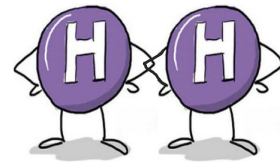


Search for resonant production of Higgs boson pairs decaying to four leptons and two b jets

Analysis status updates



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Analysis Strategy

Objects Selection >>> Events Selection >>> MVA/cut-based analysis >>> Statistical analysis

Objects Selection

$H \rightarrow 4l$

Loose Leptons

Loose electrons:

$P_t > 7 \text{ GeV}$
 $|\eta| < 2.5$
 $|d_{xy}| < 0.5 \text{ cm}$
 $|d_z| < 1 \text{ cm}$

Loose Muons:

Global Mu / Tracker Mu + 1 MS
 $P_t > 5 \text{ GeV}$
 $|\eta| < 2.4$
 $|d_{xy}| < 0.5 \text{ cm}$
 $|d_z| < 1 \text{ cm}$

Tight Leptons

Tight electrons:

Loose electron + MVA selection (BDT)

Tight Muons:

Loose muon + PF Mu ID

Lepton pairs (Z candidates)

Tight electrons / Tight Muons + relative PF isolation < 0.35 ($dR = 0.3$)
Same-flavor opposite-sign pairs
 $|SIP 3D| < 4$
Recovering the FSR photons if exist

Four leptons (ZZ candidates)

dR between any pair > 0.02
No overlapped leptons between the two Zs
Leading lepton $P_t > 20 \text{ GeV}$ and sub-leading lepton with $P_t > 10 \text{ GeV}$
 $12 < M_{ll} < 120 \text{ GeV}$
 M_{ll} (regardless the flavor) $> 4 \text{ GeV}$ for QCD suppression
On-shell Z: from the ll with the closest invariant mass to 91.18 GeV
Off-shell Z: from the remaining highest P_t leptons
 $M_{4l} > 70 \text{ GeV}$
ZZ pair with the highest scalar sum of 4l momenta is selected

$H \rightarrow bb$

Jets tight selection

PF jets
 $P_t > 20 \text{ GeV}$
 $|\eta| < 2.5$

well isolated from selected leptons* and FSR photons with $\Delta R(\text{jet}, l/\gamma) > 0.3$

Tight Jet PUID is applied for Jet $p_T < 50 \text{ GeV}$ and PUID SF is applied.

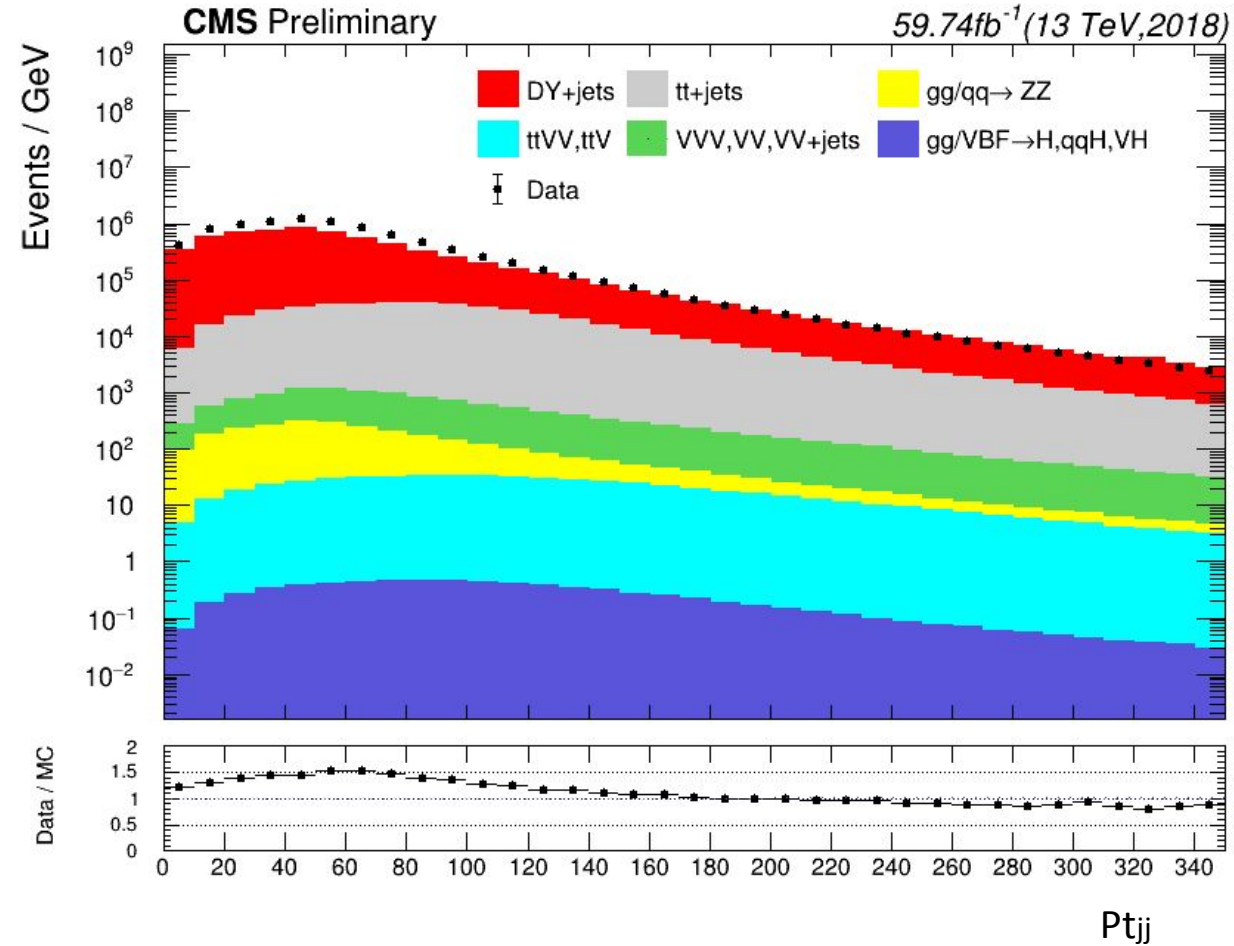
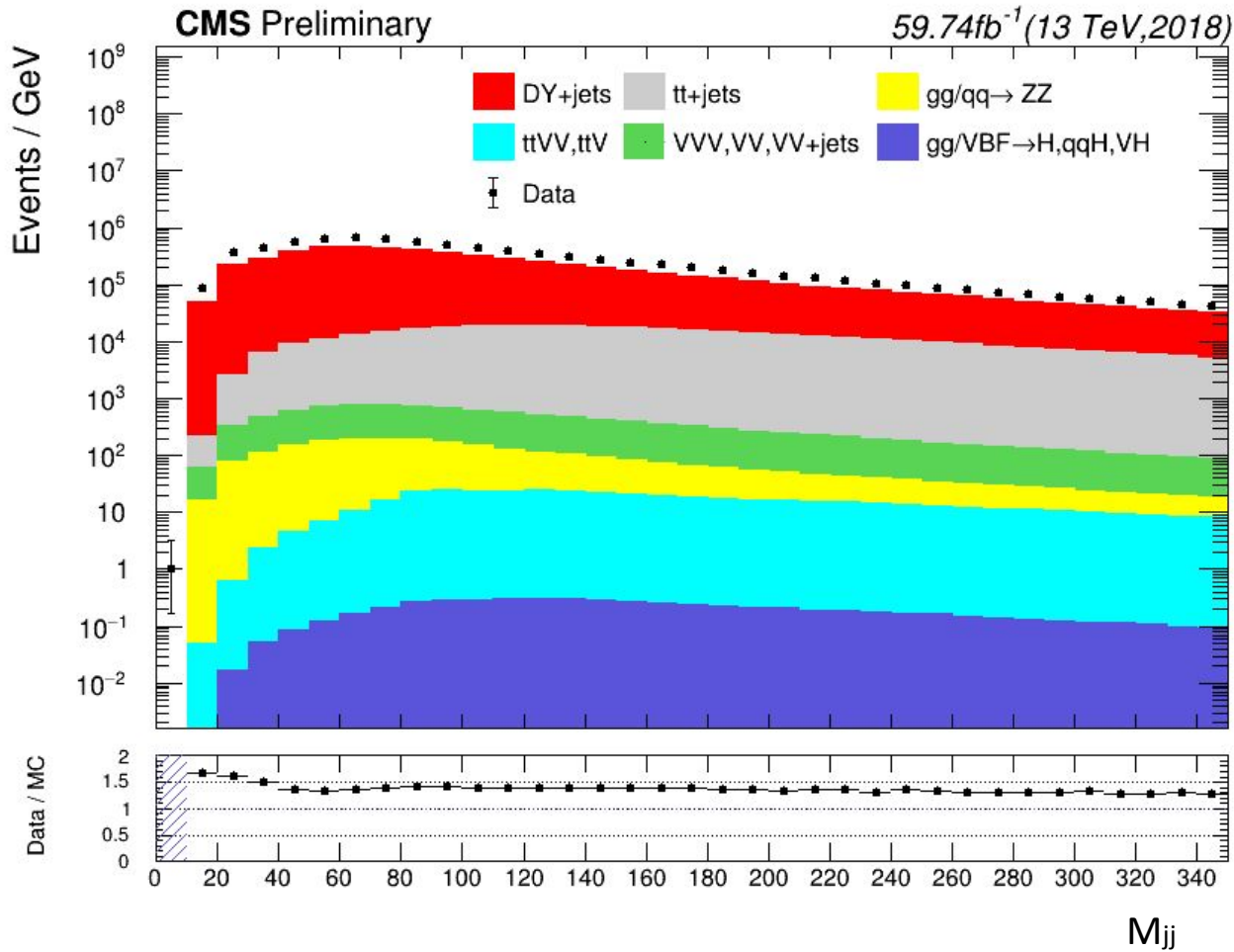
B-tagging

Highest DeepCSV score 2 jets (*anti- k_T algorithm*)
B-tagging SF is applied

Control regions tested

Z + jets

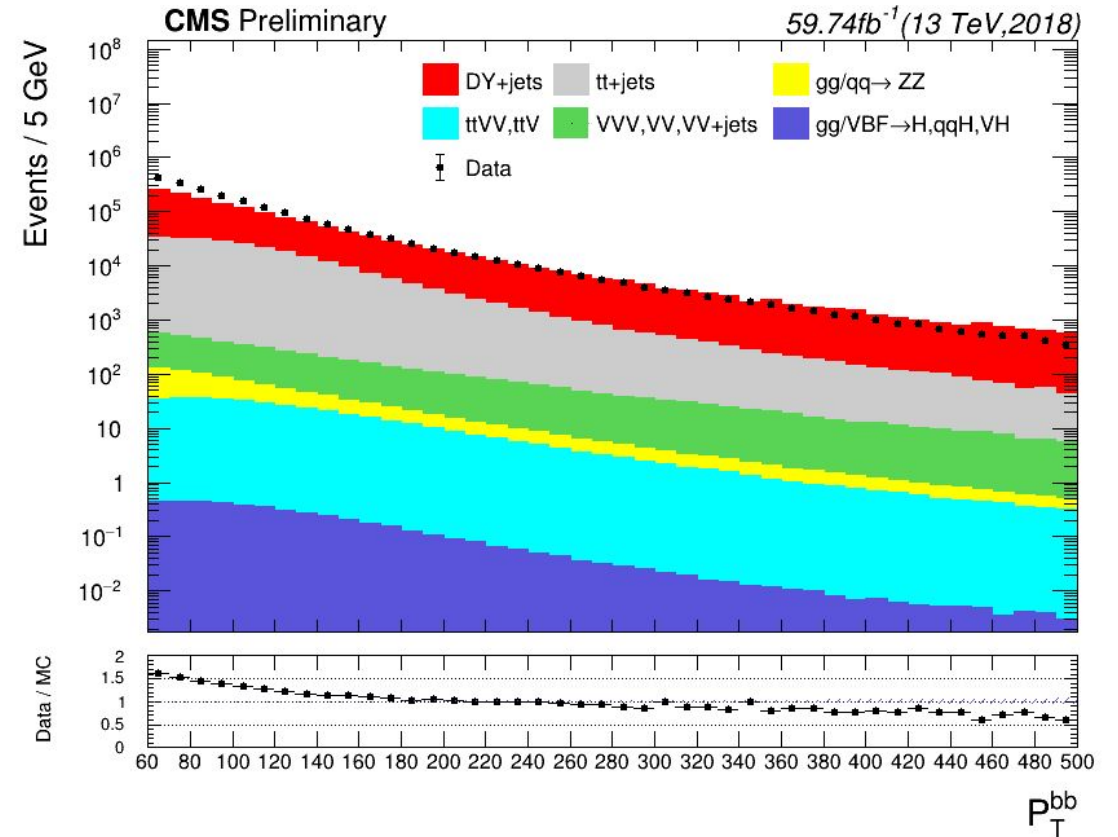
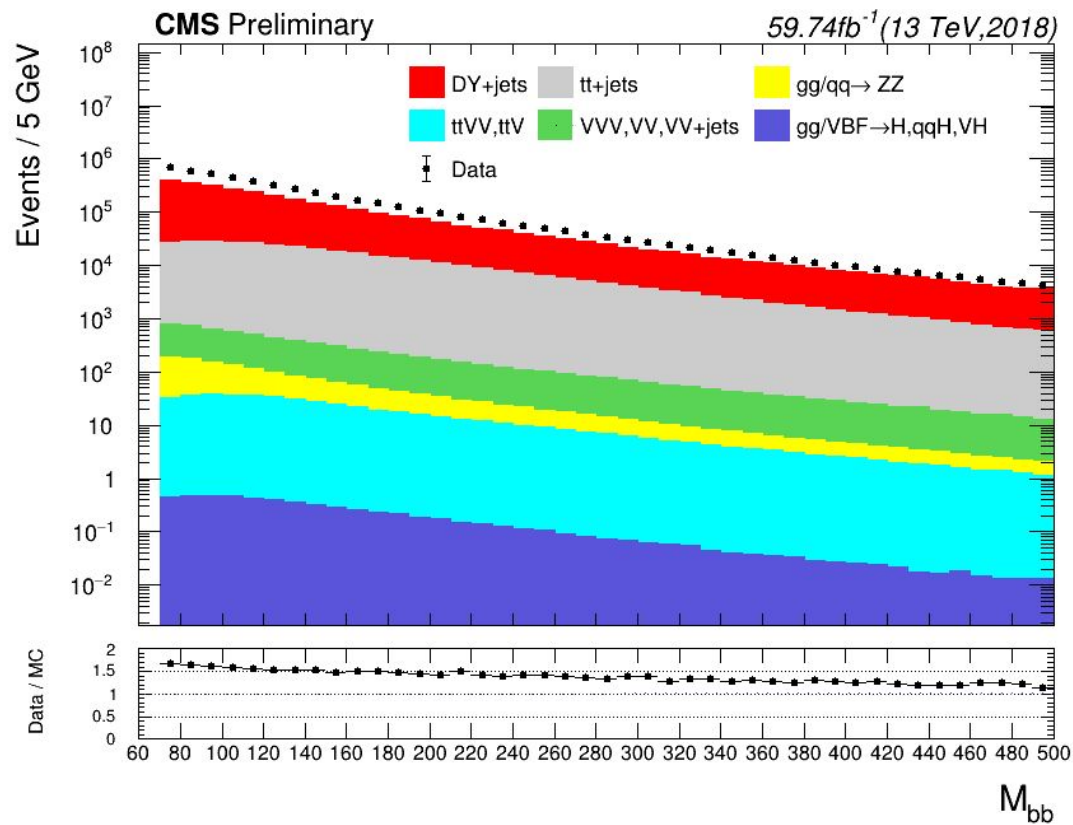
- two leptons
- at least two PF jets with $P_{\text{t}} > 20$ GeV, $|\text{Eta}| < 2.5$ and isolated by 0.3



Control regions tested

Z + b jets

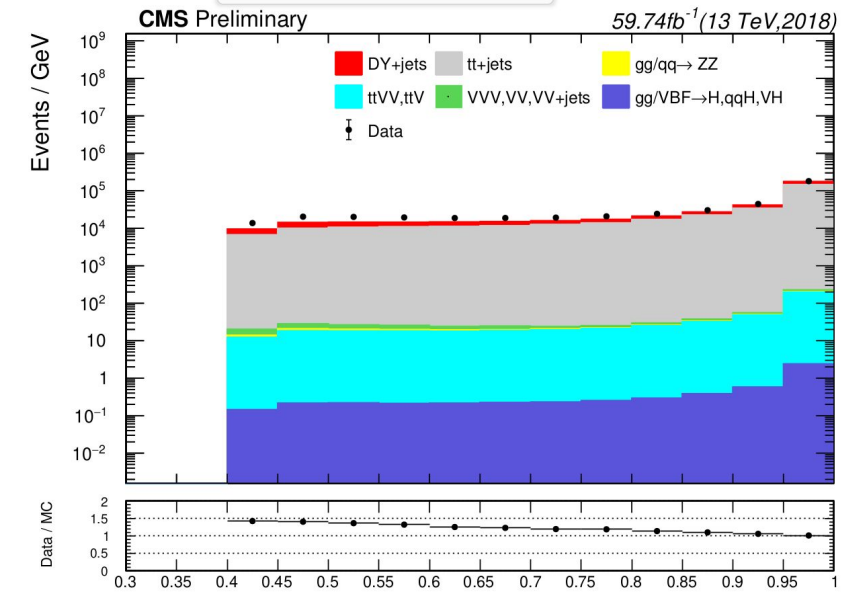
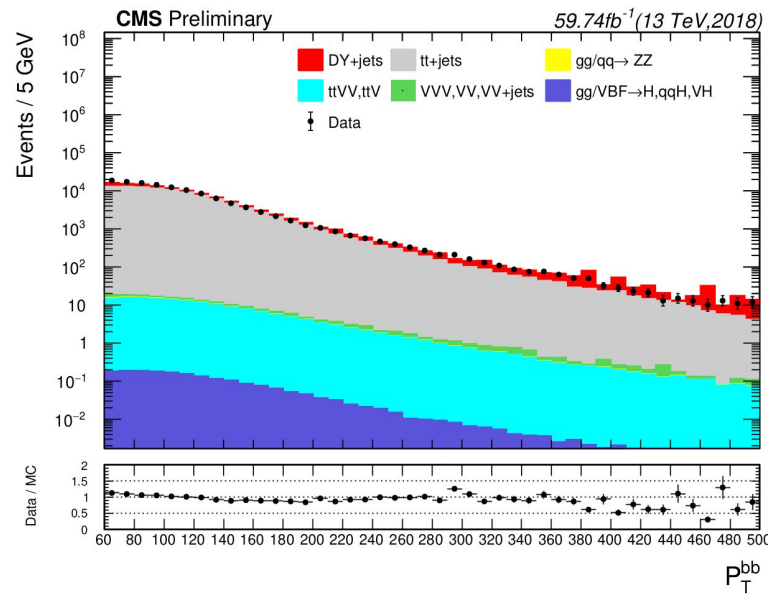
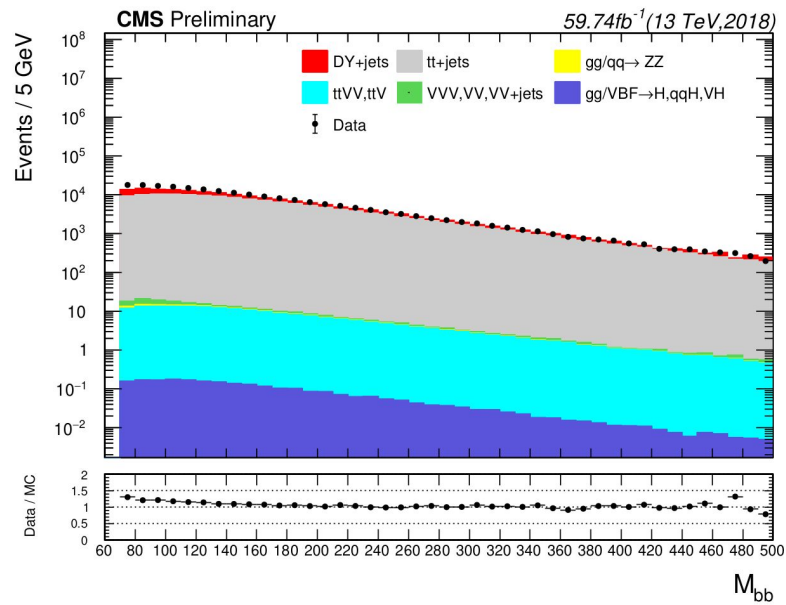
- two leptons
- at least two b-tagged jets with $P_{\text{T}} > 20$ GeV, $|\text{Eta}| < 2.5$ and isolated by 0.3 (highest score jets are selected)



Control regions tested

Z + b jets

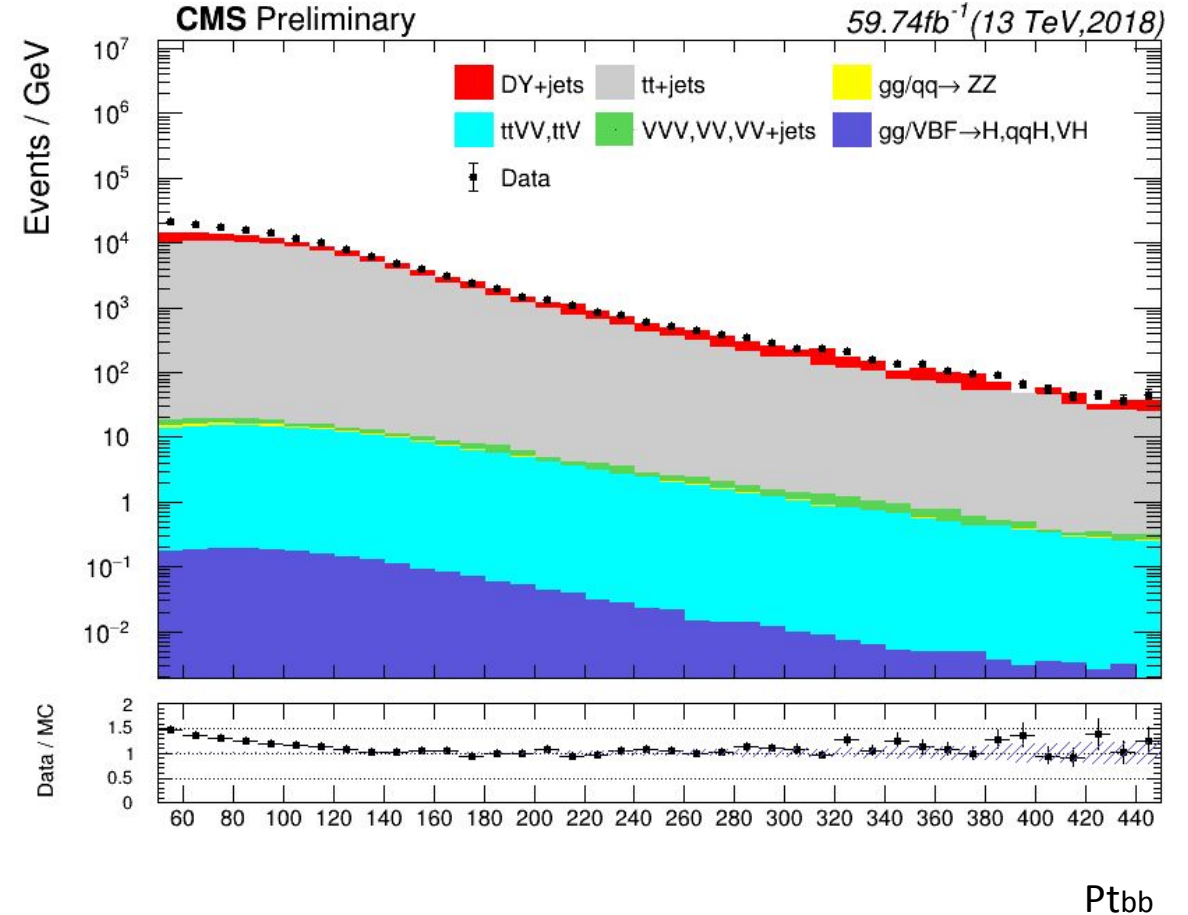
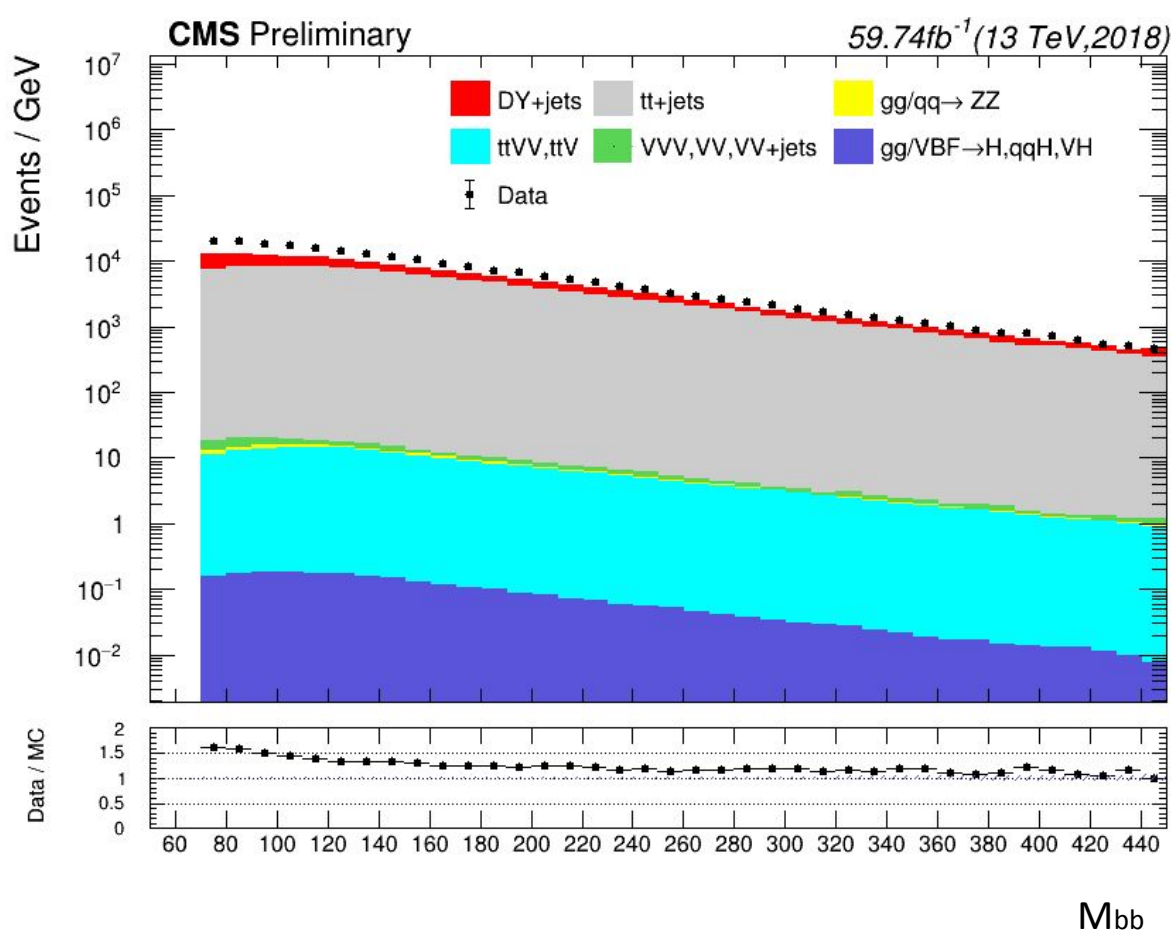
- two leptons
- at least two MWP b-tagged jets with $P_T > 20$ GeV, $|\text{Eta}| < 2.5$ and isolated by 0.3



Control regions tested

Z + b jets

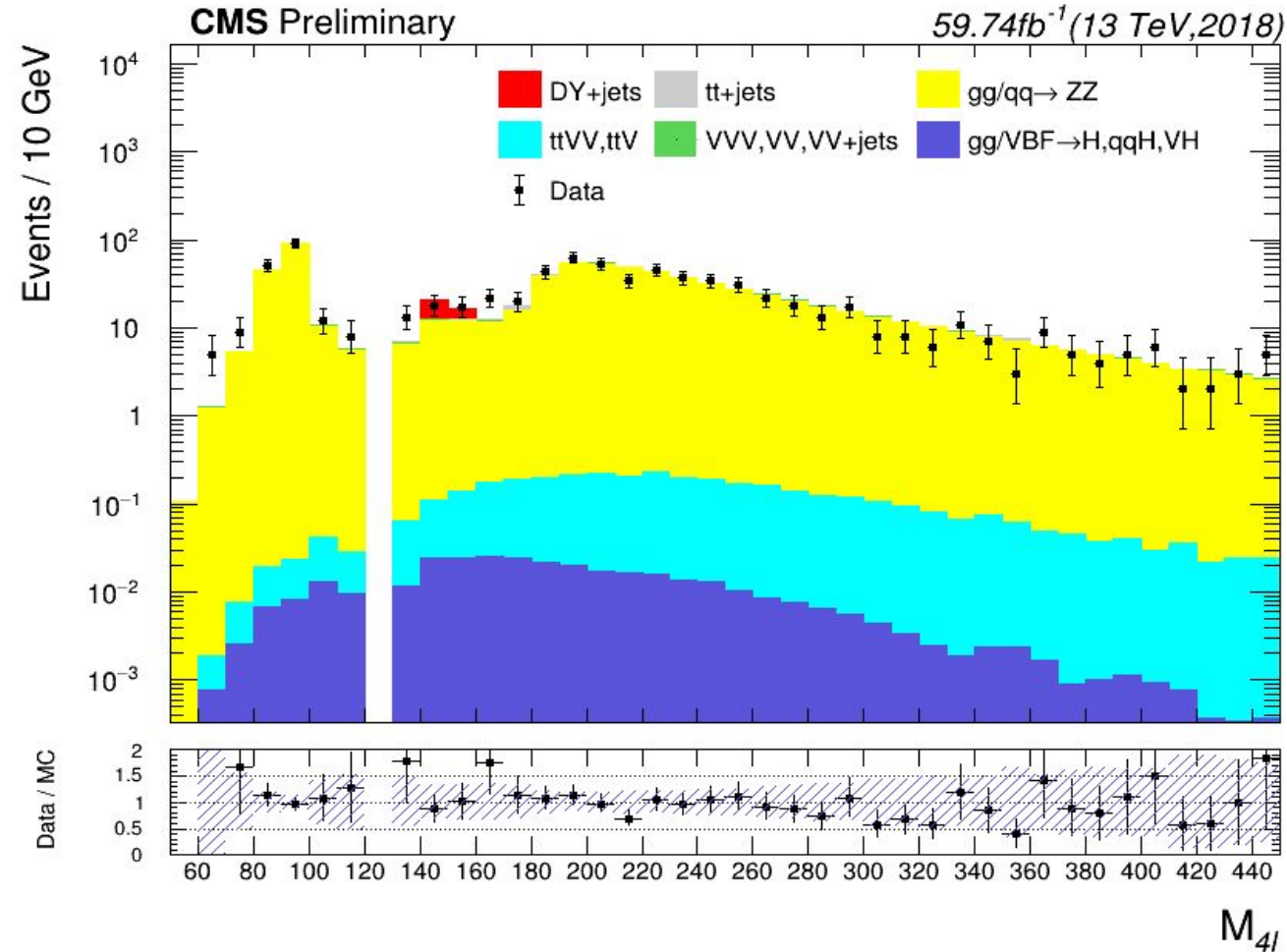
- two leptons
 - at least two b-tagged jets with $P_{\text{t}} > 20$ GeV, $|\text{Eta}| < 2.5$ and isolated by 0.3
- 1 tight + 1 tight / 1 tight + 1 loose (applied in HIG-18-016)



Control regions tested

4l SB

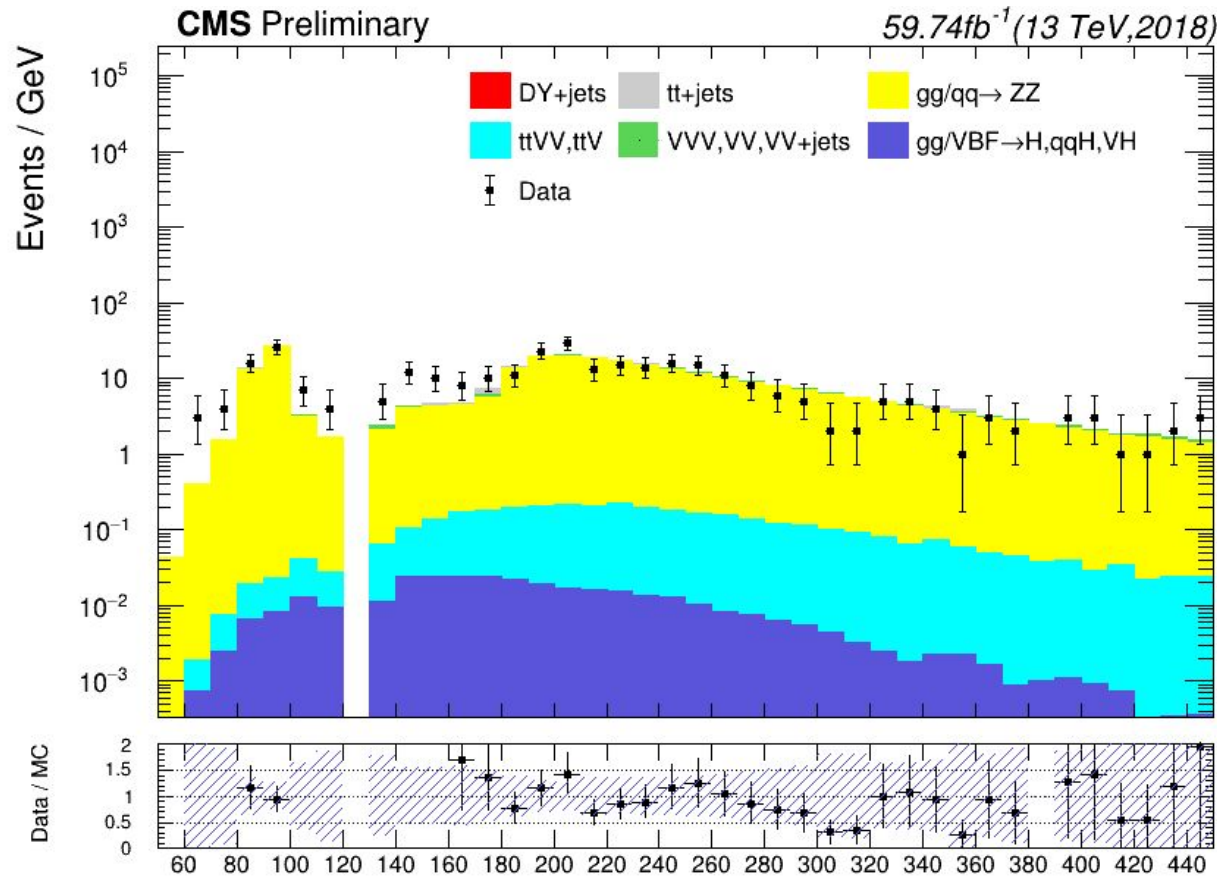
- 4l forming ZZ candidate outside the Higgs mass window



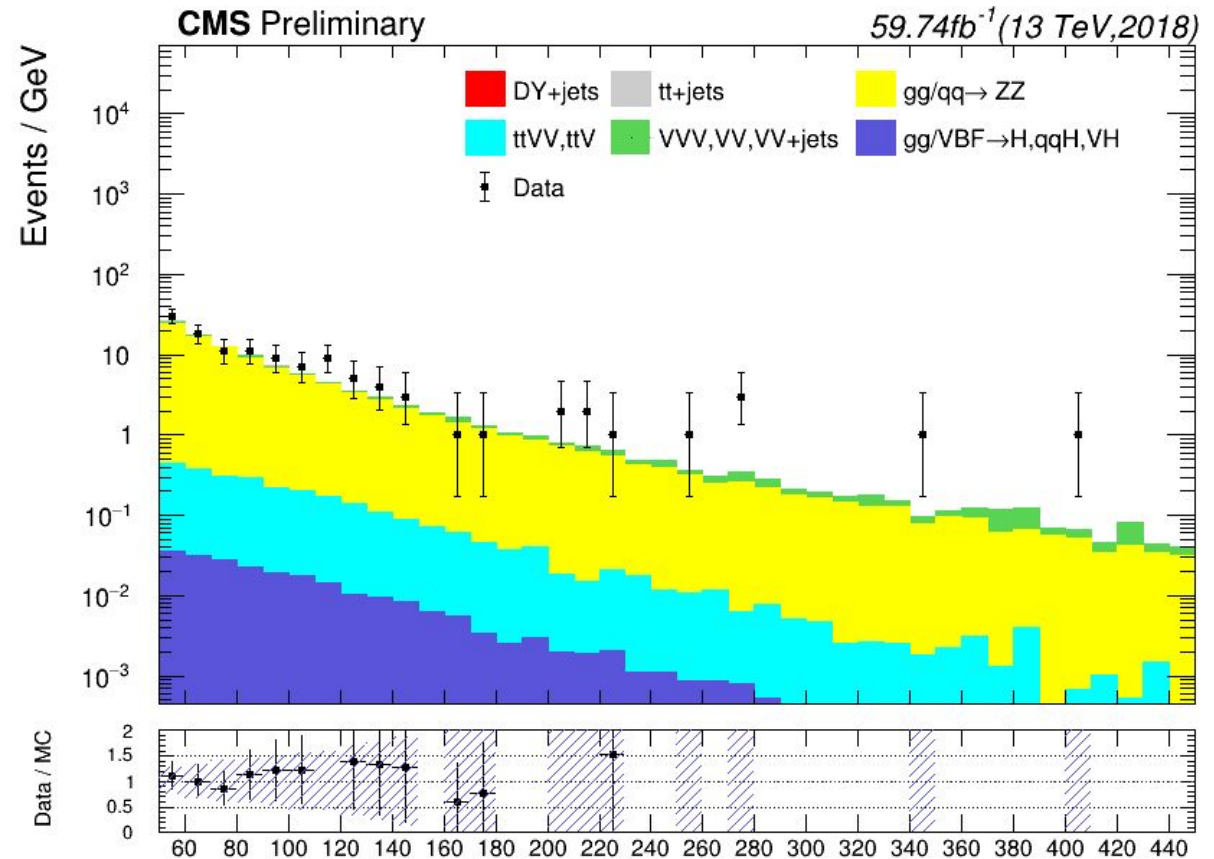
Control regions tested

4l + one b jet

- 4l forming ZZ candidate outside the Higgs mass window
- at least one b-tagged jet with $P_t > 20$ GeV, $|\text{Eta}| < 2.5$ and isolated by 0.3 (highest score is selected)



M_{4l}

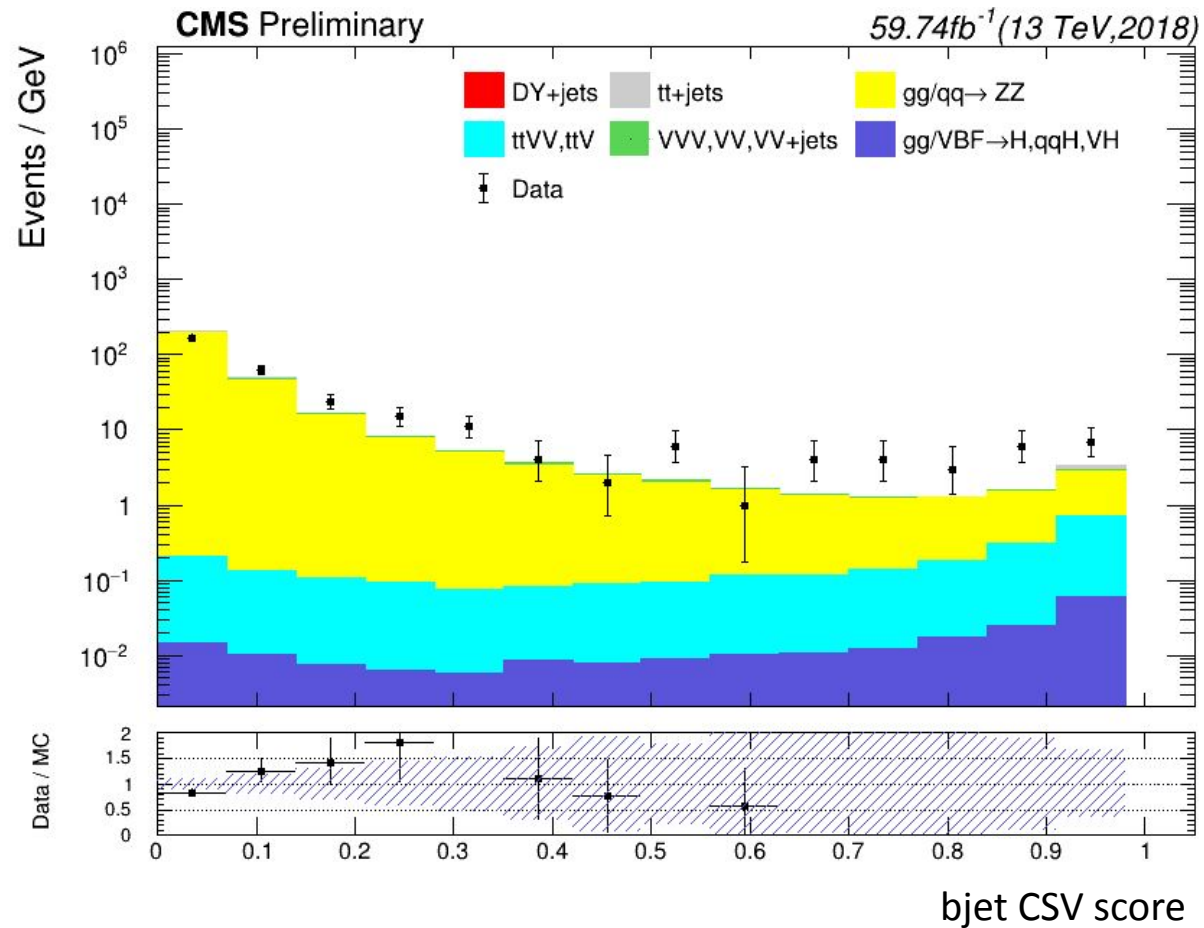


$P_{t_{bjet}}$

Control regions tested

4l + one b jet

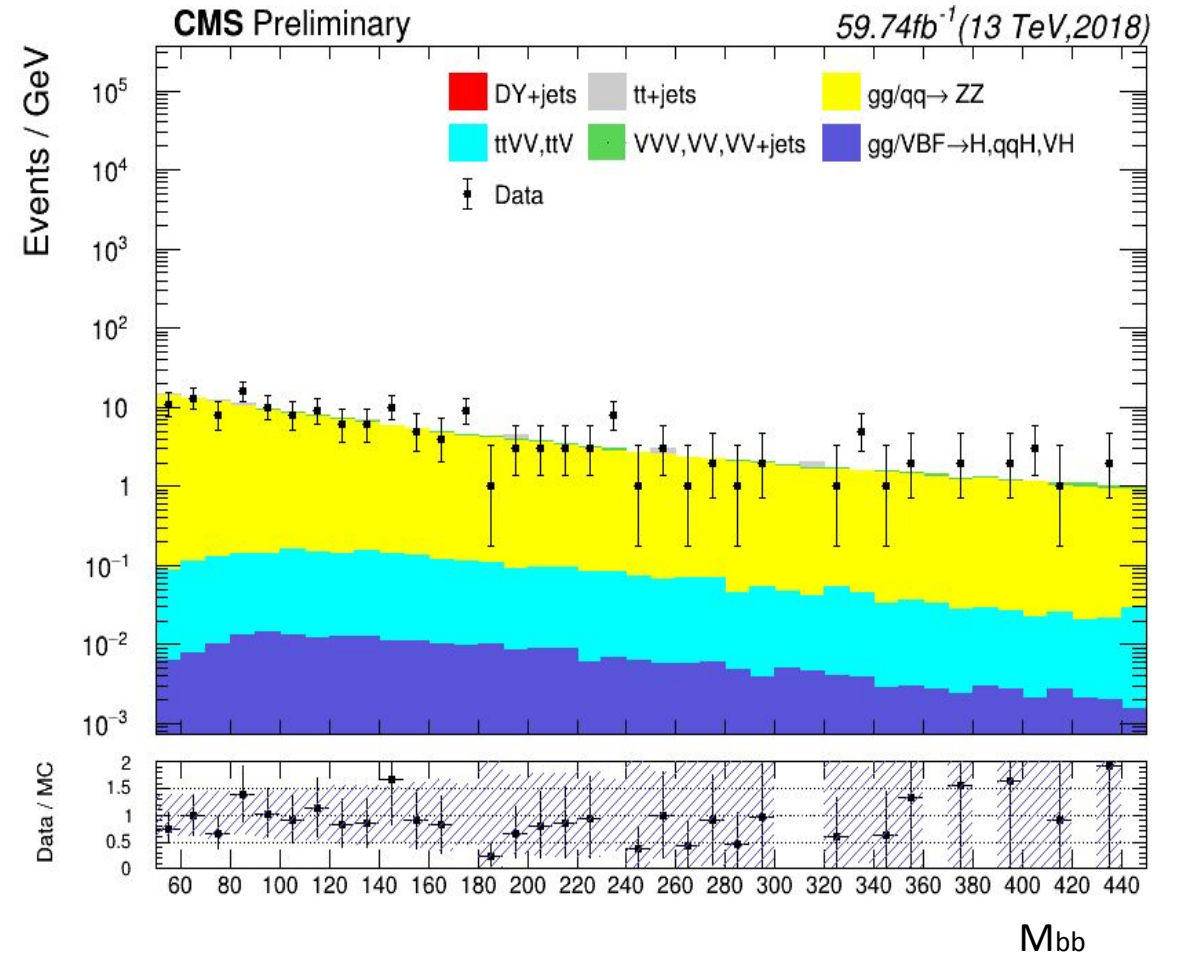
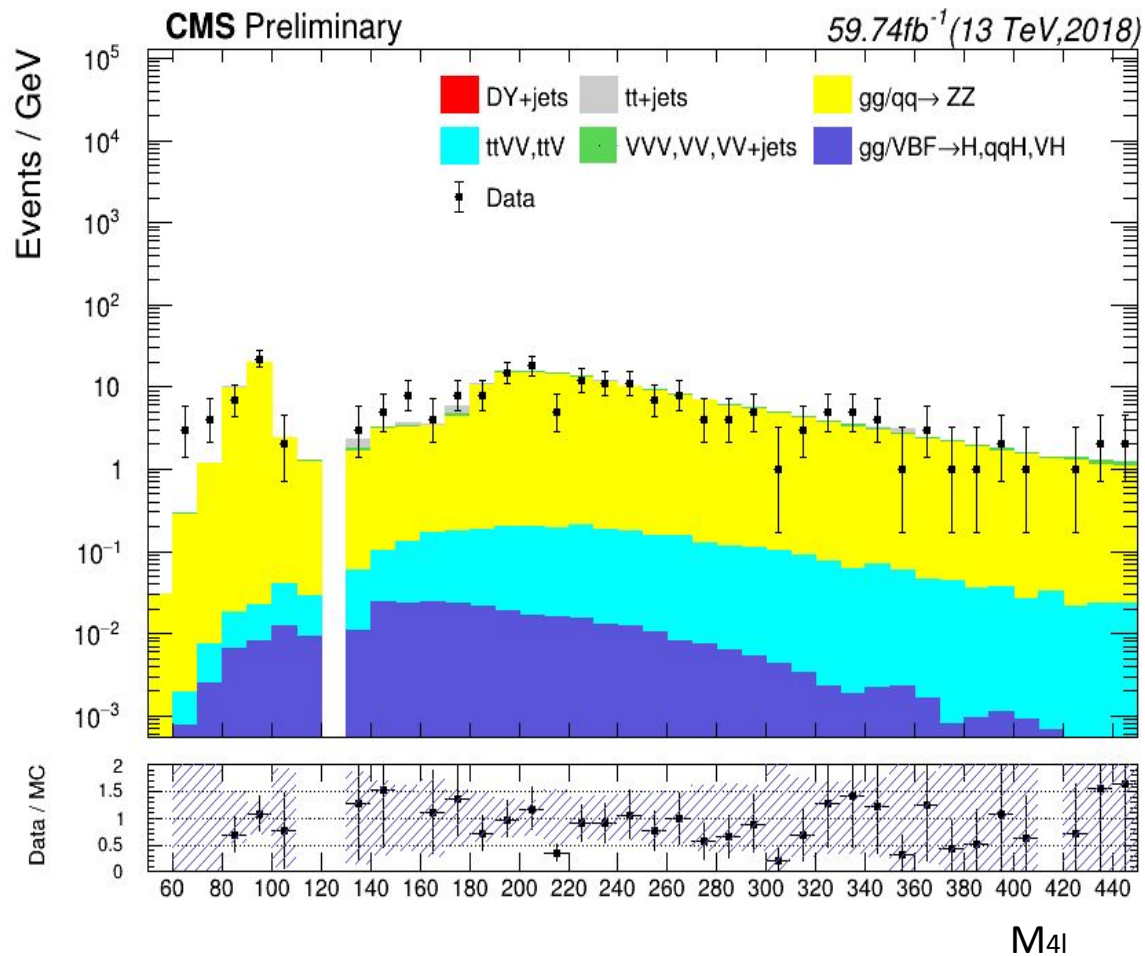
- 4l forming ZZ candidate outside the Higgs mass window
- at least one b-tagged jet with $P_t > 20$ GeV, $|\text{Eta}| < 2.5$ and isolated by 0.3 (highest score is selected)



Control regions tested

4l + jets SB

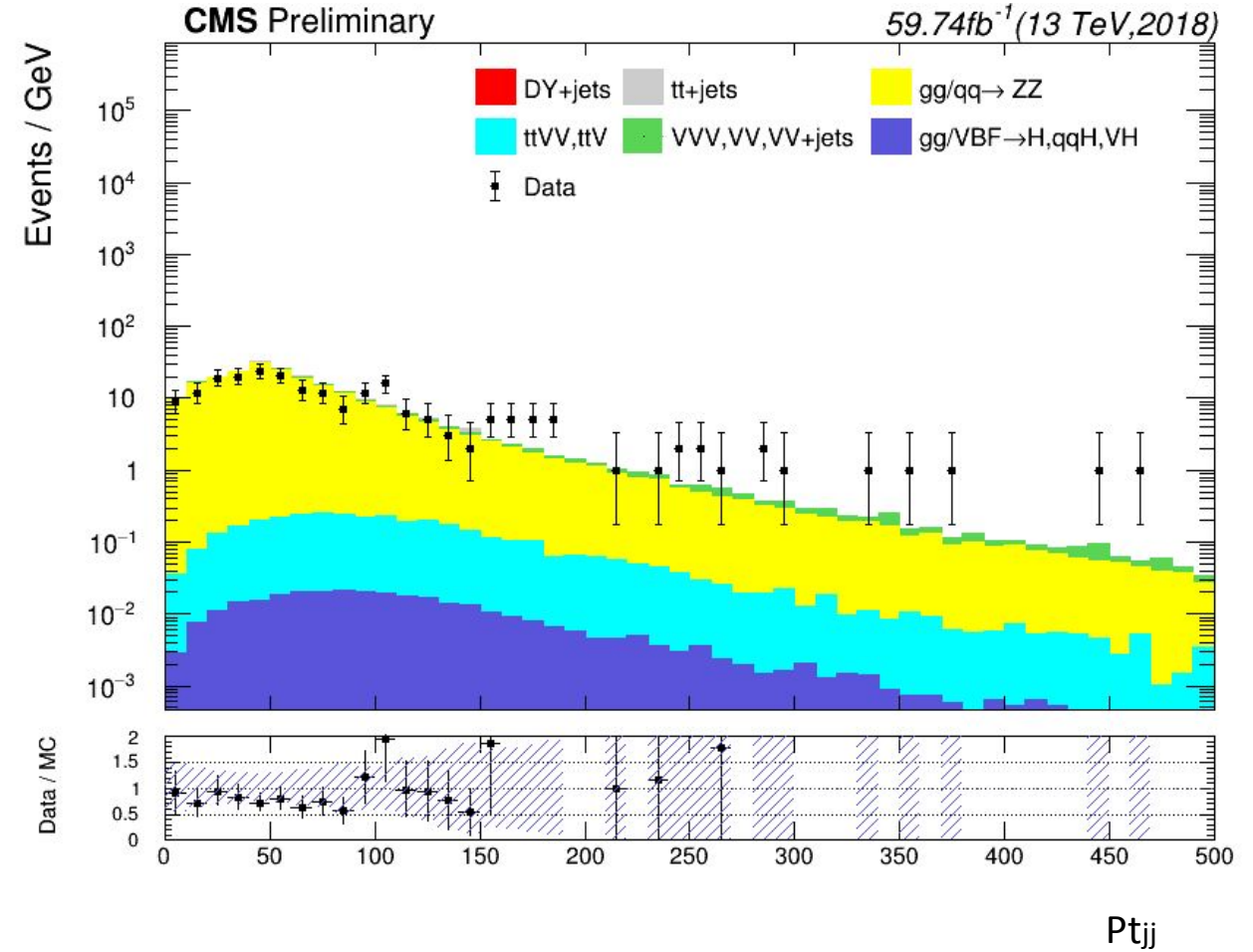
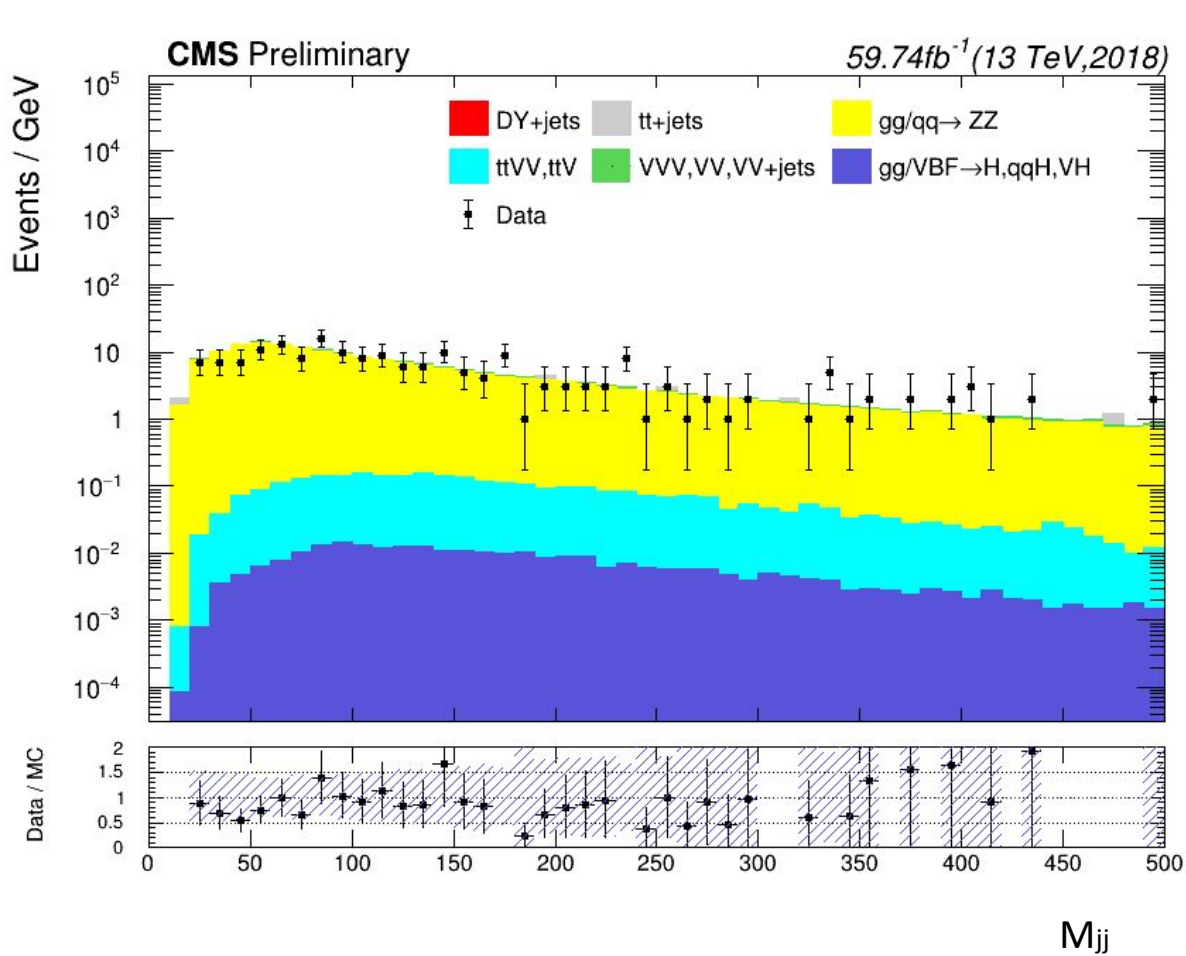
- 4l forming ZZ candidate outside the Higgs mass window
- at least two PF jets with $P_{\text{t}} > 20$ GeV, $|\text{Eta}| < 2.5$ and isolated by 0.3



Control regions tested

4l + jets SB

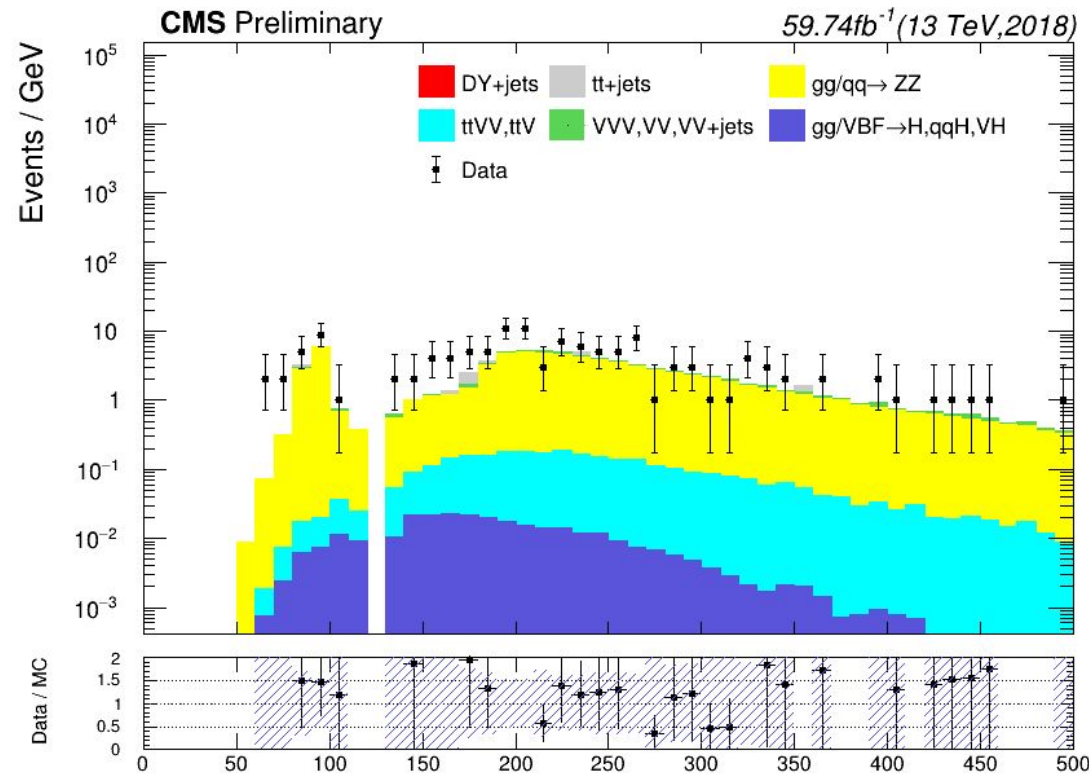
- 4l forming ZZ candidate outside the Higgs mass window
- at least two PF jets with $P_{\text{t}} > 20$ GeV, $|\text{Eta}| < 2.5$ and isolated by 0.3



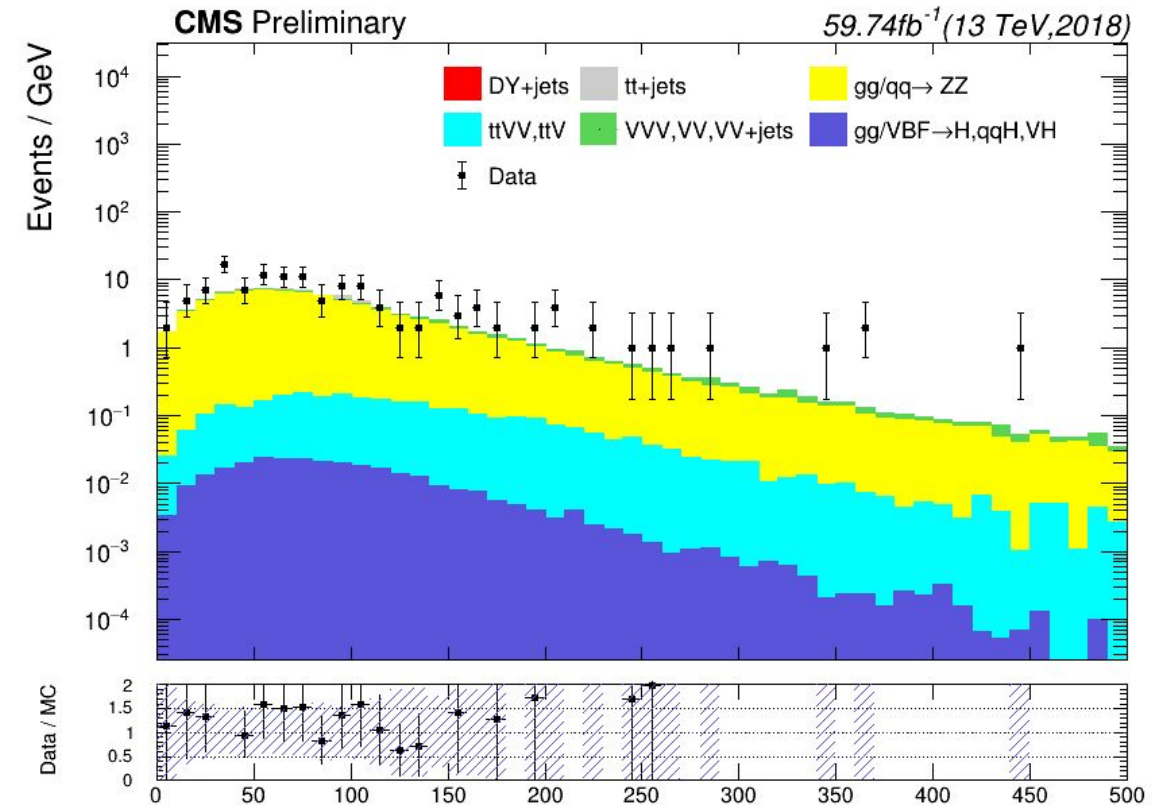
Control regions tested

4l + b jets SB

- 4l forming ZZ candidate outside the Higgs mass window
- at least 2 b-tagged jets with $P_t > 20$ GeV, $|\text{Eta}| < 2.5$ and isolated by 0.3 (highest b-tagger scores are selected)



M_{4l}

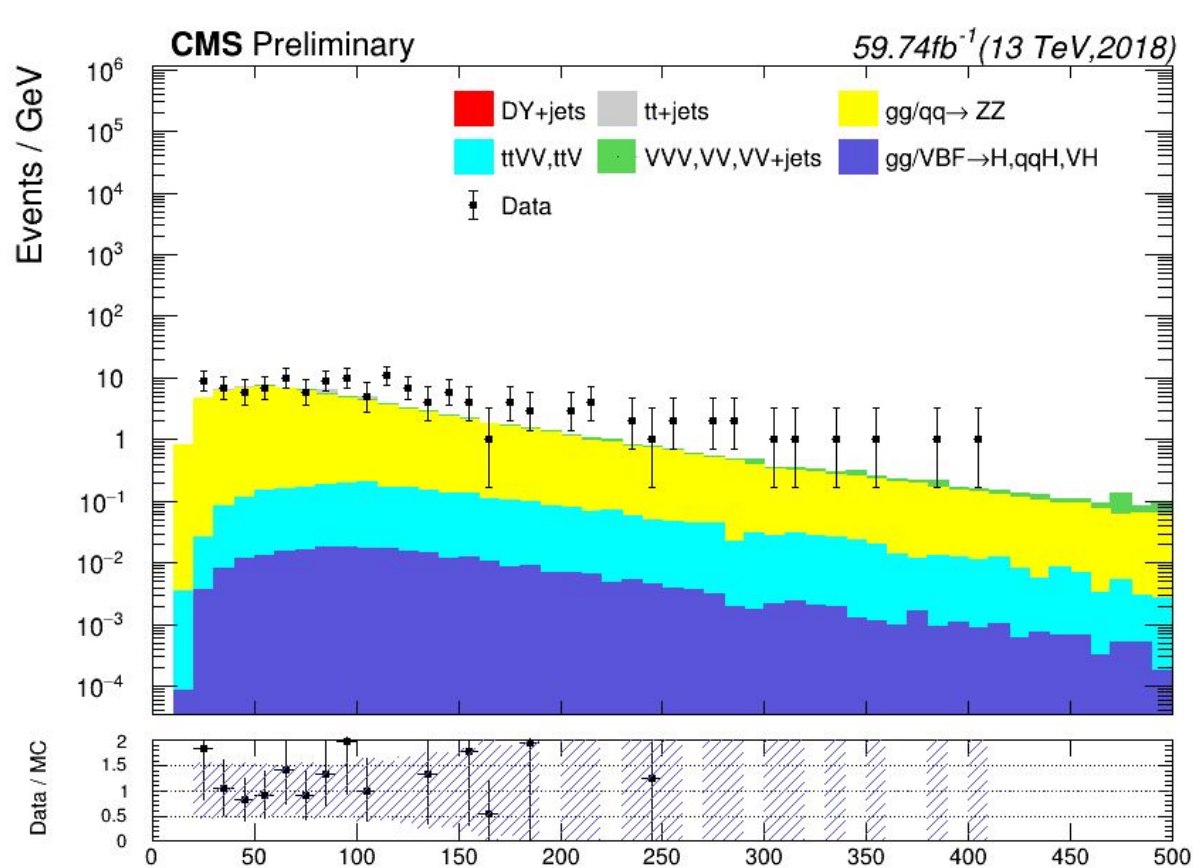


P_{t4l}

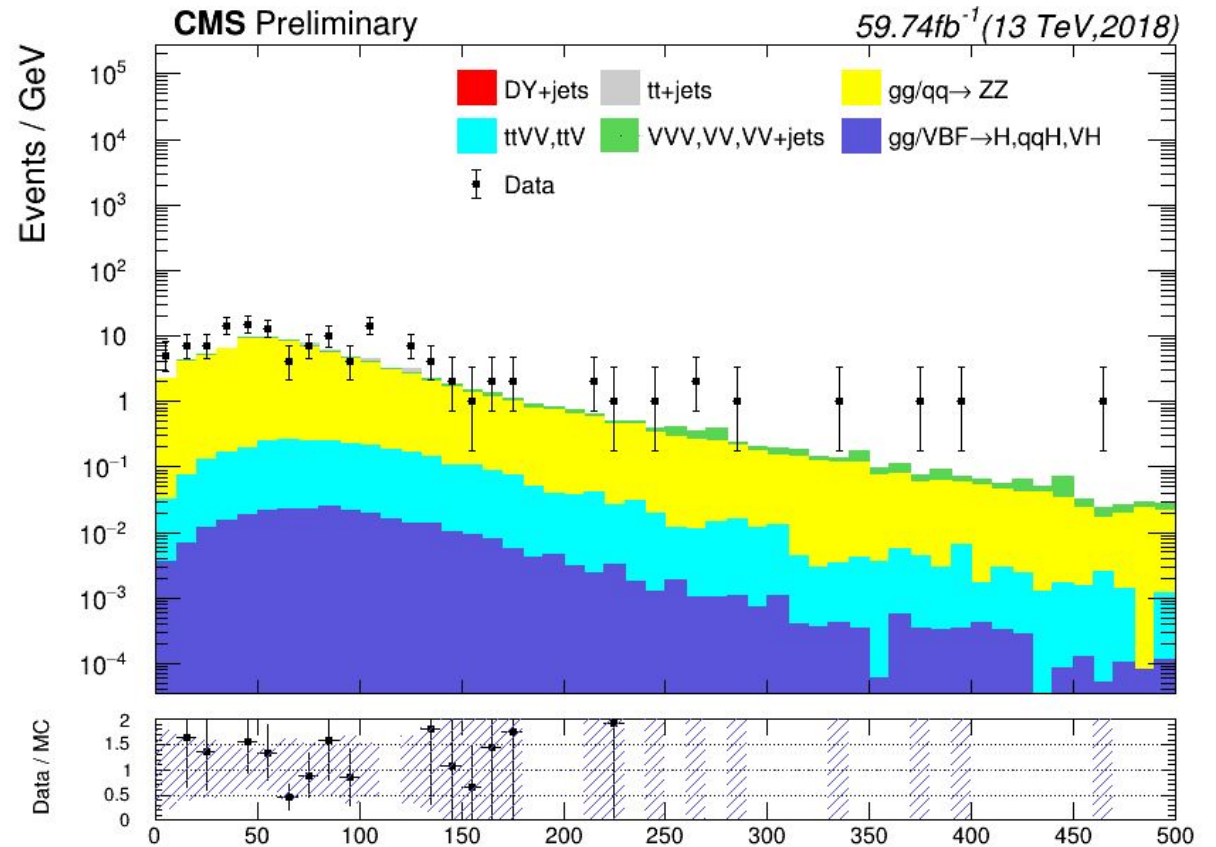
Control regions tested

4l + b jets SB

- 4l forming ZZ candidate outside the Higgs mass window
- at least 2 b-tagged jets with $P_t > 20$ GeV, $|\text{Eta}| < 2.5$ and isolated by 0.3 (highest b-tagger scores are selected)



M_{bb}



P_{tbb}

Signal regions tested

4l + 2 b jets

- 4l forming the first Higgs
- at least 2 b-tagged jets with $P_{\text{t}} > 20$ GeV, $|\text{Eta}| < 2.5$ and isolated by 0.3 (highest b-tagger scores are selected)

SM bkg ~ 13
Data = 16

4l + 2 PF jets

- 4l forming the first Higgs
- at least 2 PF jets with $P_{\text{t}} > 20$ GeV, $|\text{Eta}| < 2.5$ and isolated by 0.3 (highest P_{t} are selected)
- if more than 3 PF jets are exist, the highest B-tagging score is selected

SM bkg ~ 13
Data = 16

4l + 2 b jets

- 4l forming the first Higgs
- at least two b-tagged jets with $P_{\text{t}} > 20$ GeV, $|\text{Eta}| < 2.5$ and isolated by 0.3
1 tight + 1 tight / 1 tight + 1 loose (*applied in HIG-18-016*)

4l + b jet + PF jet

- 4l forming the first Higgs
- at least one b-tagged jet with $P_{\text{t}} > 20$ GeV, $|\text{Eta}| < 2.5$ and isolated by 0.3
- at least one PF jet with $P_{\text{t}} > 20$ GeV, $|\text{Eta}| < 2.5$ and isolated by 0.3

SM bkg ~ 28
Data = 31