# STATUS OF THE ZH RECOIL ANALYSIS

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# OUTLINE



## STATUS OF THE HIGGS RECOIL ANALYSIS

- Status of Ang LI and Gregorio Bernardi Analysis
  - Updated to March 2021
- Recap of the analysis Sylvie and I carried out
  - Simple Higgs recoil mass and Z boson mass fit using ROOFIT
  - Preliminary results using SHAPED-BASED analysis with COMBINE software
- Next steps …

COLLABORATION REPOSITORY

https://github.com/HEP-FCC/FCCeePhysicsPerformance/tree/master/case-studies/higgs/mH-recoil

# ANG AND GREG: FIT RESULTS



## ANG LI & GREGORIO BERNARDI ANALYSIS

- Check for details of each analysis step
- Choose new selection cut and produced CutFlow table
- Fit with new selection

**Selections**

### Old Selection

1. At least one Z boson
2. $m_Z \in [80, 100]$ GeV
3. $p_T^{\mu} > 10$ GeV

### New Selection

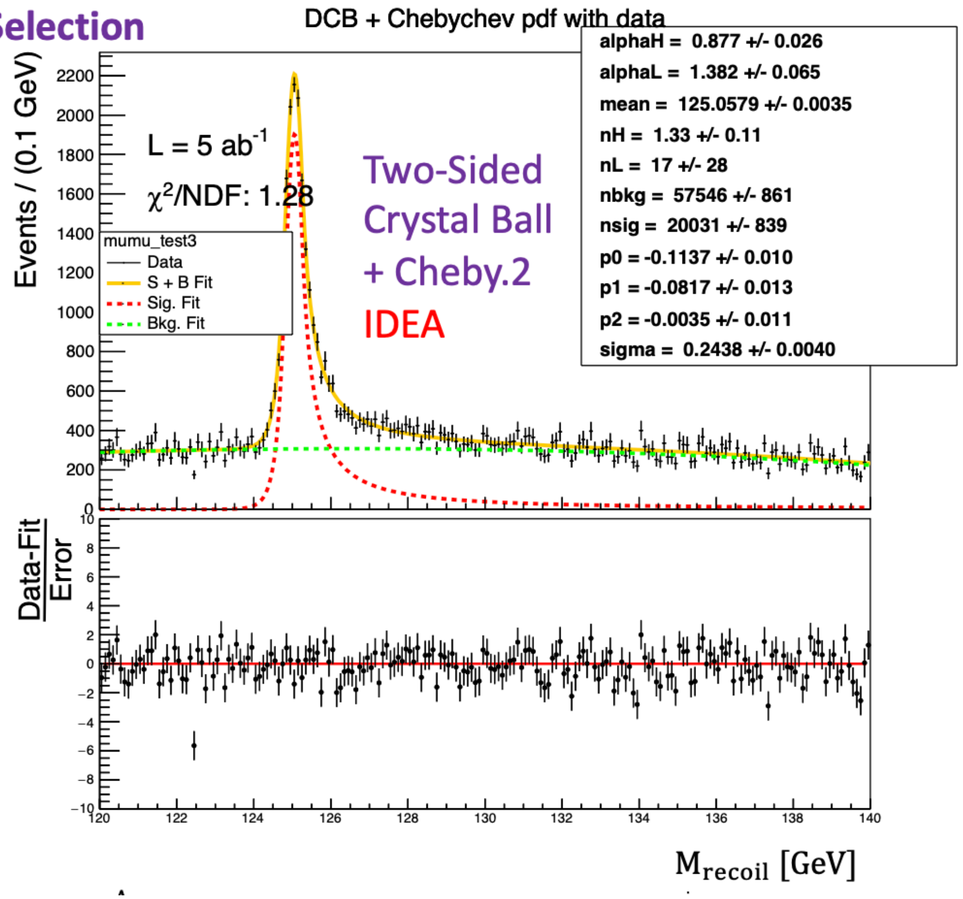
1. At least one Z boson
2. One Z boson
3. $m_Z \in [80, 100]$ GeV
4. $p_T^{ll} \in [10, 70]$ GeV

# ANG AND GREG: FIT RESULTS

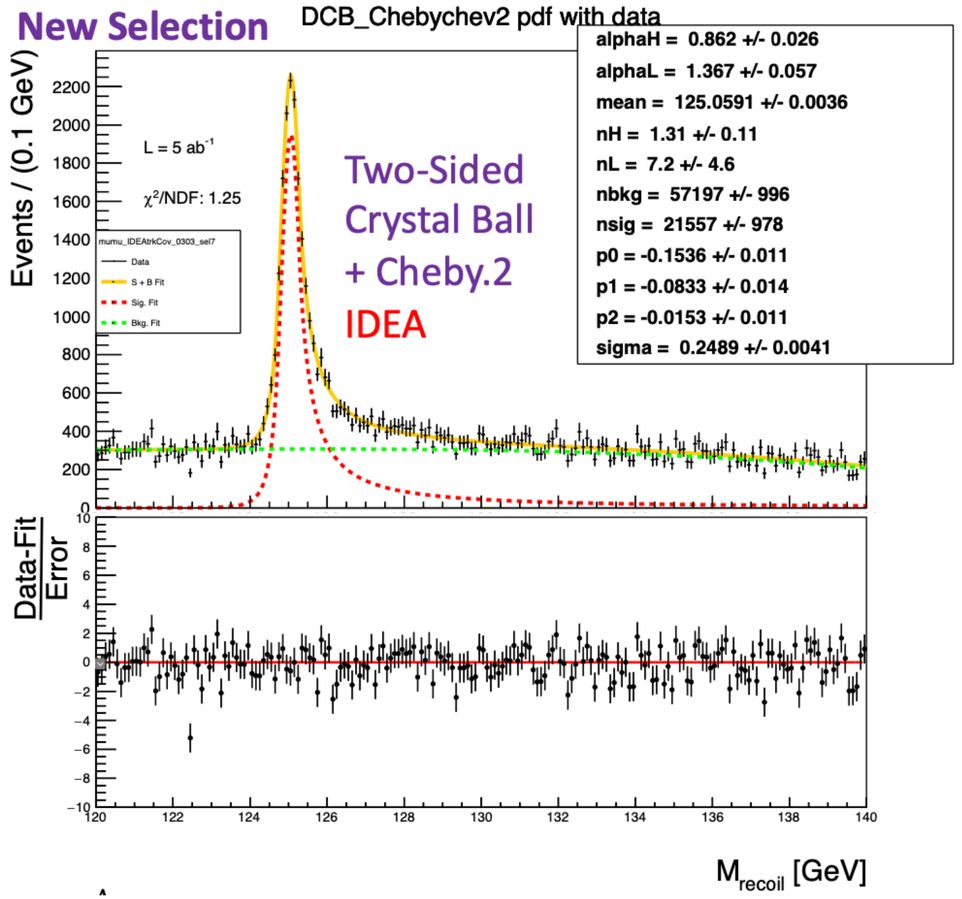


## Two-Sided Crystal Ball + Chebychev2 fit of $M_{recoil}$ in the Higgs region (120-140 GeV)

**Old Selection**




**New Selection**



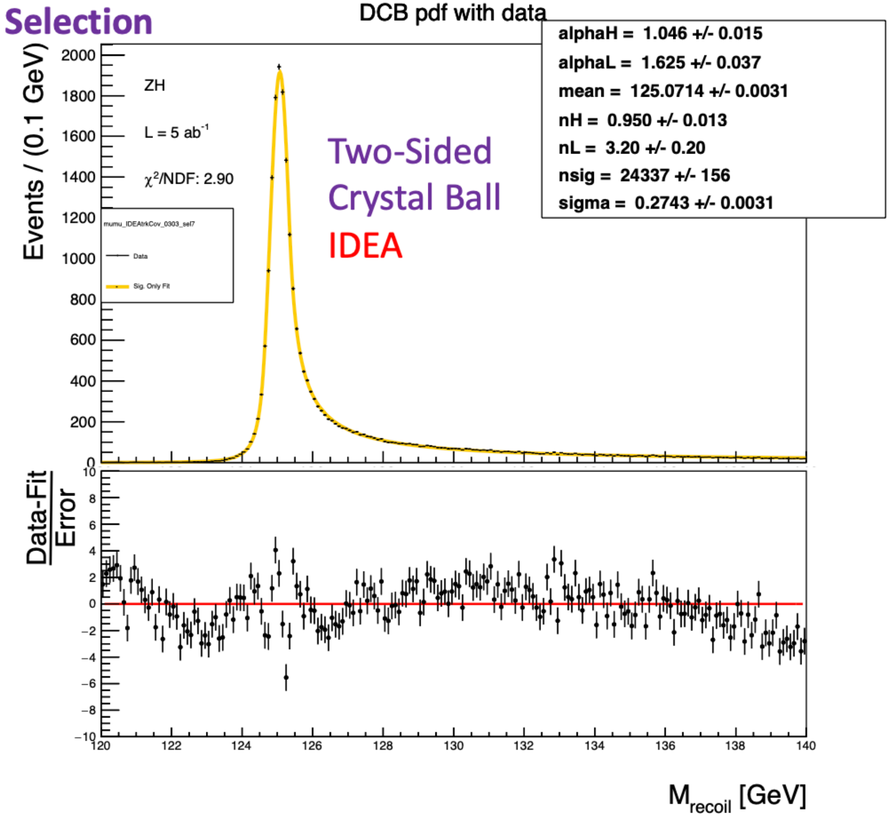
# ANG AND GREG: FIT RESULTS



## Two-Sided Crystal Ball Signal Only fit of $M_{recoil}$ in the Higgs region (120-140 GeV)

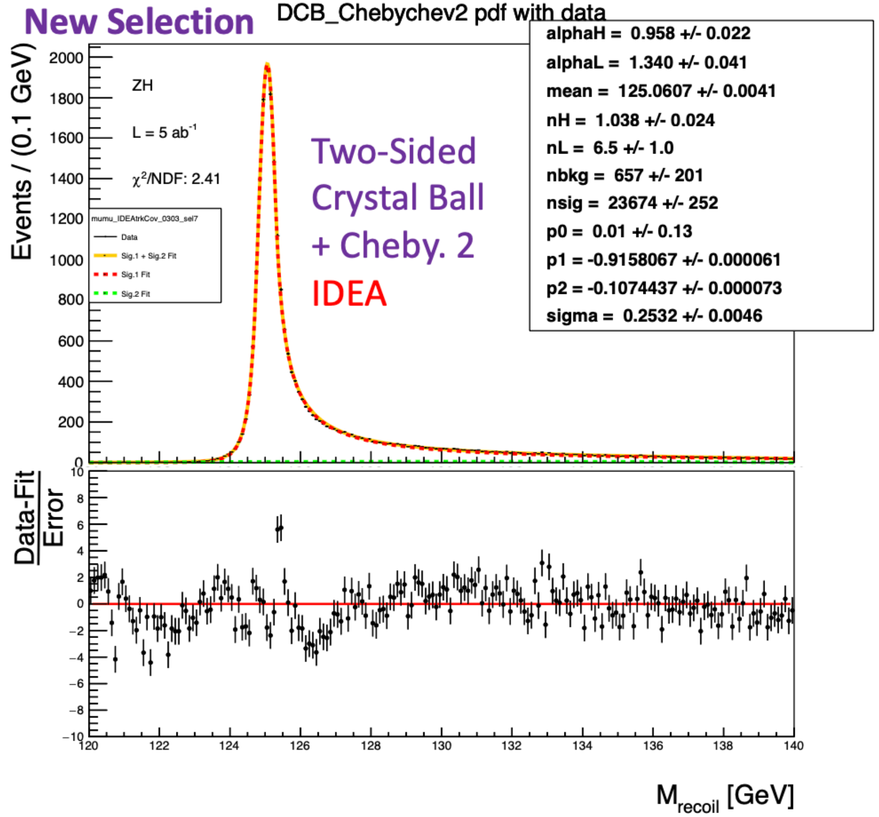
**New Selection**

DCB pdf with data




**New Selection**

DCB_Chebychev2 pdf with data




$\chi^2/_{NDF}$ is far from 1, double crystal ball does not describe the signal well
Need to find other function for the signal modeling

# ANG AND GREG: FIT RESULTS



## PROBLEMS:

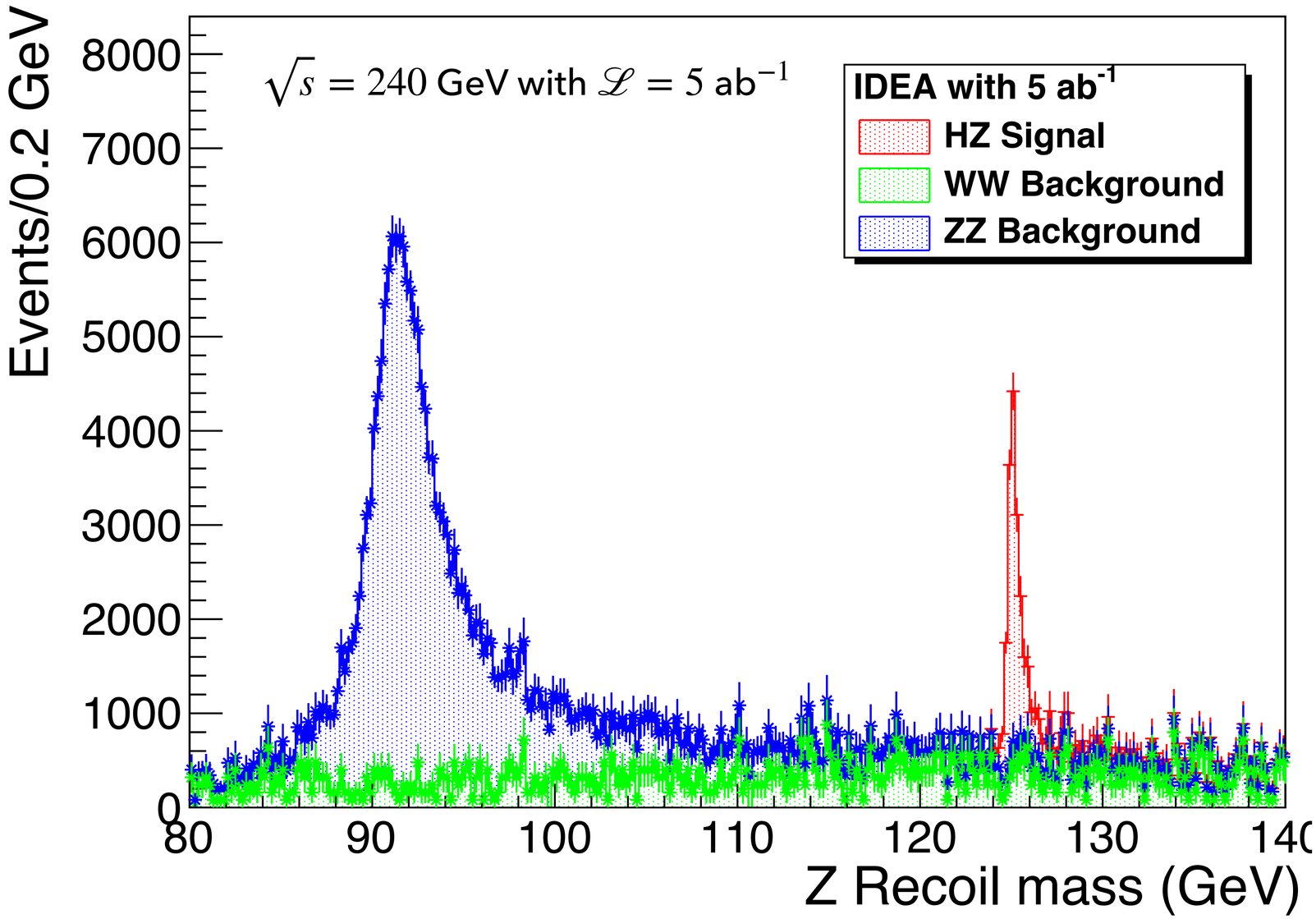
- the uncertainties on the Higgs and Z masses increase when introducing the bkg
  - Determine whether it is a problem of the fit power not able to disentangle properly signal and background (can be solved with templates analysis)
  - Define more stringent constraint for background reduction
- The signal shape is not properly described by a CrystalBal
  - Look for the best shape to describe both signal and background

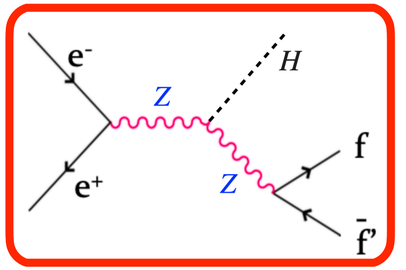
**LOOKING INTO THE CORRELATION BETWEEN HIGGS MASS AND THE PARAMETERS OF THE CHOSEN FITTING FUNCTION**

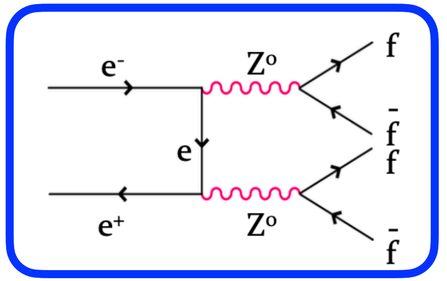
# HIGGSTRAHLUNG PROCESS: SIGNAL SELECTION

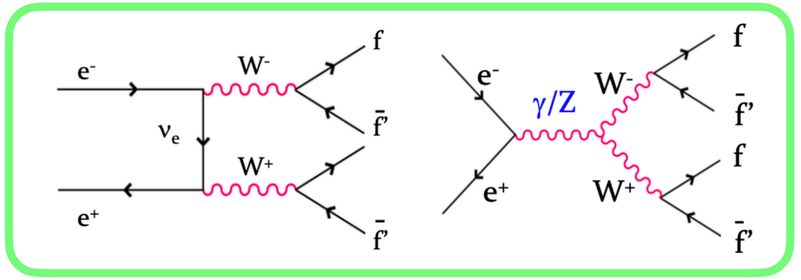
OUR ANALYSIS






The signal selection criteria are:

- two muons of opposite charge with $p_T > 1$ GeV
- $|\eta| < 2.4$
- $m_Z \in [80,100]$ GeV

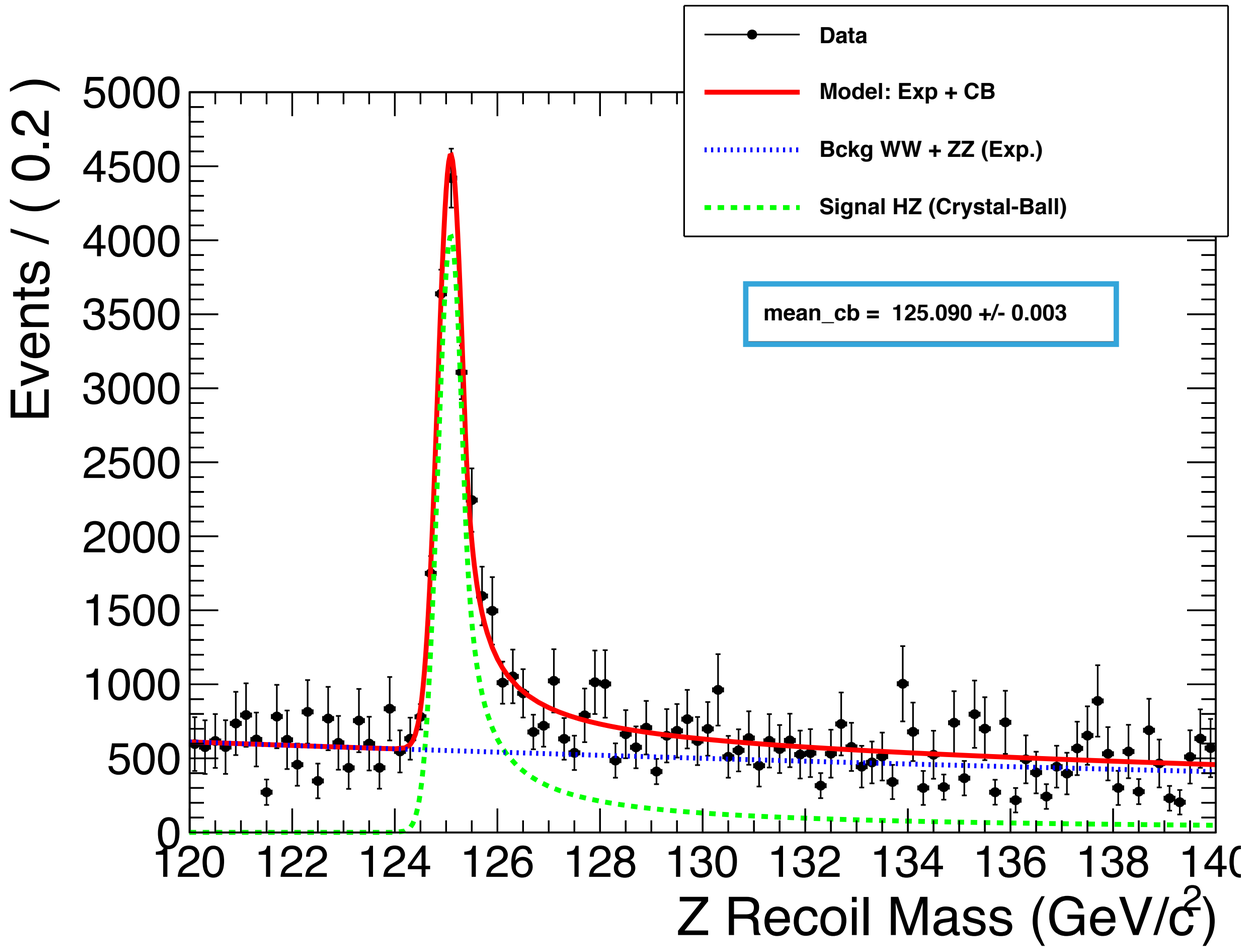
# HIGGS MASS FIT

OUR ANALYSIS

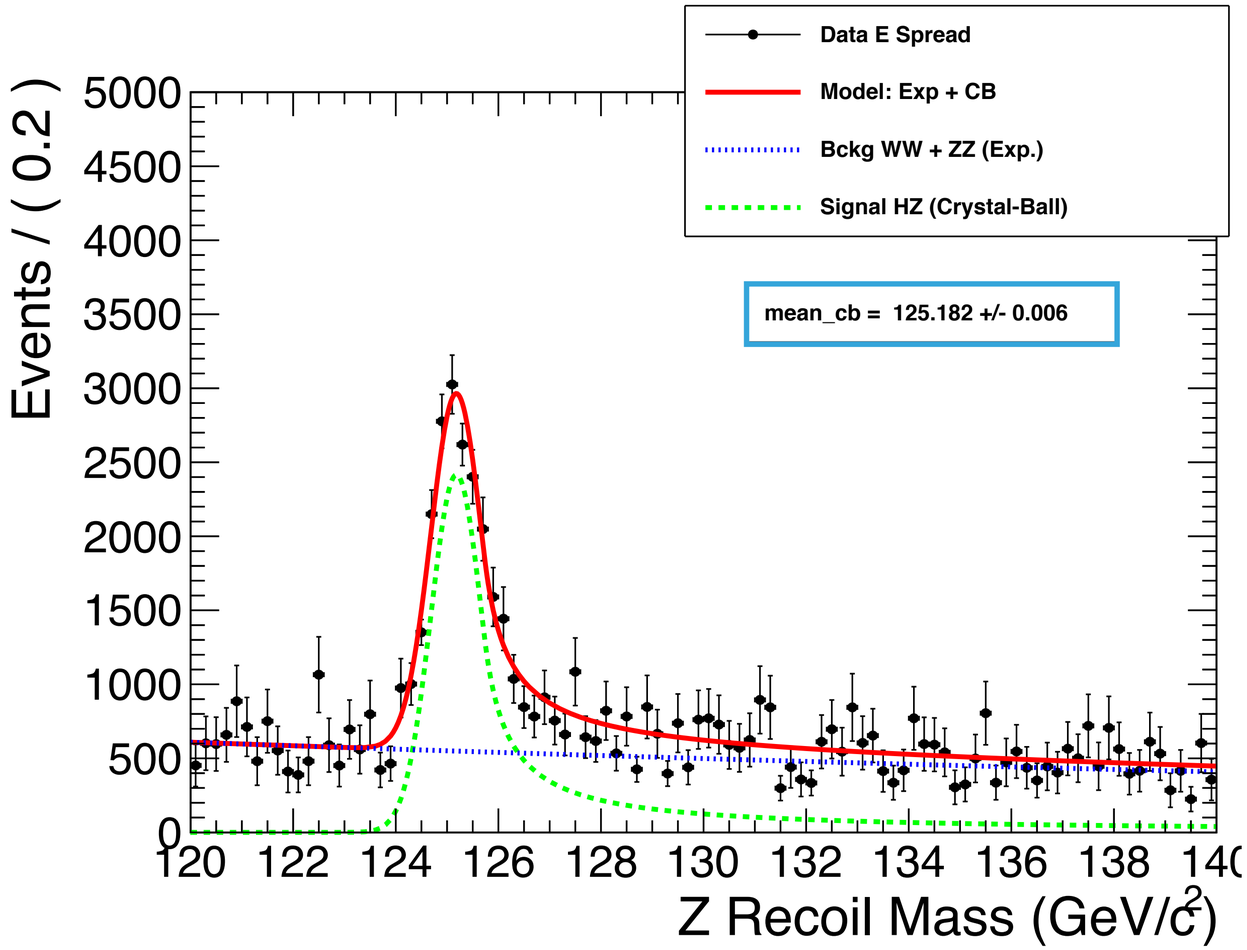


Crystal-Ball (signal) + Exponential (Background)

## WITHOUT BEAM ENERGY SPREAD




## BEAM ENERGY SPREAD OF 0.192 GEV



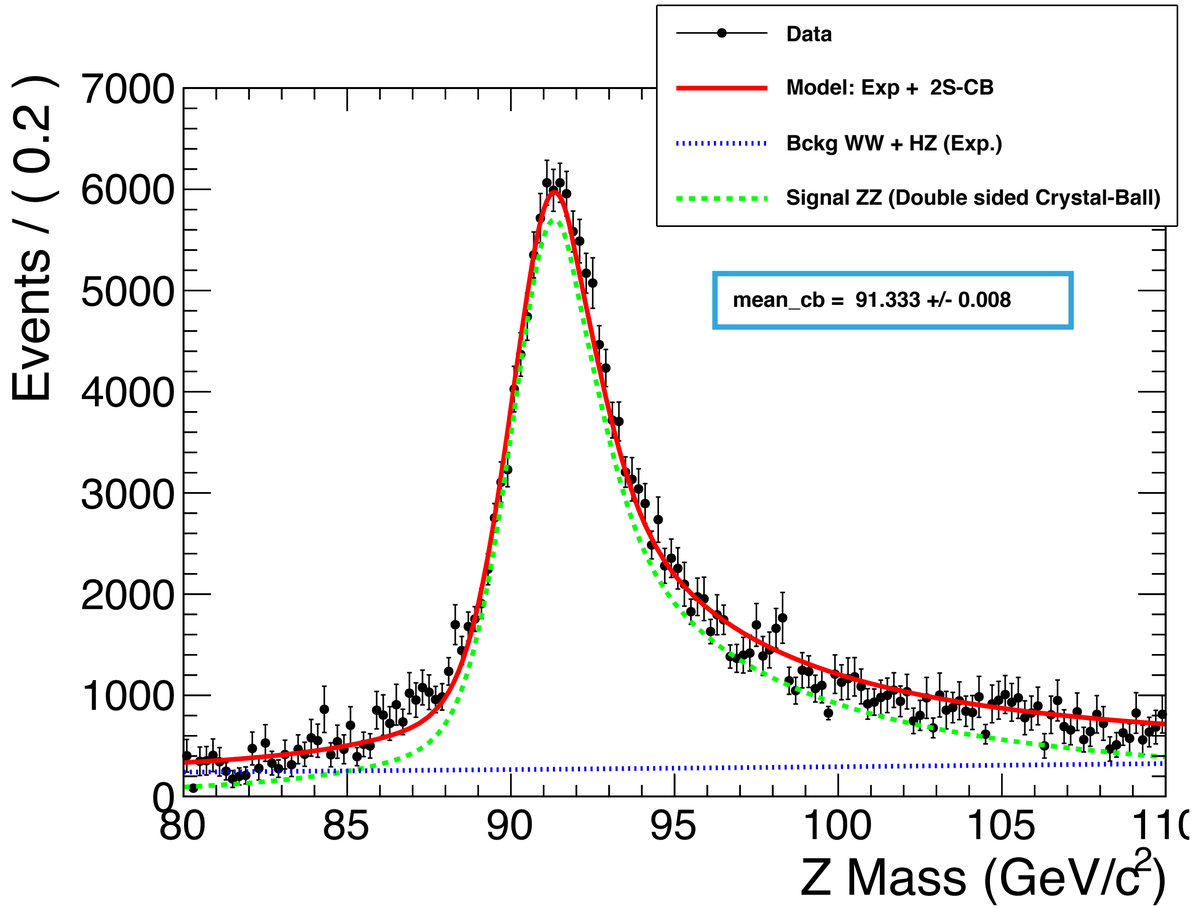
# Z INVARIANT MASS FIT

OUR ANALYSIS

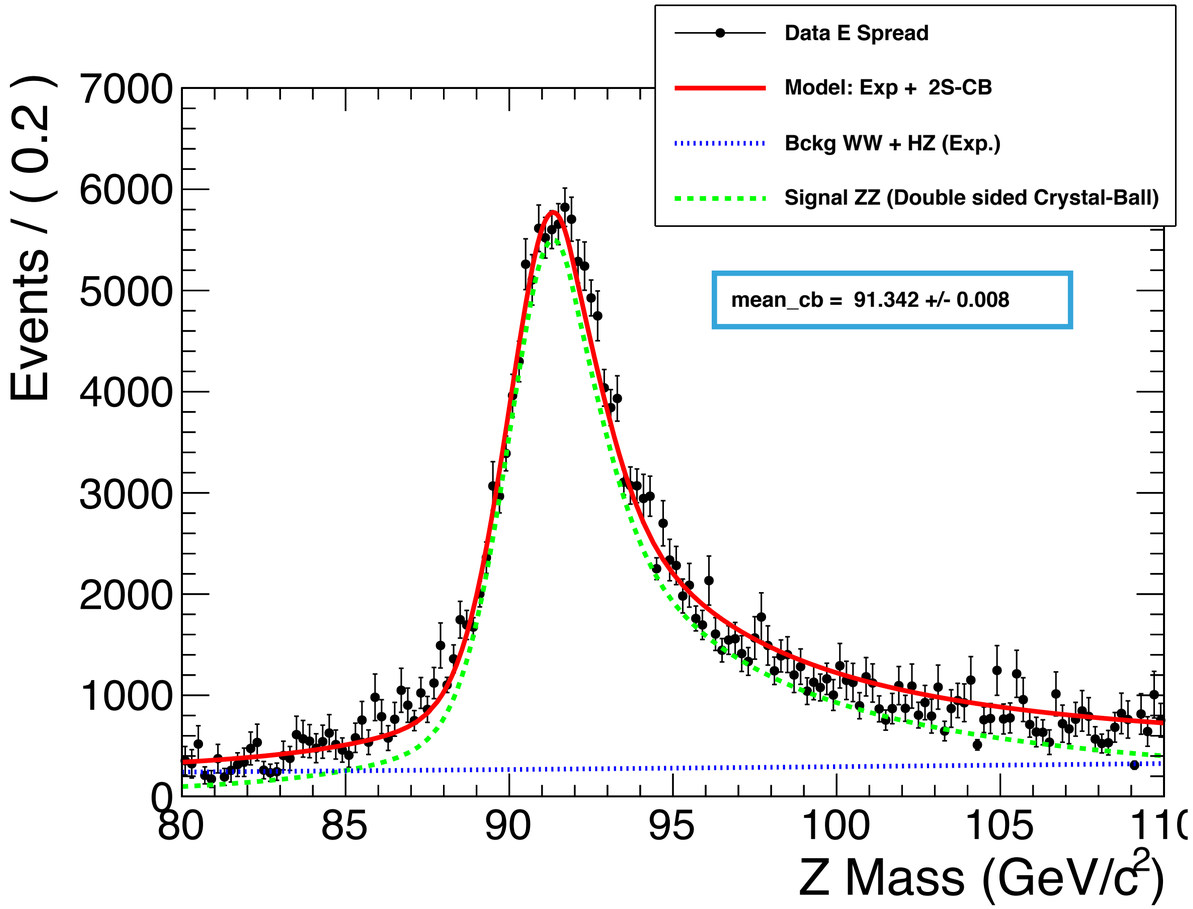


Double-sided Crystal-Ball (signal) + Exponential (Background)

## WITHOUT BEAM ENERGY SPREAD




## WITH BEAM ENERGY SPREAD OF 0.192 GEV



# FIT RESULTS

OUR ANALYSIS



| | $M_H$ (GeV) | σ (GeV) |
|---|---|---|
| Without BES | 125.09 | 0.003 |
| With BES | 125.182 | 0.006 |

With BES, the uncertainty of the fitted mass is increased by a factor 2

| | $M_Z$ (GeV) | σ (GeV) |
|---|---|---|
| Without BES | 91.333 | 0.008 |
| With BES | 91.342 | 0.008 |

BES has negligible effect on the Z width

Caveat: fits not always stable

→ required fine tuning of the parameters settings

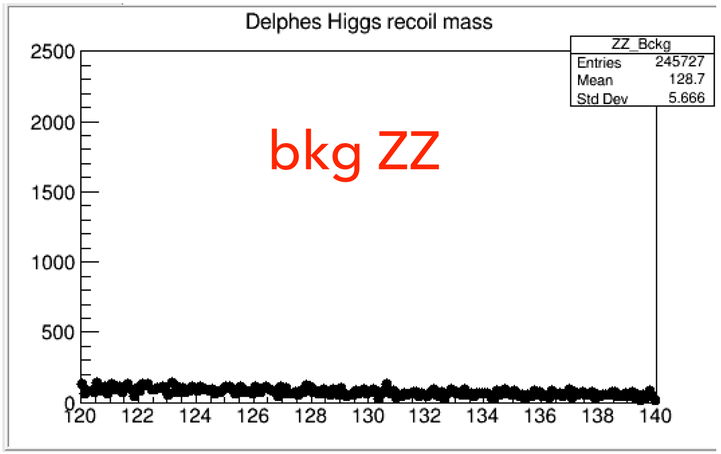
# SHAPE-BASED ANALYSIS WITH TEMPLATES

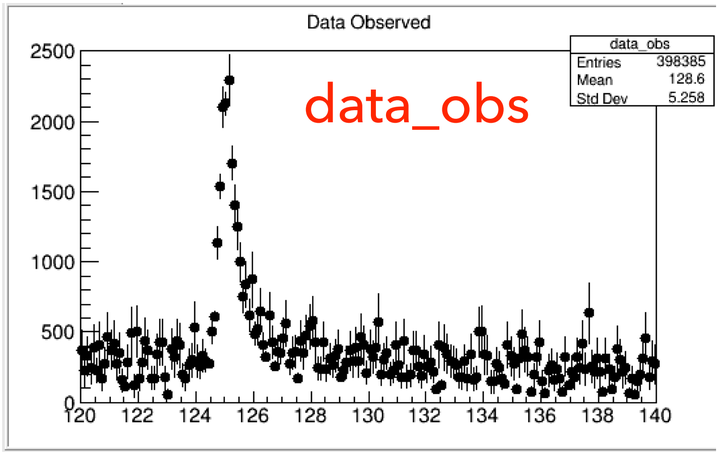
OUR ANALYSIS

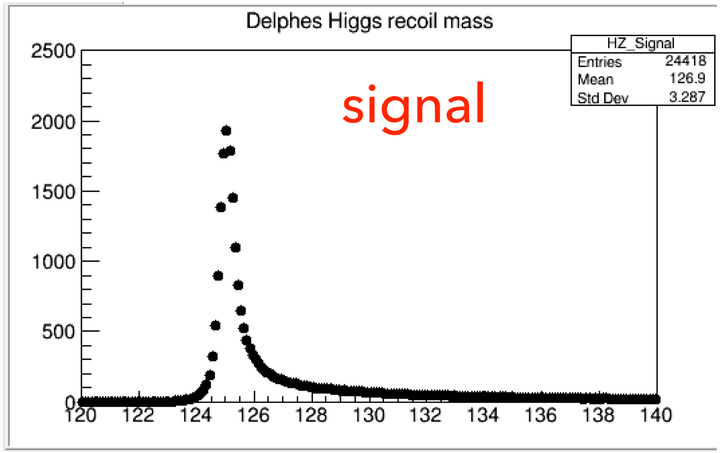


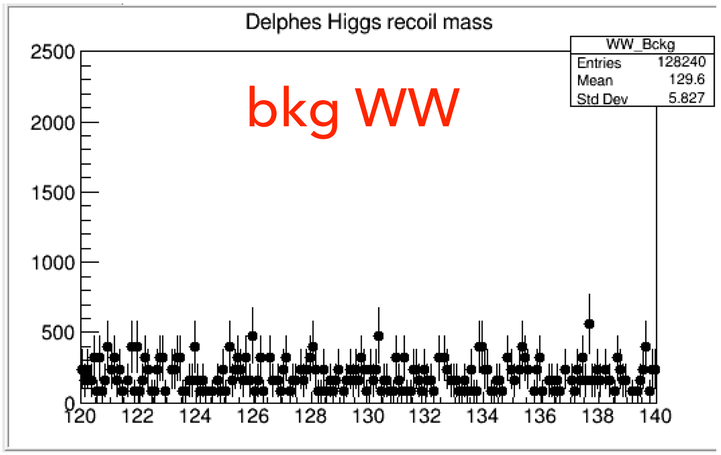
→ MOVE to a shape-based analysis with templates using *combine* software in the context of the *combine* software tool used for statistical analysis

- Instead of a one-bin counting experiment, fit a binned distribution
- Using TEMPLATES (TH1 histograms) sensitive to the presence of signal:
  - one for the data and one for each signal and background processes



# SHAPE-BASED ANALYSIS WITH TEMPLATES



## TO DO:

- Add the systematic uncertainties (USING TEMPLATES)
  - Using an unbinned shape analysis –> need only the parametric formula describing the background to produce the model shifted by $\pm 1\sigma$ (use the background fit by Ang and Greg)
- Obtaining the NLL curve as a function of the Higgs masses
- Make the analysis with larger statistics samples **centrally produced**

https://hep-fcc.github.io/FCCeePhysicsPerformance/General/#common-event-samples

# SHAPE-BASED ANALYSIS WITH TEMPLATES



## OTHER PROBLEM TO TACKLE:

- Determine the best selection efficiency
- How much would we gain in precision if we had a $B = 3$ T instead of $B = 2$ T?
- Adding missing background to the analysis

- What is the precision with which we can control BES @ 240 GeV?

# SHAPE-BASED ANALYSIS WITH TEMPLATES



## OTHER PROBLEM TO TACKLE:

- Determine the best selection efficiency
- How much would we gain in precision if we had a $B = 3$ T instead of $B = 2$ T?
- Adding missing background to the analysis
  - Easily done with templates –> add the shapes that describe the systematic in the combine Datacard
- What is the precision with which we can control BES @ 240 GeV?
  - Make an analysis assuming a 10% precision on the determination of the BES and see how the fit changes (Introduce this effect as a systematic)

# THANK YOU

# BACKUP SLIDES