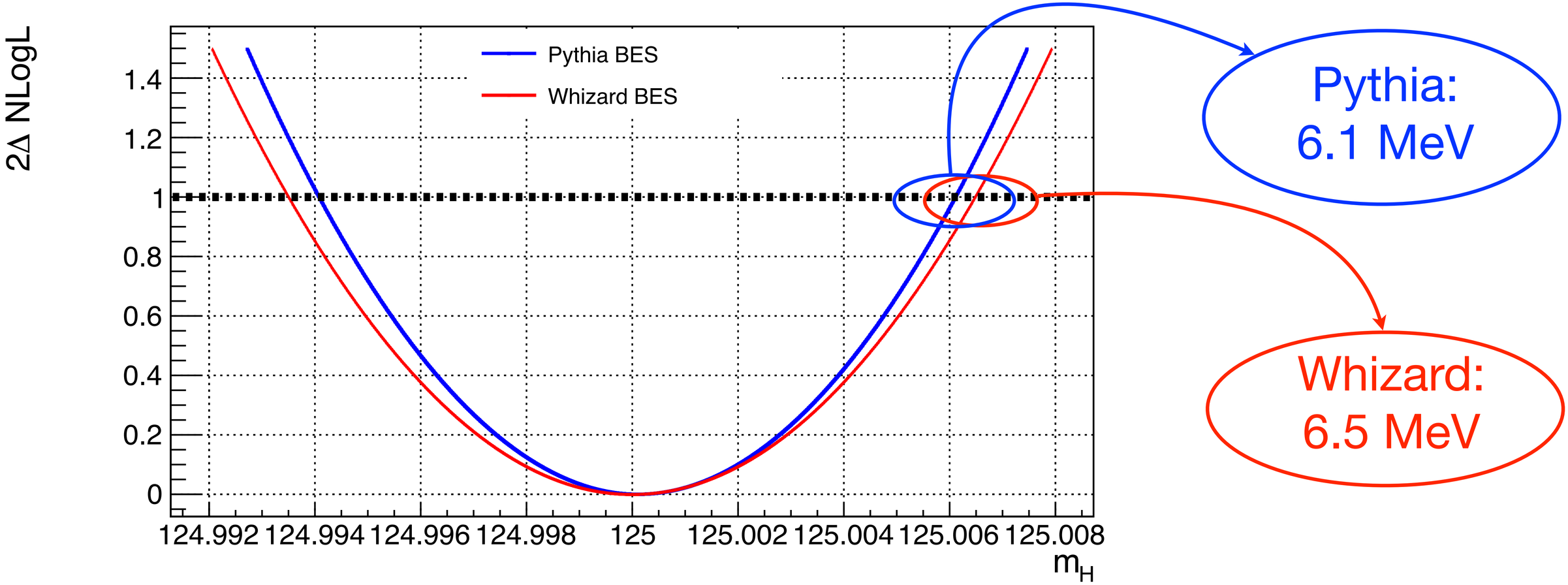
- Double-sided Crystal Ball fits parameters for Pythia and Whizard samples
- Note the difference between the fit parameters, especially for the mean and sigma





Log Likelihood Versus m_H

PYTHIA and Whizard samples with BES



Precision on the Higgs mass measurement

Summary

	No BES	BES	Shape dependency
PYTHIA	3.6 MeV	6.1 MeV	5.9 MeV
Whizard	4.8 MeV	6.5 MeV	-