FCCee Higgs Recoil

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Case study working meeting - Higgs recoil - May 26 2021

Overview

Study of the Higgs mass and cross section measurements at FCCee in the ZH production process

Preliminary work and results

- Getting familiar with FCC framework for slimming/baseline analysis
- Sample production and validation
- Baseline implementation of analysis and cuts
- Setting up statistical analysis for cross section and mass measurement with proper uncertainties
- Focus on machine parameters (e.g. BES) and detector parameters (reconstruction eff) as useful feedback

Statistical analysis performed using the CMS statistical tool “Combine” (RooFit based)

- Building likelihood model based on signal and background templates
- Including uncertainties

MC Samples overview

All samples for now privately produced, in order to be consistent with the studies presented (and not all necessary samples are/were ready yet):

- Pythia8+Delphes using latest Delphes card to simulate IDEA detector
- Cross checks performed with central samples, all looks good
- ISR/FSR/BES enabled (BES @ 198 MeV)
- Analysis performed with FCC framework based on RDataFrame (except the usage of the json files, own mcdb)

Signal samples:

- Nominal 125 GeV
- Off-mass samples: +/- 50, 100 MeV (as central)

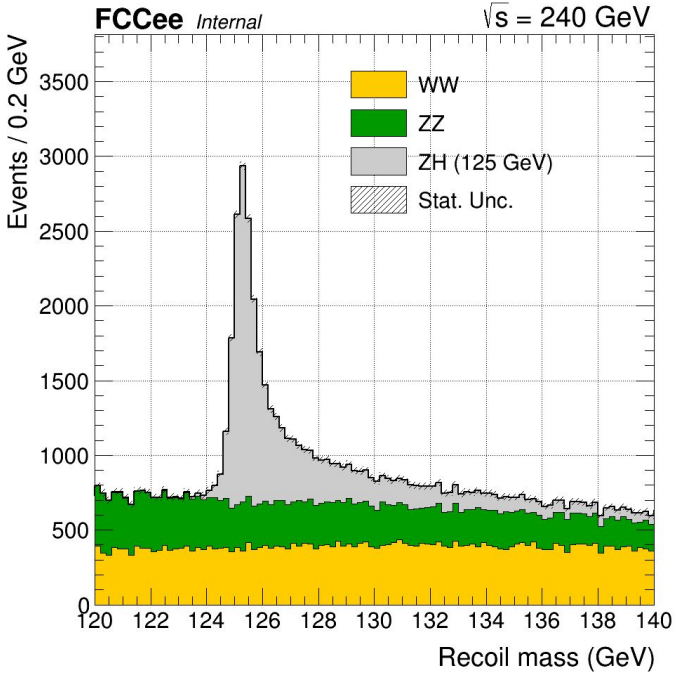
Background samples:

- WW (exclusive, see next slide), ZZ

Systematic uncertainty samples to infer shape uncertainty (see later):

- Variation of BES parameter with +/- 6%
- Applied to backgrounds and nominal 125 GeV signal sample (assume similar uncertainty for other mass points)

Baseline analysis



Process	Generated	Events	Uncertainty	sqrt(evts)
ZH (inclusive)	10M	22813.41	47.99	151.04
WW (exclusive*)	10M	38874.94	184.16	197.17
ZZ (inclusive)	10M	27297.35	136.19	165.22

(*) Let W's decay exclusively to leptons (e, mu, tau): **stat uncertainty reduction with factor of 3** (note: central samples done with W→mu or W→tau with tau→mu)

→ Muon p_T > 10 GeV
→ One resonance pair 80 < m(μ,μ) < 100 GeV
→ Recoil mass within [120, 140] GeV

→ Events normalized to 5 /ab luminosity
→ Sample statics below expected data statistics for all processes
→ Based on preliminary cuts, to be optimized (numbers not "final")

Background parameterization

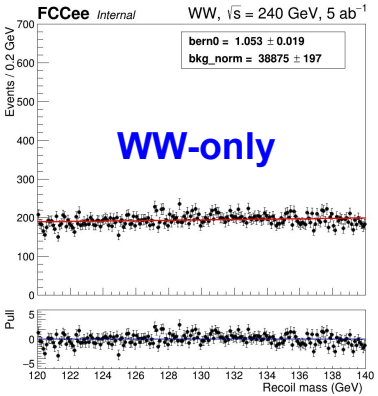
Polynomial approximation in recoil mass range of [120,140] GeV

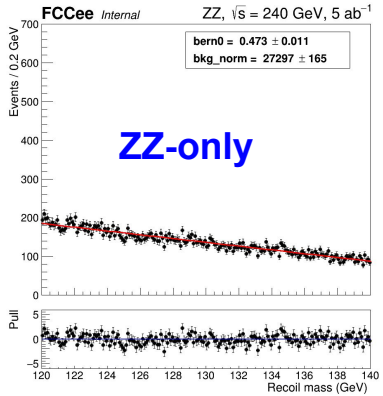
Usage of BernStein polynomials

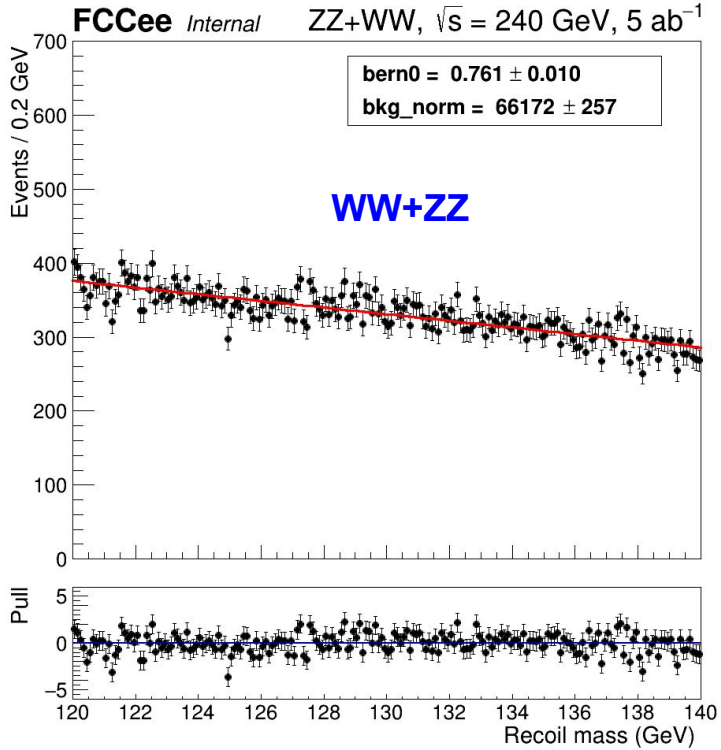
- Positive defined between [0,1]
- Analytical integration in Combine (faster, more stable)

Merge WW and ZZ backgrounds

- Difficult to constrain them separately using the recoil mass distribution only
- One can define control regions to constrain ZZ and/or WW backgrounds
- Depends on the impact of the ZZ/WW yields on the fit (to be studied)







Signal parameterization (1)

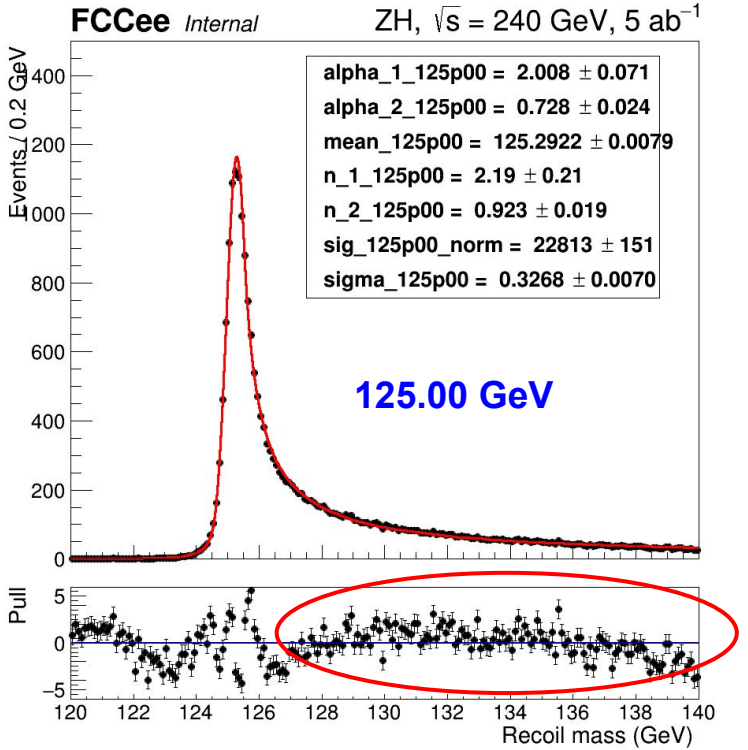
Double-sided Crystal Ball (DSCB)

- 6 free parameters + 1 normalization
- Implementation as analytical integration in Combine (faster, more stable)

DSCB trend observed in exponential tails as well as at peak

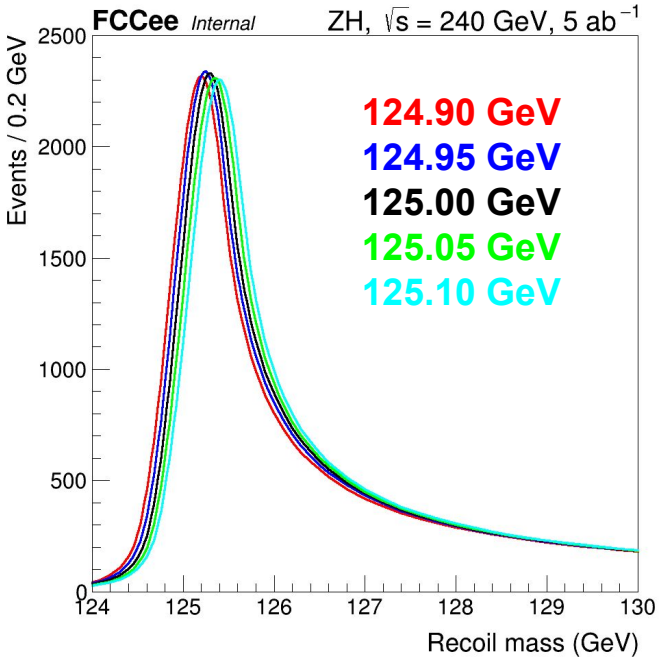
- Need to optimize the fit

→ Plots of other signals (124.9. 124.95, 125.05 and 125.10 GeV in backup)

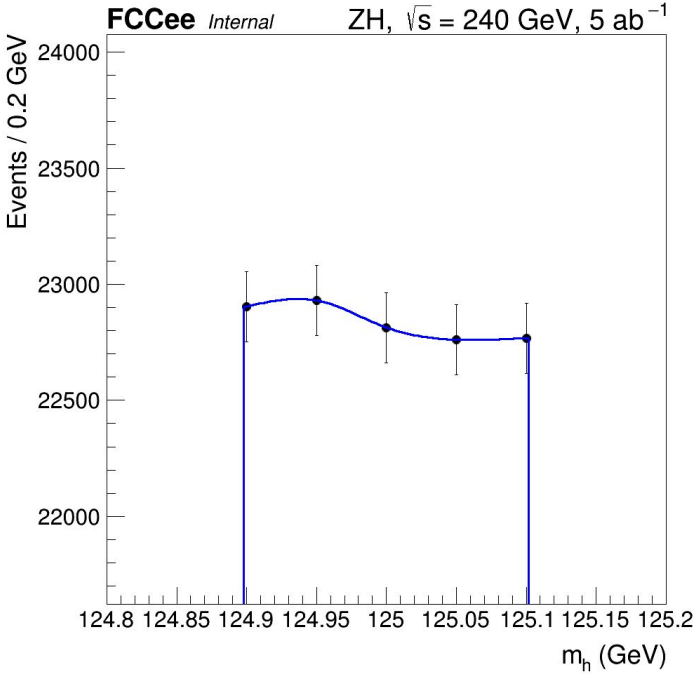


Signal parameterization (2)

DSCB fit repeated for all signals, and parameterize the fit parameters as function of mH using Spline



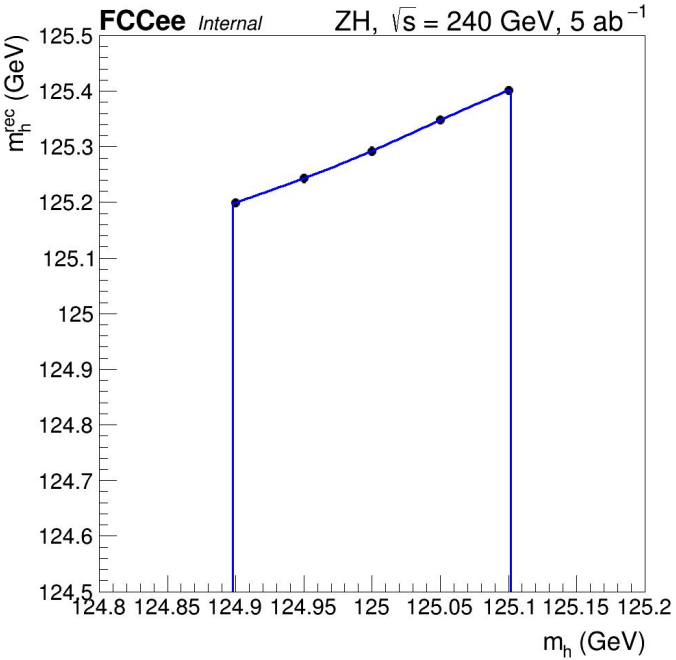
Yields - normalization



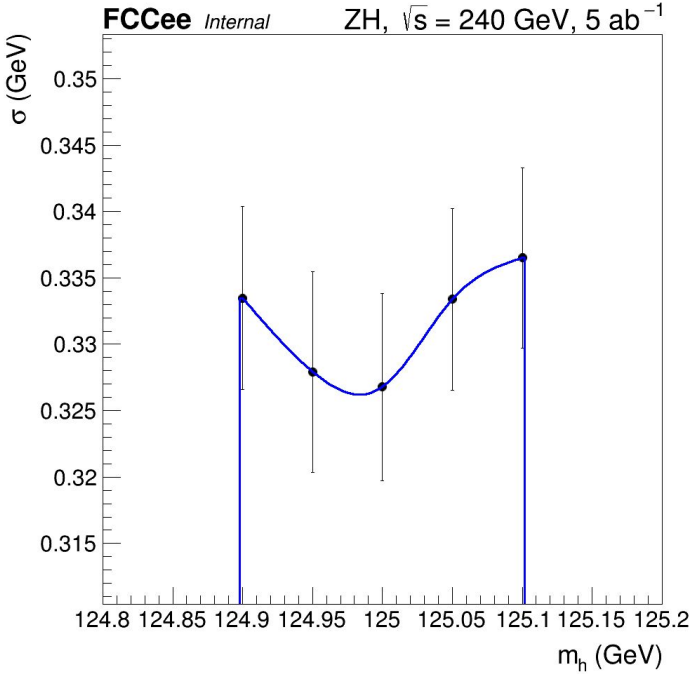
Signal parameterization (3)

DSCB fit repeated for all signals, and parameterize the fit parameters as function of mH using Spline

Signal mean (reco)



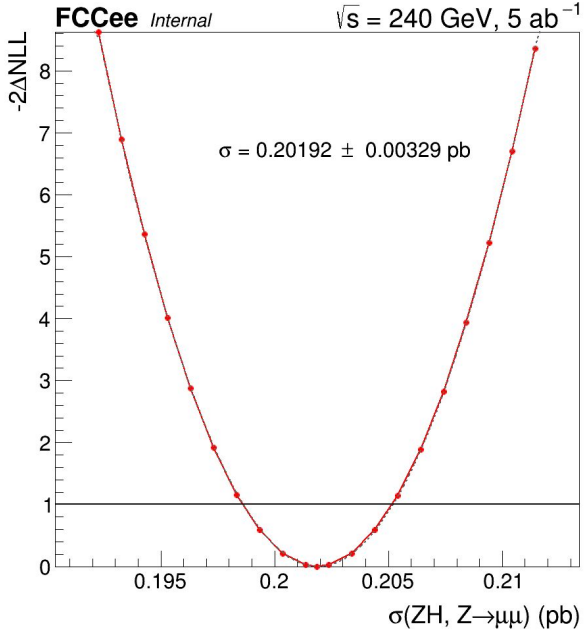
Signal width

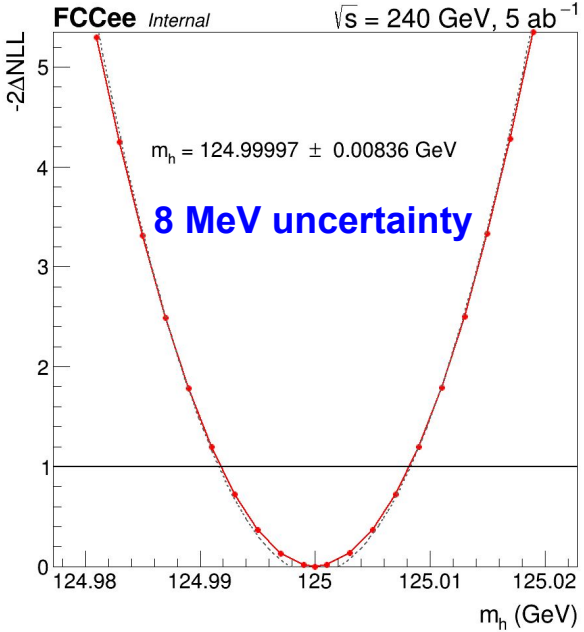


Statistical analysis

Fits performed using Combine by injecting 1 “unit” of signal at 125.00 GeV, corresponding to 0.201868 pb

- Fit to Asimov dataset, let signal and background normalizations float, as well as the Higgs mass parameter mH
- Likelihood scans to extract cross sections and Higgs mass and uncertainties
- No experimental uncertainties accounted for so far → **stat-only result**





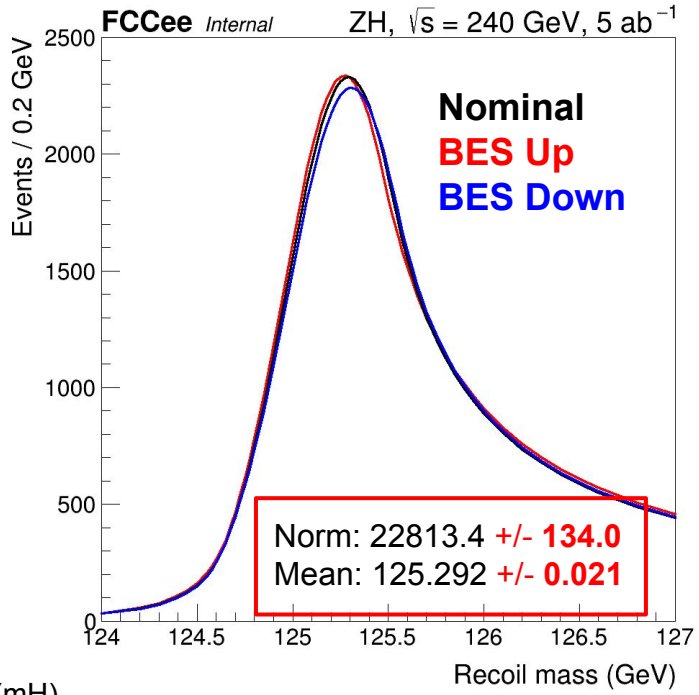
Parameter	Prefit	Postfit
Background	66172 +/- 0 (*)	66172 +/- 334

(*) +/-0: no stat. Uncertainty taken into account

Beam Energy Spread (BES)

BES can be a dominant systematic uncertainty as it directly alters the recoil mass distribution

- BES set to 0.165% according to CDR → per beam 120 +/- 0.198 GeV
- Uncertainty on BES estimated 6% → +210/-187 MeV additional smearing
- New samples generated with this variation (WW, ZZ and ZH at 125.00 GeV)



Signal:

- Mainly affects mass peak and normalization for DSCB
- Up and Down variations symmetrized
- 125.00 GeV generated only, assume identical uncertainty for other masses

Backgrounds:

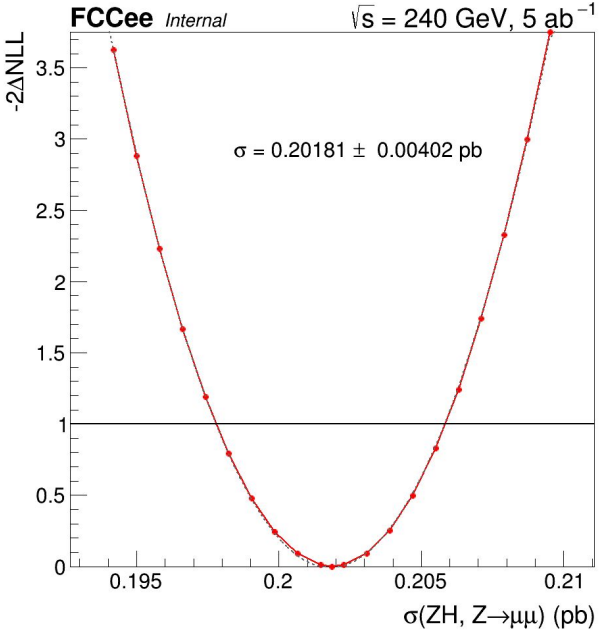
- Only normalization effect, symmetrized
- WW+ZZ: 66172.3 +/- 250.7 events

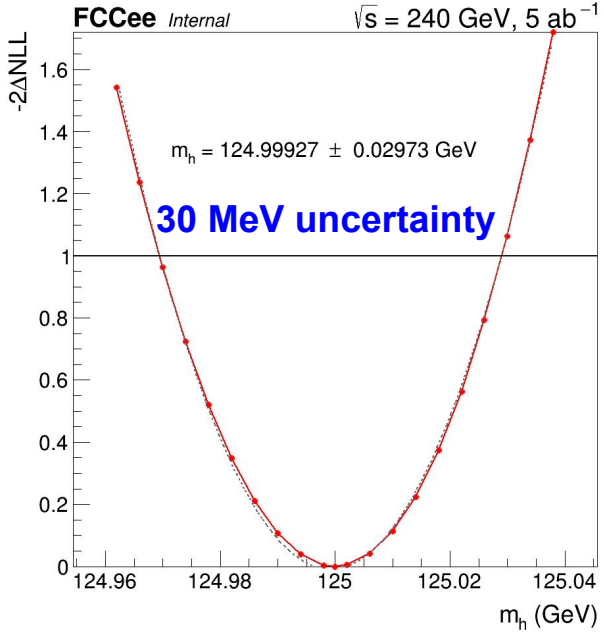
In general: 6% small effect, need accuracy on norm (xsec) and statistics for the shapes (mH)

Statistical analysis wit BES

Fits performed using Combine by injecting 1 “unit” of signal at 125.00 GeV, corresponding to 0.201868 pb

- Fit to Asimov dataset, let signal and background normalizations float, as well as the Higgs mass parameter mH
- Multiplicative Gaussian constraint term in likelihood (can float freely between +/- 1σ)
- Likelihood scans to extract cross sections and Higgs mass and uncertainties





Parameter	Prefit	Postfit
Background	66172 +/- 0 (*)	66172 +/- 410
BES	0 +/- 0 (*)	-9.4488e-04 +/- 9.89e-01 (unconstr.)

(*) +/-0: no stat. Uncertainty taken into account

Summary and outlook

Analysis framework and fitting model setup and validated

Optimization:

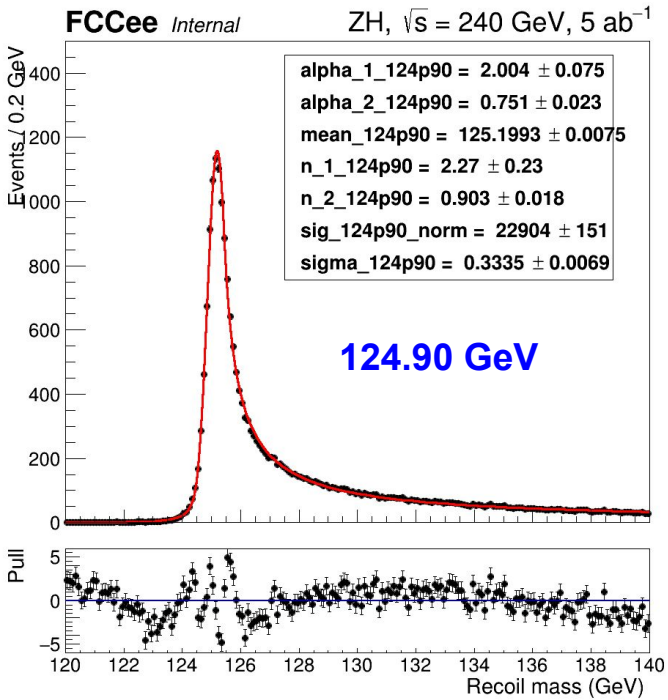
- Signal DSCB functional form: remove biases
- Finetune cuts
- Optimization of lepton pair selection (suppress the wrong pairs)
- Include electron channel

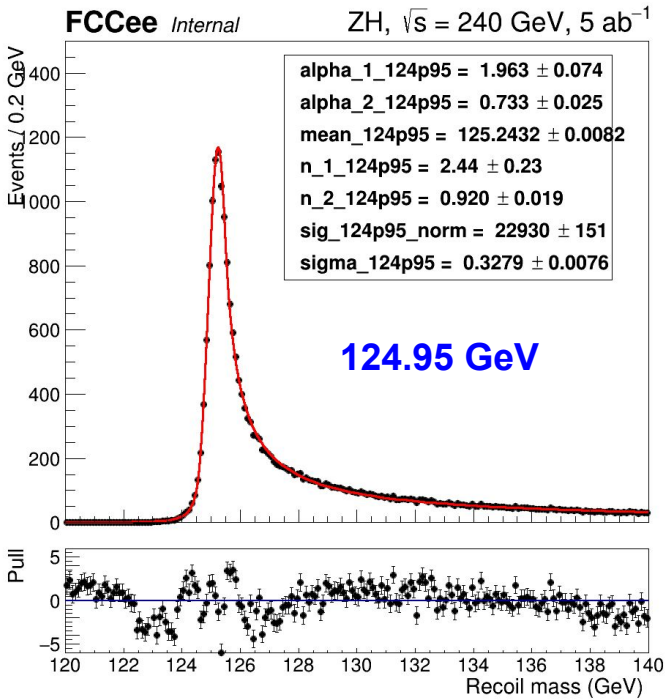
Fitting model:

- Add and study relevant systematic uncertainties
- Study dependency of xsec/mH on background normalization
- Study the dominant systematic uncertainties
- Control regions to constrain relevant uncertainties (?)

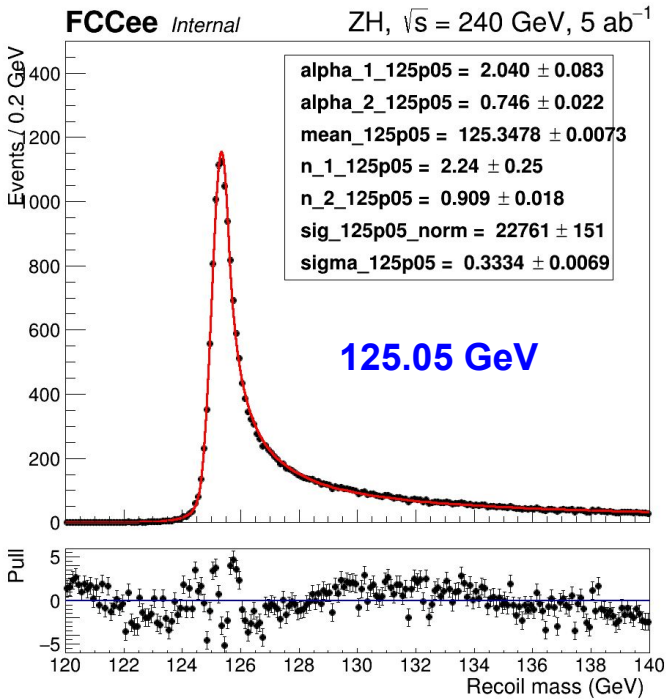
Backup

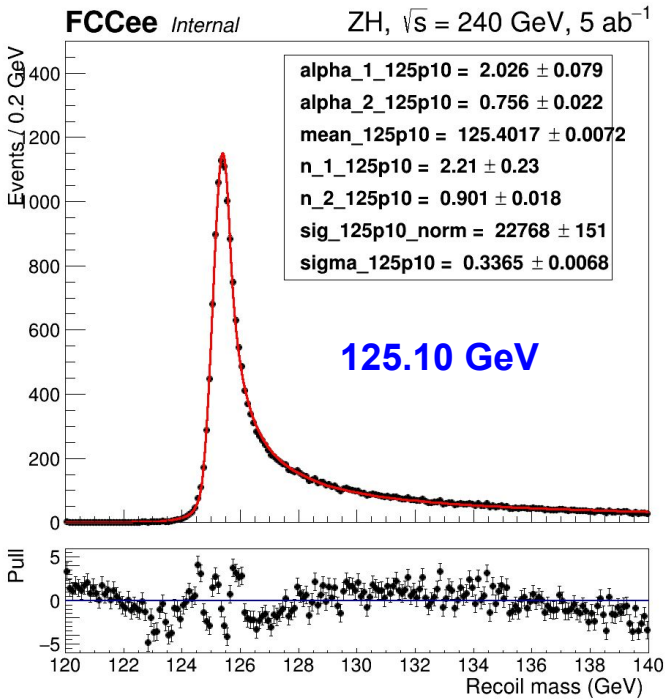
Signal DSCB fit





Signal DSCB fit

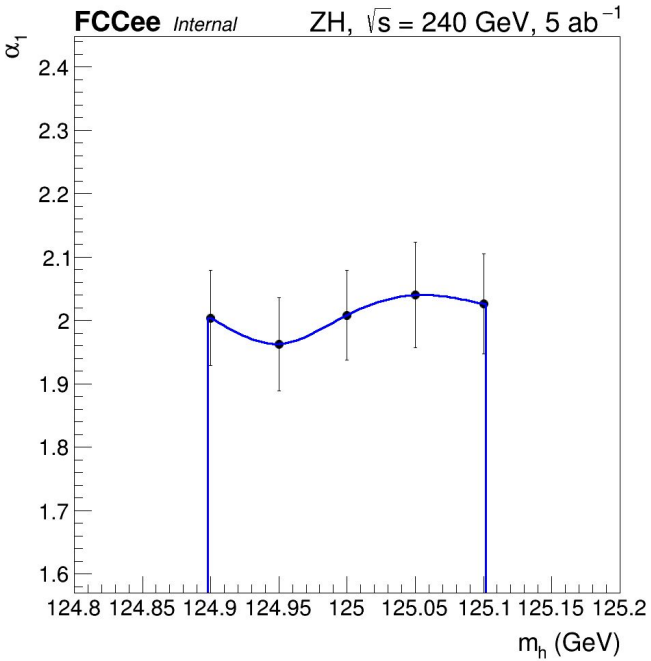




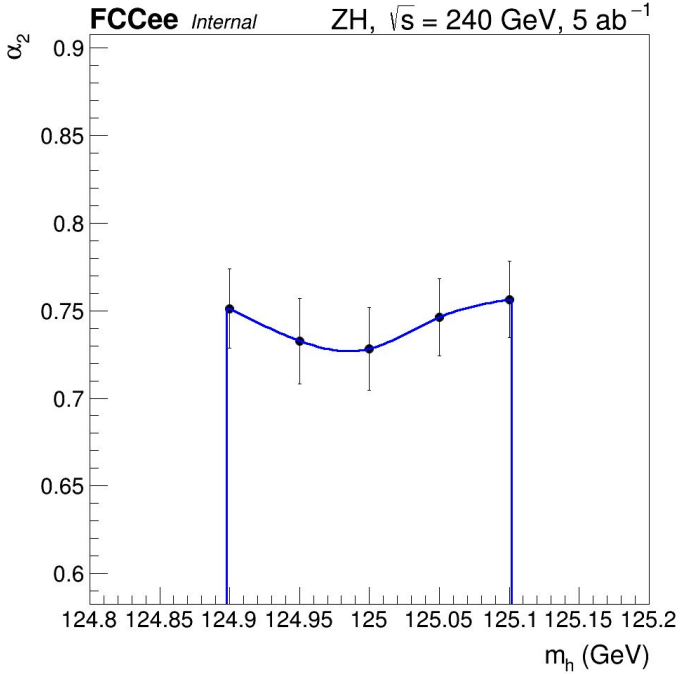
Signal parameterization

DSCB fit repeated for all signals, and parameterize the fit parameters as function of mH using Spline

Alpha_1



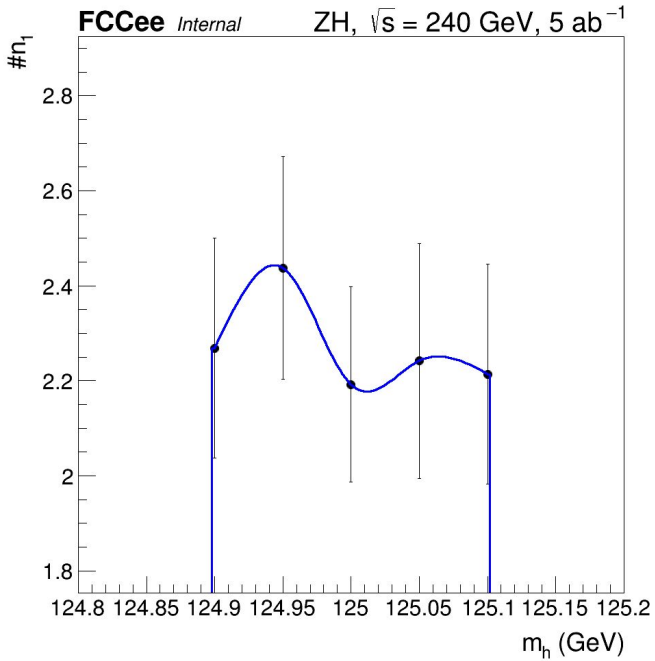
Alpha_2



Signal parameterization

DSCB fit repeated for all signals, and parameterize the fit parameters as function of mH using Spline

n_1



n_2