# Search for the Higgs boson decaying to a pair of muons in pp collisions at 13 TeV with the ATLAS detector


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On behalf of the ATLAS collaboration



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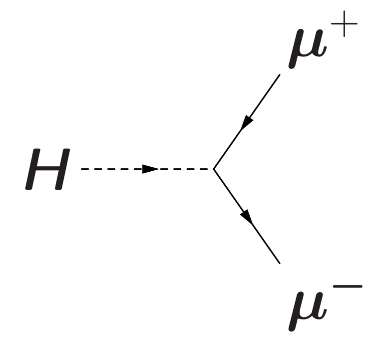
## Introduction

- Does Higgs boson decay to two muons?
- Predicted by SM via Yukawa coupling, but not yet observed...




- Search for $H \to \mu\mu$ performed using ATLAS pp collision data ($\sqrt{s}$ = 13 TeV, 139 fb$^{-1}$).
- Very challenging channel due to small branching fraction ($\sim 2 \times 10^{-4}$) and large background (mainly Drell-Yan).

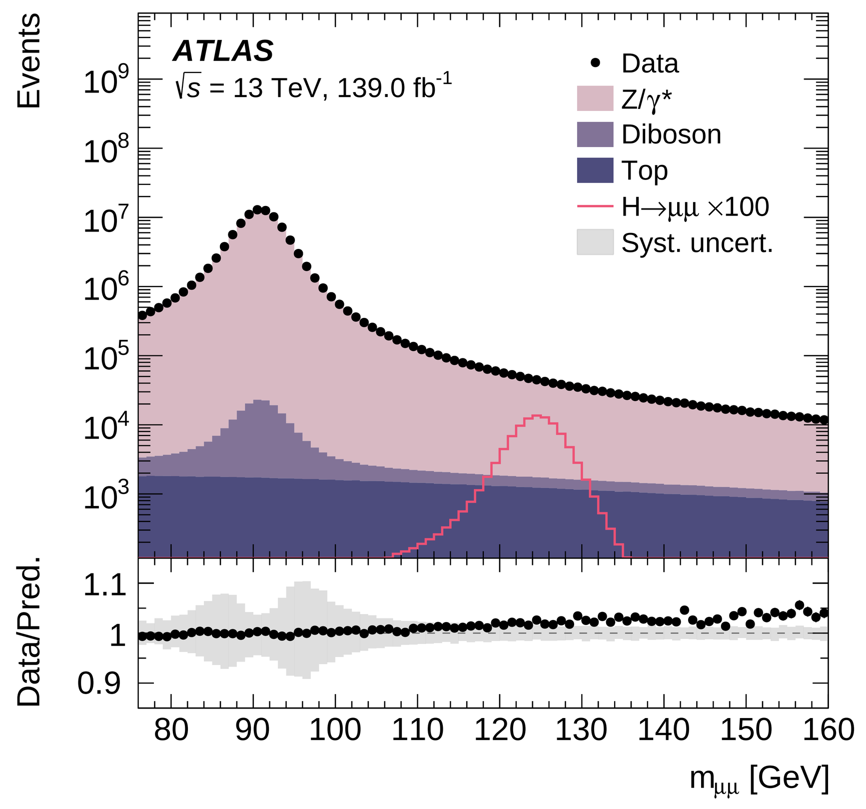



Figure 1: $m_{\mu\mu}$ inclusive distribution.

- 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).

## 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

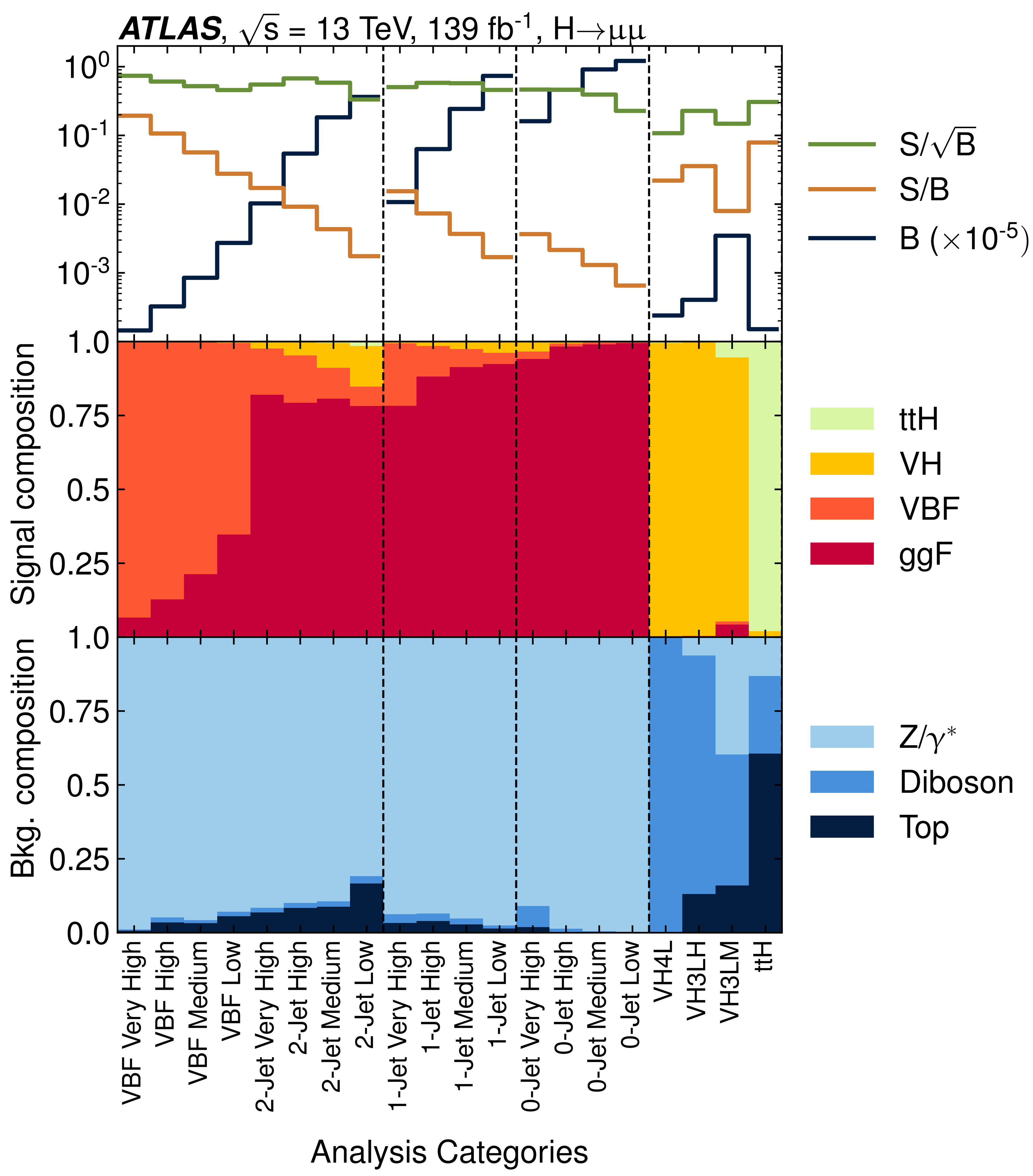



Figure 2: Summary of categorization.

## 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 ∼ 3.2 GeV.
  - Main signal systematics:
    - $\mu$ momentum scale and resolution.
    - Missing higher order QCD correction.
    - Parton showering and underlying events.

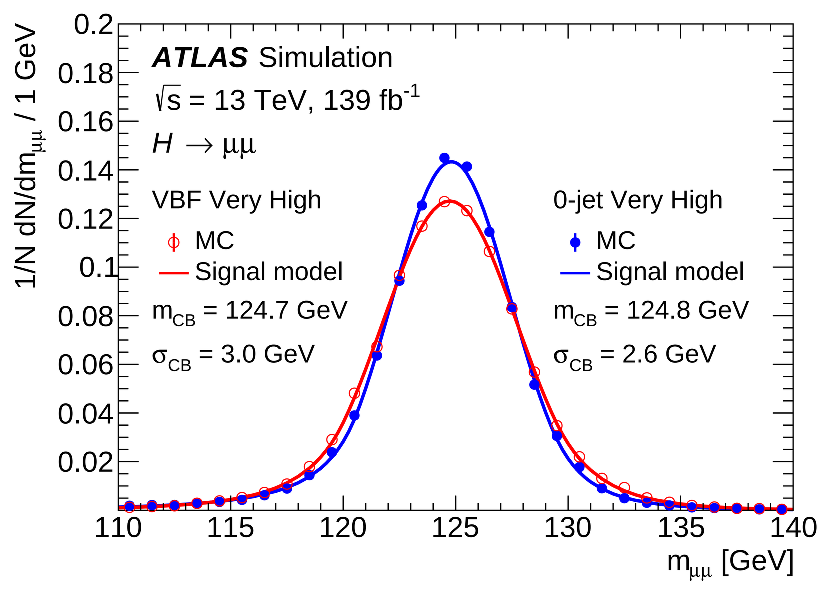



Figure 3: Example of signal parametrization.

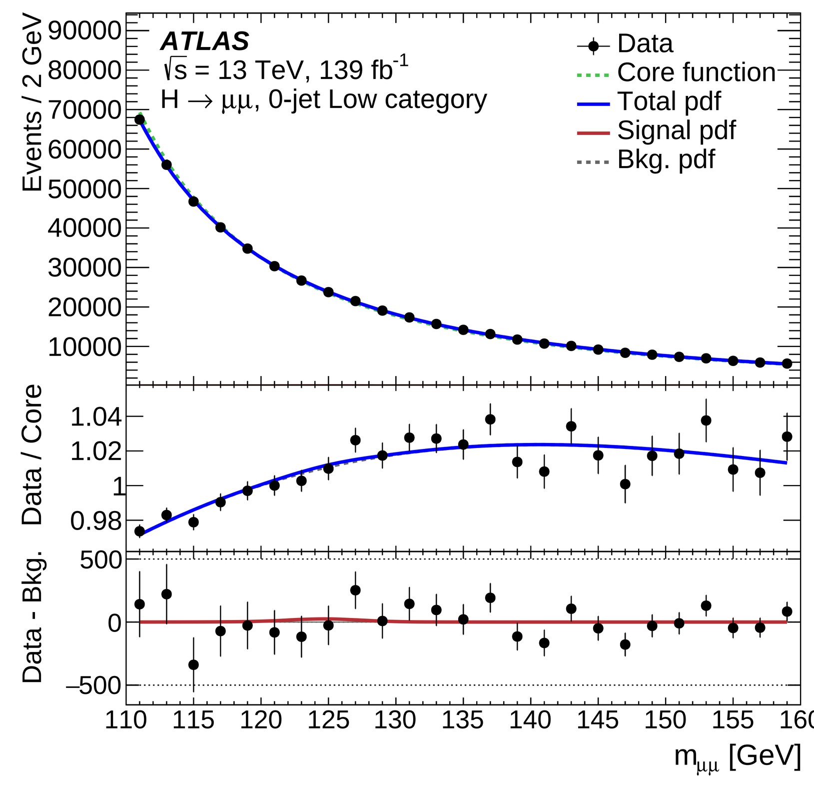
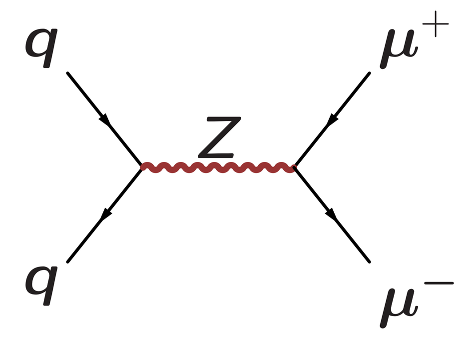



Figure 4: Example of background modeling.

- Backgrounds include Drell-Yan (DY), diboson, top.
  - Mainly focus on DY.




- Background shape modeled with (Core) × (Empirical)
  - Core function.
    - LO DY line-shape convolved with Gaussian muon resolution.
    - All parameters are fixed.
  - Empirical function
    - Power-law or Epoly 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% × expected data statistical error

## Results

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

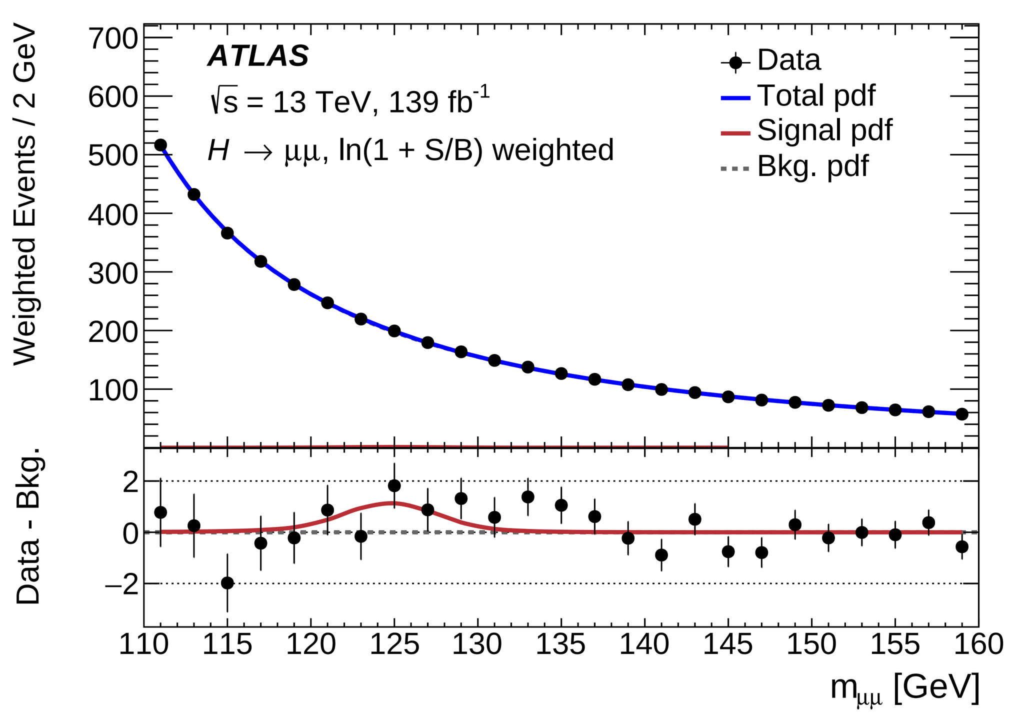



Figure 5: Post-fit $m_{\mu\mu}$ distribution.

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

See results!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