MSSM Higgs search via bb decay at CMS experiment with Run 2016 Ultra Legacy proton proton collision data

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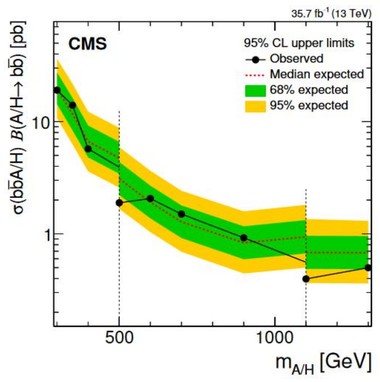
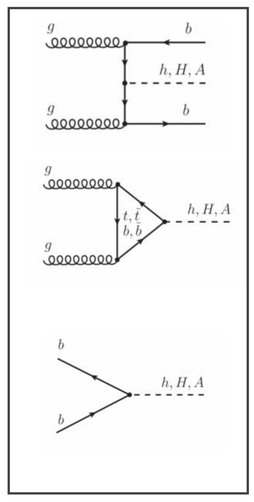
Motivation



Results based on Run 2 (13 TeV, 35.7 fb⁻¹) CMS analysis.

- Many new searches, such as the Two-Higgs-Doublet Model (2HDM) and the Minimal Supersymmetric Standard Model (MSSM), predict additional neutral Higgs bosons (H and A).
- In the MSSM, Yukawa couplings to b-quarks are enhanced ~tan²β, boosting the production cross section in b-associated channels.
- The dominant decay mode of these heavy states is H/A → bb̄, which provides a promising final state to search for new resonances.
- At high tan β, the cross section enhancement and improved background suppression by requiring multiple b-tagged jets make this channel especially sensitive.
- The main challenge is the overwhelming QCD multijet background, which requires dedicated trigger strategies and data-driven background modeling.

Analysis Strategy



- The search targets heavy neutral Higgs bosons (H/A) predicted in the MSSM, produced predominantly via b-associated production, a process strongly enhanced at large tan β and decaying into bottom-quark pairs (H/A →b $\bar{b}$). The dominant experimental challenge is the overwhelming QCD multijet background, which requires dedicated trigger design, event selection, and data-driven background modeling.
- To suppress background and maximize sensitivity, dedicated triggers requiring two online b-tagged jets are employed, significantly reducing the QCD event rate. Offline selection then requires ≥ 3 jets passing a medium b-tag working point to improve signal purity.
- The two leading b-tagged jets are used to reconstruct the dijet invariant mass (M_{12}), which is expected to show a resonance peak in the presence of a heavy Higgs signal.
- Signal shapes are modeled from Monte Carlo simulations using a Novosibirsk function, while the background is estimated primarily through data-driven methods, using control triggers and event-by-event reweighting to accurately describe the QCD contribution.
- A binned likelihood fit to the M_{12} spectrum is then performed to search for a resonance above the smooth background and set limits on the production cross section.

Data, MC Samples

Data:

L= 35.7fb^{-1} , $\sqrt{s}$ =13 TeV

Datasets used: BTagCSV (signal region) and JetHT (control region)

Monte Carlo Samples (UL2016 campaign):

Signals	Generated with POWHEG (NLO) + PYTHIA 8 (CP5) SUSY gluino-mediated heavy Higgs production: m(H)=120-2000 GeV
Backgrounds	QCD: PYTHIA 8 (LO) Top (TT, ST): POWHEG (NLO) + PYTHIA 8 V+jets (W/Z, DY): MADGRAPH5_aMC@NLO (LO) + PYTHIA 8

Trigger Strategy

Trigger Type	Trigger Path	Purpose
Physics (Unprescaled)	HLT_DoubleJetsC100_DoubleBTagCSV_p026_DoublePFJetsC160 HLT_DoubleJetsC100_DoubleBTagCSV_p014_DoublePFJetsC100MaxDeta1p6	Signal triggers
Control (Prescaled)	HLT_PFJet140_v	Control region trigger
Control (Background)	HLT_PFJet140_v(0-900GeV) HLT_PFJet200_v(900-1400GeV) HLT_PFJet260_v(1400-2000GeV)	Background modeling

Event Selection

Signal Region

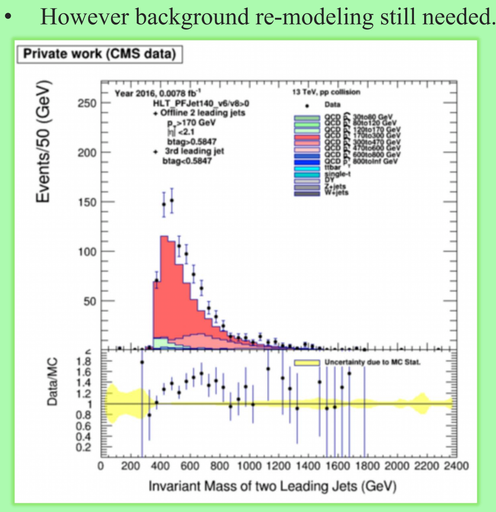
- Physics trigger bit
- 3 leading pT "Jets" loose ID
- 1st and 2nd jets
  - pT ≥ 170 GeV
  - |η| ≤ 2.1
  - Medium b tag WP
- 3rd jet
  - pT > 170 GeV
  - |η| ≤ 2.1
  - Medium b-tag WP

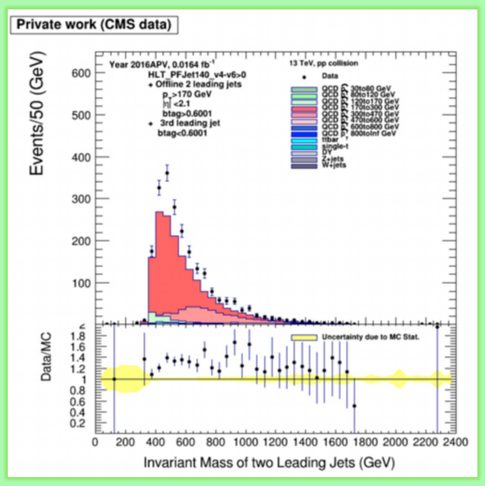
Control Region

- Physics/Prescale trigger bit
- 3 leading pT "Jets" loose ID
- 1st and 2nd jets
  - pT > 170 GeV
  - |η| < 2.1
  - Medium b tag WP
- 3rd jet
  - pT > 170 GeV
  - |η| < 2.1
  - non b-tagged

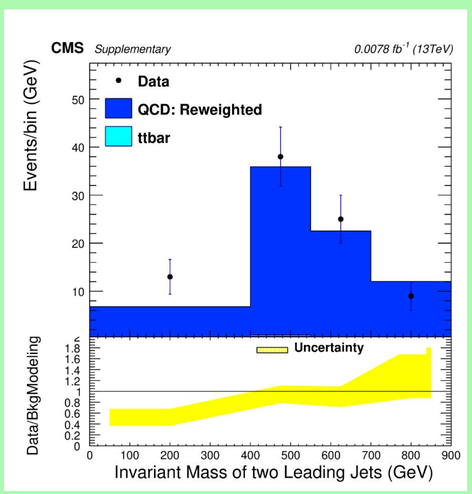
Data/MC Comparison

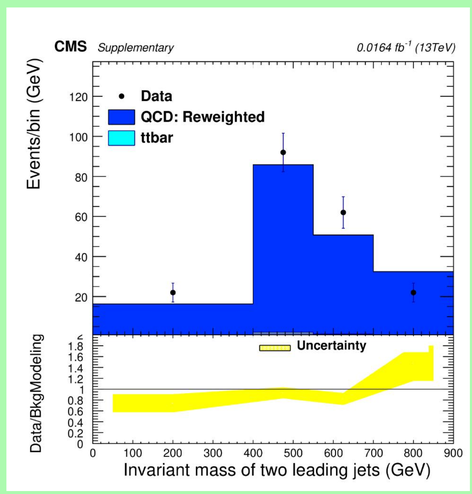
- Data and simulated MC events are compared in 2 jets region and control regions defined by prescaled triggers.
- This comparison validates the modeling of jet kinematics, b-tagging performance, and trigger efficiencies before background estimation and signal extraction.
- After applying ID, b-tagging, and trigger SFs, improved agreement between data and MC is observed in key observables such as jet pT, pseudorapidity (η), and dijet invariant mass M12.
- However background re-modeling still needed.





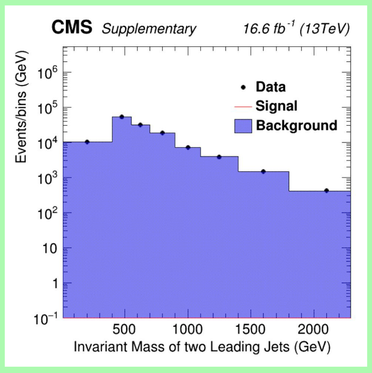
Background Modeling

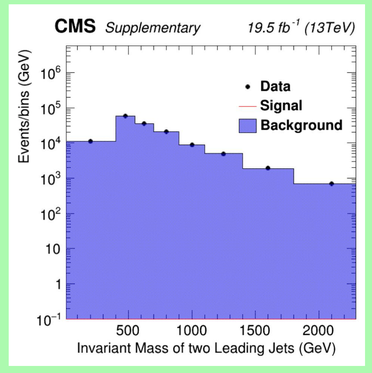




The QCD multijet background estimation is validated in a dedicated region containing events selected with a trigger requiring at least one jet with pT > 140 GeV and including three offline b-tagged jets. The QCD multijet prediction is compared to the observed data collected in the first (upper) or second (lower) half of 2016.

Post-fit Distributions

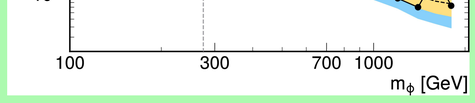


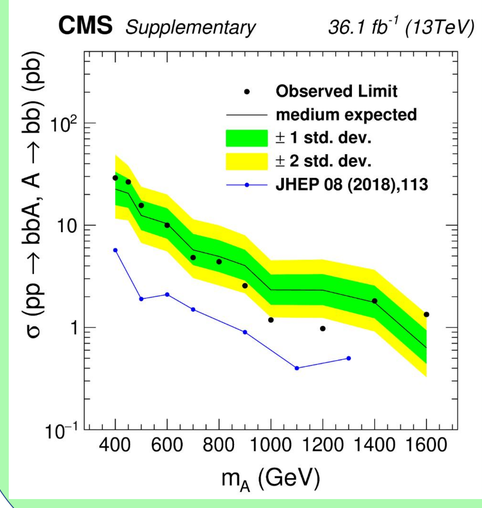


Observed and predicted distributions of the invariant mass of the two leading jets in the parallel analysis of data collected in the first (upper) or second (lower) half of 2016. The predicted distribution is the result of a maximum likelihood fit performed for a signal with m(A)=1 TeV.

Upper Limits

For the parallel analysis, the (bottom)plot presents the expected and observed upper limits for the Higgs b-associated production cross-section times branching fraction of the decay into a b-quark pair at 95% CL, obtained with 2016 data in the context of the parallel analysis. The corresponding observed limit obtained by the nominal analysis using the same data set is shown in blue.





For the published CMS result, the (top)plot shows the expected and observed upper limits for the b-quark-associated Higgs boson production cross section times branching fraction of the decay into a b quark pair at 95% CL as functions of m(ϕ), corresponding to the combination with the 2016 data. The vertical dashed line separates the mass range where only the 2017 SL category contributes on its left, from the region where also the 2017 FH and 2018 FH categories contribute on its right. The expected limits from the 2017 SL, 2017 FH, and 2018 FH data sets as well as from previously published result based on the 2016 data set are also shown as colored lines.

Summary

- A search for heavy neutral MSSM Higgs bosons decaying to bb̄ was performed using Run 2 CMS data (35.7 fb⁻¹, 13 TeV).
- 95% CL upper limits on σ(pp→bH/A)×BR(H/A→bb̄) were set across a wide mass range.
- The results place strong constraints on MSSM scenarios, particularly in the high tanβ region.

The 11th China LHC Physics Conferenc(CLHCP2025):
29 Oct – 2 Nov, 2025, Xinxiang, Henan, China

[1] CMS Collaboration, Search for neutral MSSM Higgs bosons decaying to bb̄, CMS-SUS-24-001 (2025).
[2] CMS Collaboration, JHEP 11 (2018) 151, [arXiv:1805.12191].

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