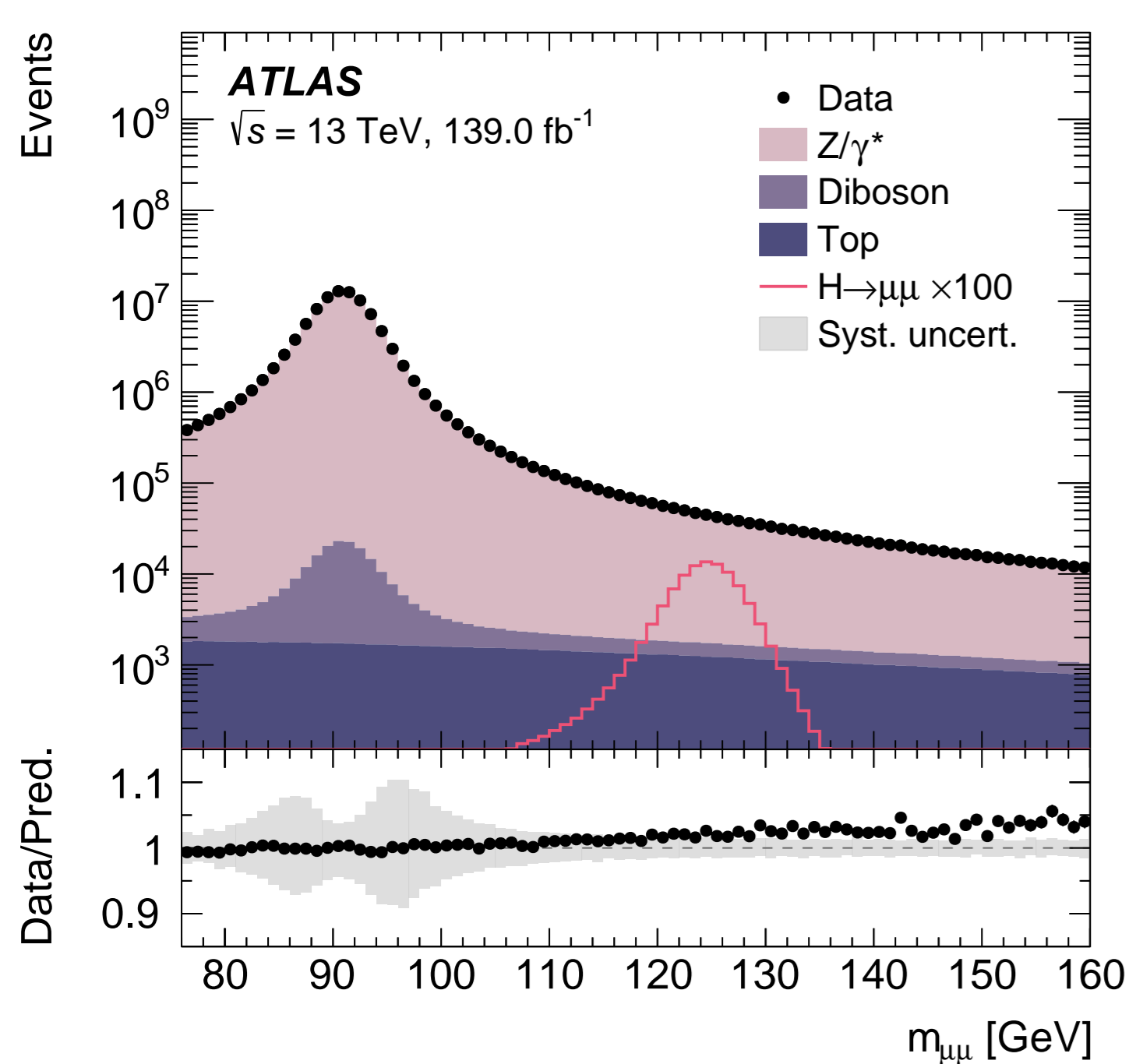
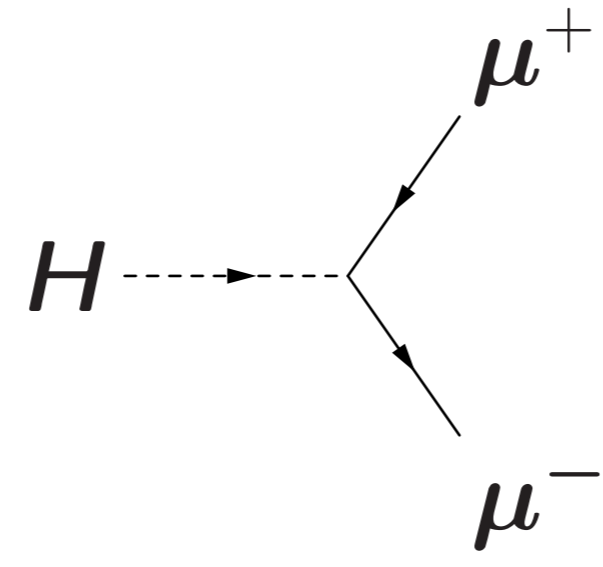


## Introduction

- Does Higgs boson decay to two muons?
- Predicted by SM via Yukawa coupling, but not yet observed...
- Search for  $H \rightarrow \mu\mu$  performed using ATLAS pp collision data ( $\sqrt{s} = 13 \text{ TeV}$ ,  $139 \text{ fb}^{-1}$ ).
- Very challenging channel due to small branching fraction ( $\sim 2 \times 10^{-4}$ ) and large background (mainly Drell-Yan).



- Small S/B ratio  $< 0.1\%$ .
- Hard to find signals (requires good separation between signal and background).
- Result can be easily biased by background mismodeling (background modeling is a crucial part in this analysis).

Figure 1:  $m_{\mu\mu}$  inclusive distribution.

## Event selections and categorization

- Select events with two isolated opposite-sign muons.
- Split in ggF, VBF VH and ttH channels.
- Dedicated BDTs trained for each channel using muon and jet kinematics and split events to 20 categories.
- 12 ggF + 4 VBF + 3 VH + 1 ttH
- Different Higgs production modes well separated

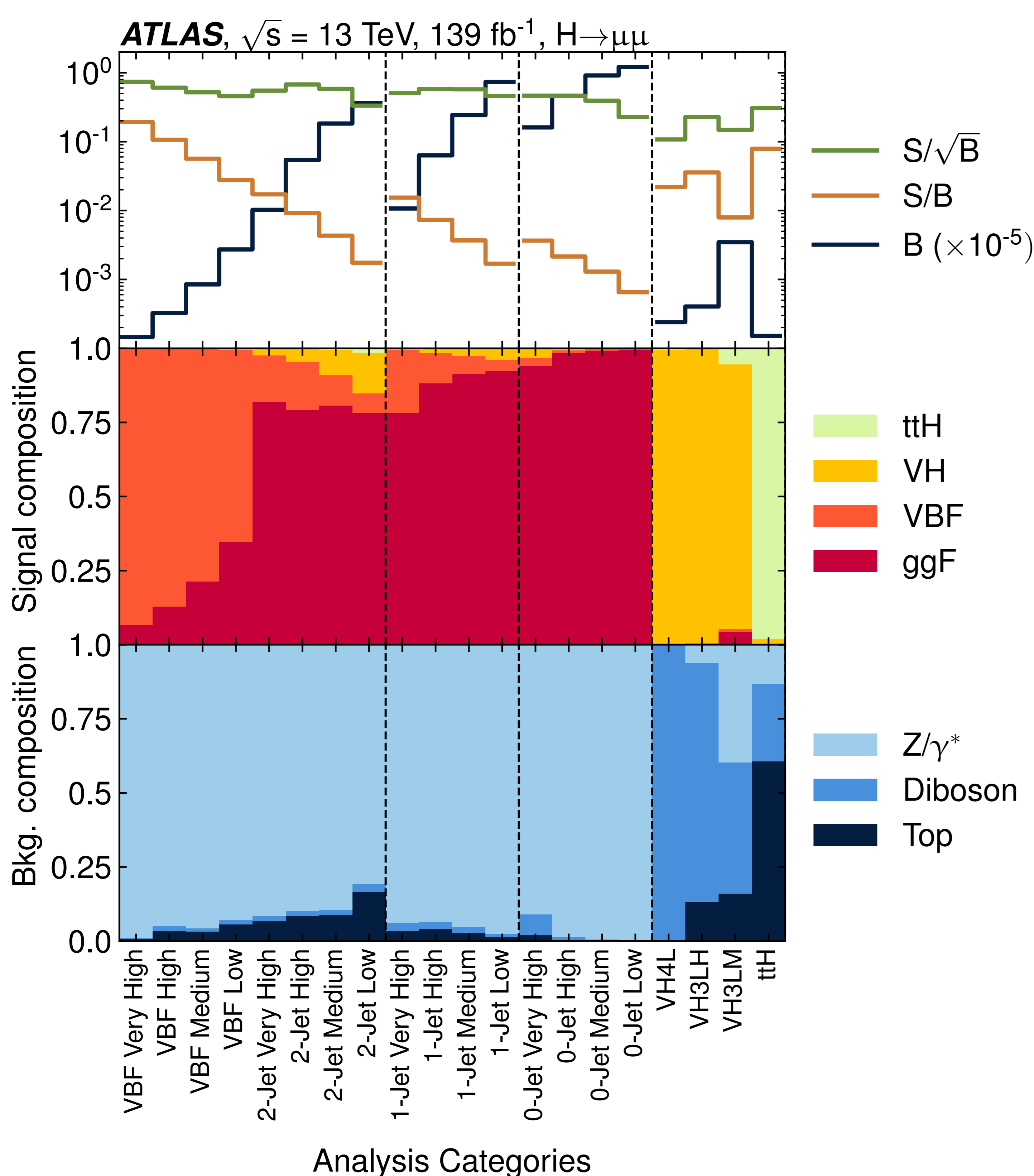


Figure 2: Summary of categorization.

## Signal and background modeling

- Signal/background  $m_{\mu\mu}$  modeled with analytic functions.
- Signal shape parametrized with double-sided Crystal Ball.
  - Gaussian + asymmetric power-law tails.
  - Gaussian width  $2.6 \sim 3.2 \text{ GeV}$ .
  - Main signal systematics:
    - $\mu$  momentum scale and resolution.
    - Missing higher order QCD correction.
    - Parton showering and underlying events.

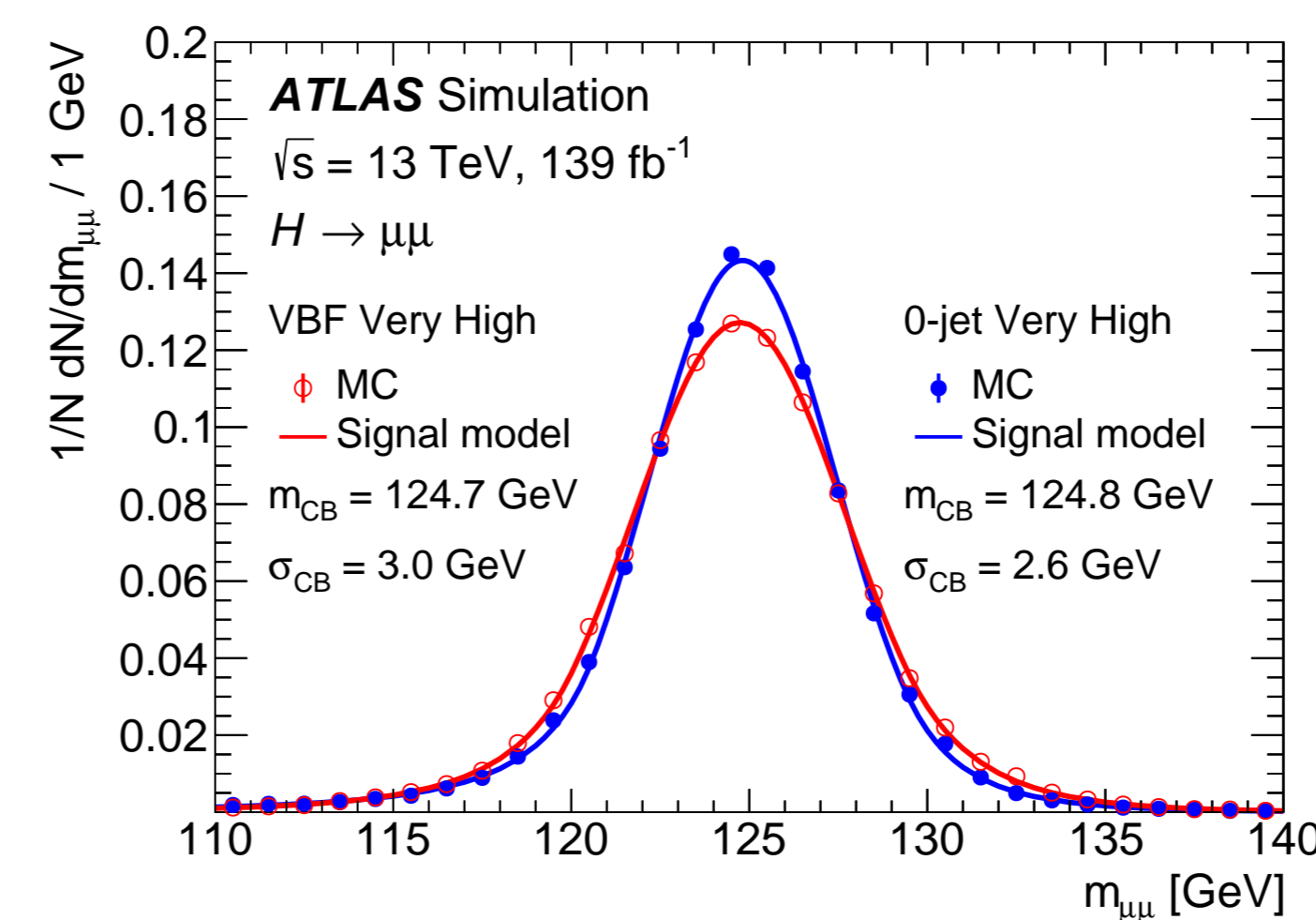


Figure 3: Example of signal parametrization.

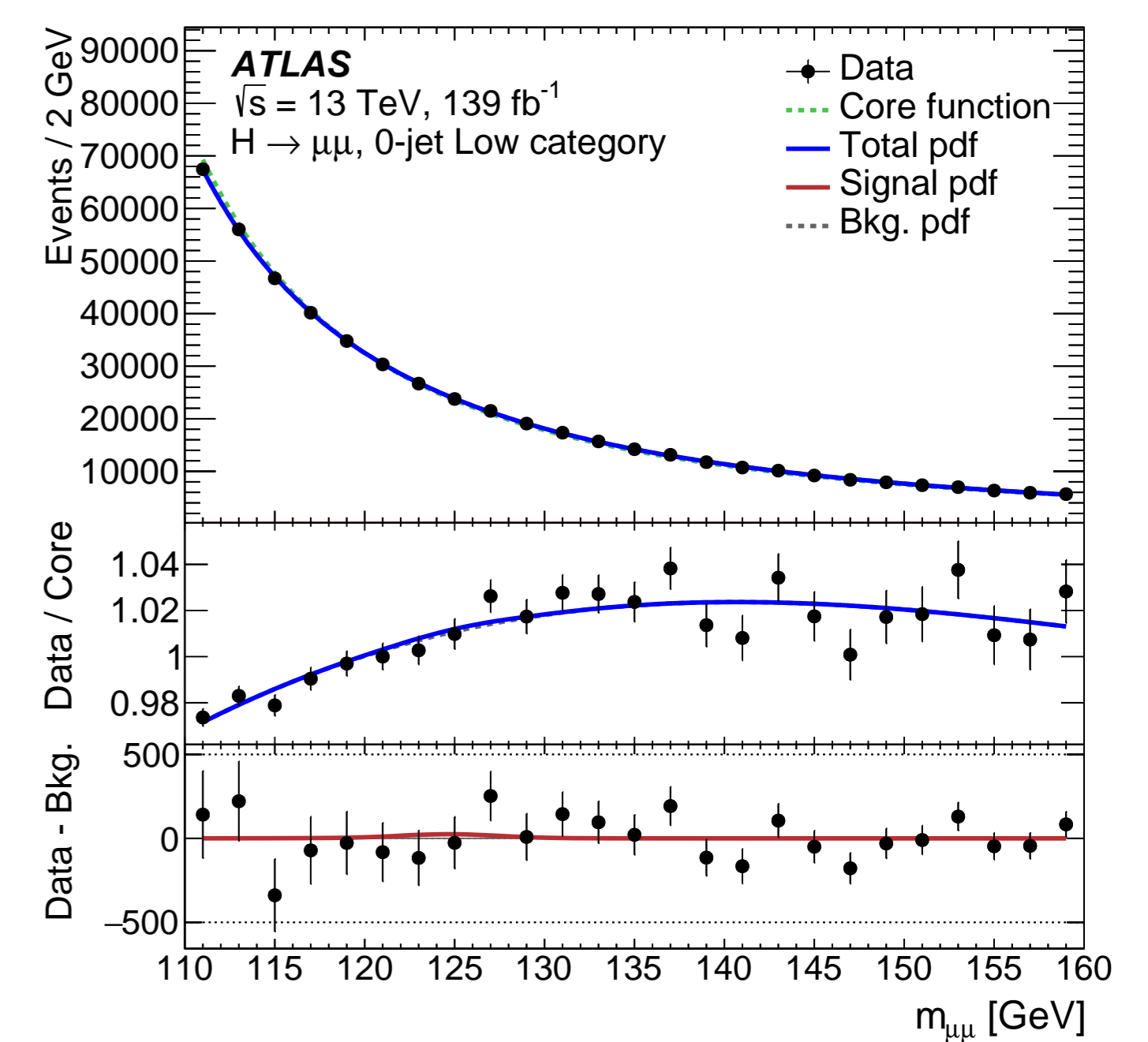
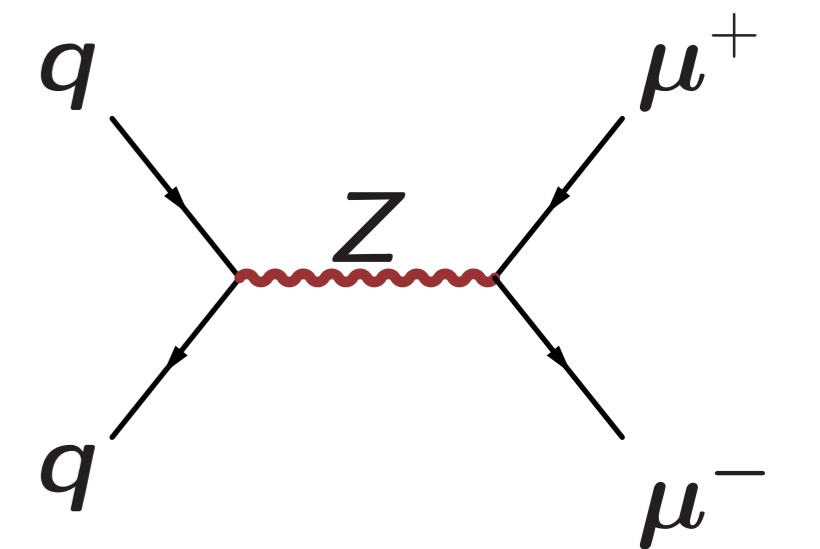


Figure 4: Example of background modeling.

- Backgrounds include Drell-Yan (DY), diboson, top.
  - Mainly focus on DY.
- Background shape modeled with (Core)  $\times$  (Empirical)
  - Core function.
    - LO DY line-shape convolved with Gaussian muon resolution.
    - All parameters are fixed.
  - Empirical function
    - Power-law or Epolynomial functions (different in each category).
    - Free parameters absorb mismodeling from core function.
    - Function choices selected based on spurious signal test.
- Spurious signal test performed to evaluate background modeling bias.
  - Perform S+B fit to background simulation.
  - Resulting S is the "spurious signal" (SS).
  - Require  $SS < 20\% \times$  expected data statistical error



## Results

- Simultaneous fit to  $m_{\mu\mu}$  spectrum in all categories.
- Signal strength:  $\mu = 1.2 \pm 0.6 (\pm 0.6(\text{stat.})_{0.1}^{0.2}(\text{sys.}))$ .
- Observed (expected) significance:  $2\sigma$  ( $1.7\sigma$ ).
- Upper limit:  $\text{Br}(H \rightarrow \mu\mu) < 4.7 \times 10^{-4} = 2.2 \times \text{SM}$ .

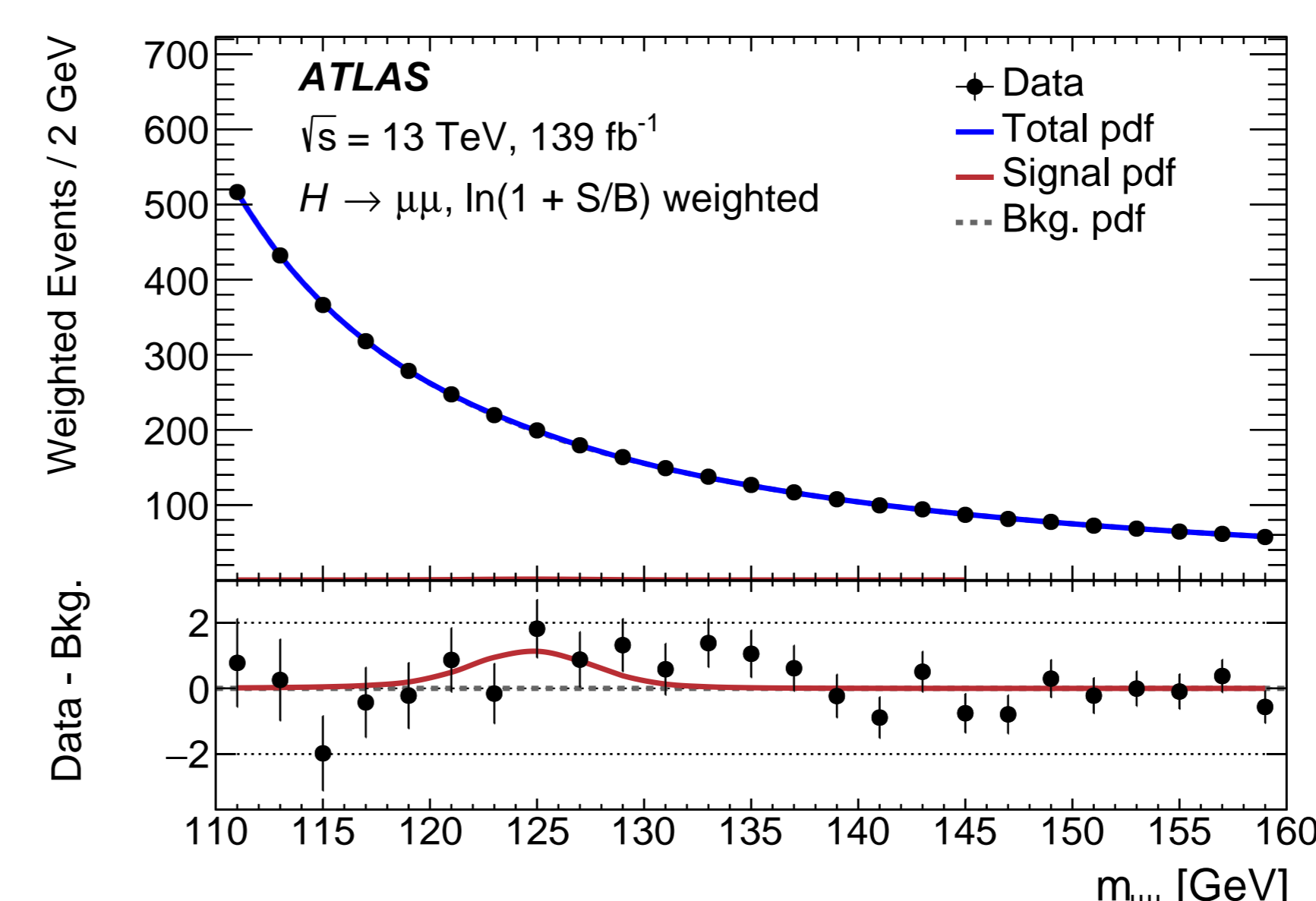


Figure 5: Post-fit  $m_{\mu\mu}$  distribution.

- Statistically limited.
- $\sim 2.5$  improvement wrt  $36 \text{ fb}^{-1}$  results.
  - $\sim 25\%$  due to better analysis techniques.



See results!