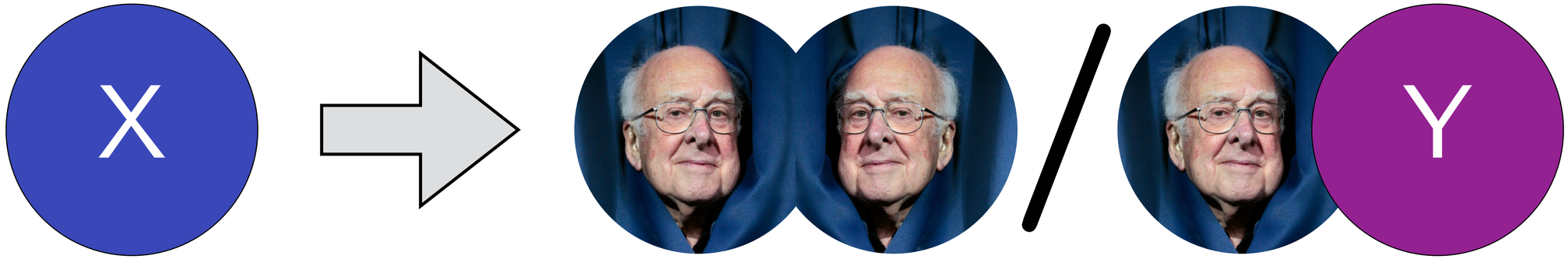

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Resonant HH/HY searches at the CMS experiment

Tobias Kramer
on behalf of the CMS collaboration

Higgs 2023, Beijing

29.11.2023

Production

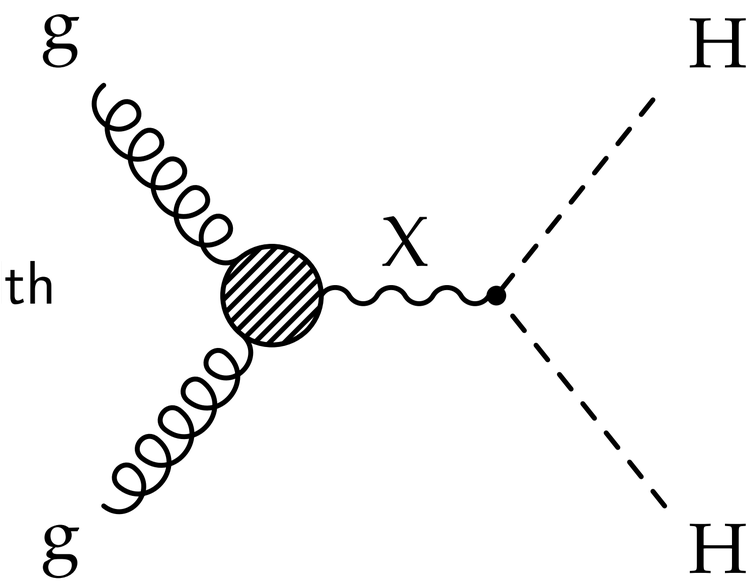
- gluon-gluon fusion of heavy resonance X
- X decays to either HH or HY

Analyses

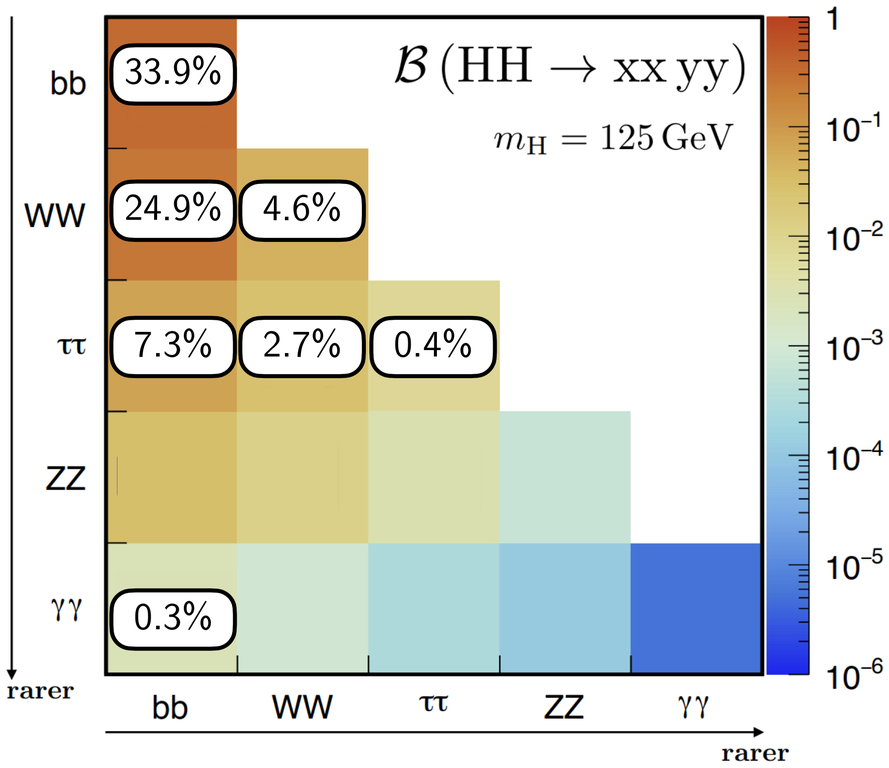
- H/Y decays to different final states
- analyses target different spin and mass hypotheses
- mostly model independent, only depend on mass, spin and width

Different theories

- 2HDM
- composite-Higgs
- warped extra dimensions
  - **Radion** (spin 0) / **Graviton** (spin 2)
- SUSY (**NMSSM**)
- two-real-scalar-singlet extension of the SM (**TRSM**)



SM HH branching fractions



X→HH/HY→γγbb
arXiv:2310.01643 (*sub. to JHEP*)

HH→ bbWW (both resonant and non-resonant):
CMS-PAS-HIG-21-005

HH→Multilepton (both resonant and non-resonant):
JHEP 07 (2023) 095

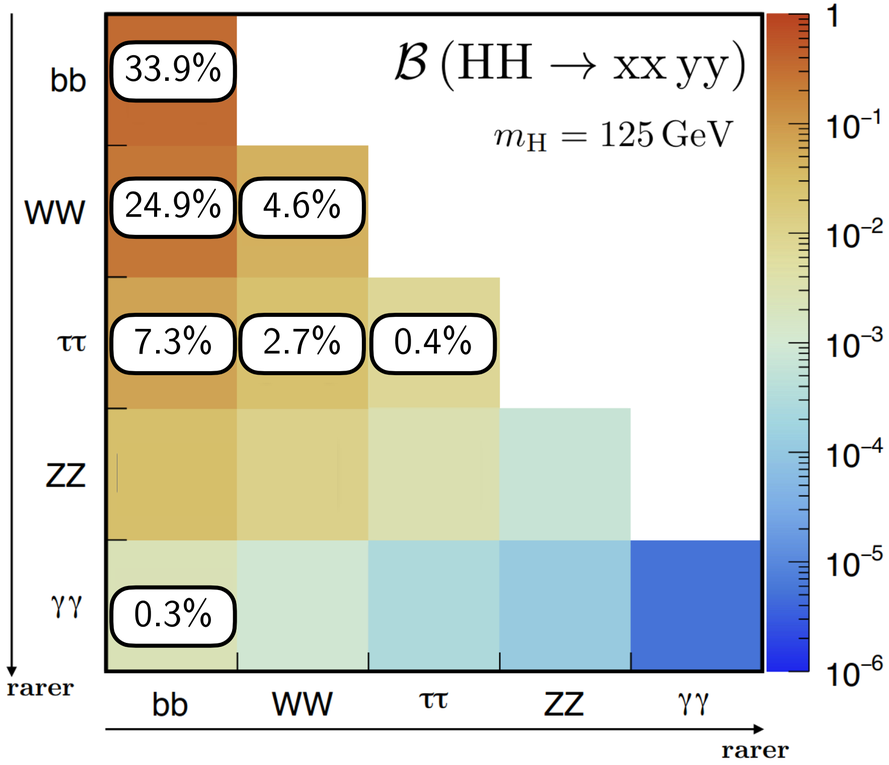
X→YH→bbbb (boosted):
Phys. Lett. B 842 (2023) 137392

X→HH→bbbb:
CMS-PAS-B2G-20-004

X→HH→bbWW/bbττ (boosted)
JHEP 05 (2022) 005

X→HY→ττbb
JHEP 11 (2021) 057

SM HH branching fractions



In this talk:

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X→HH→bbWW/bbττ (boosted)
JHEP 05 (2022) 005

X→HY→ττbb
JHEP 11 (2021) 057

Scope

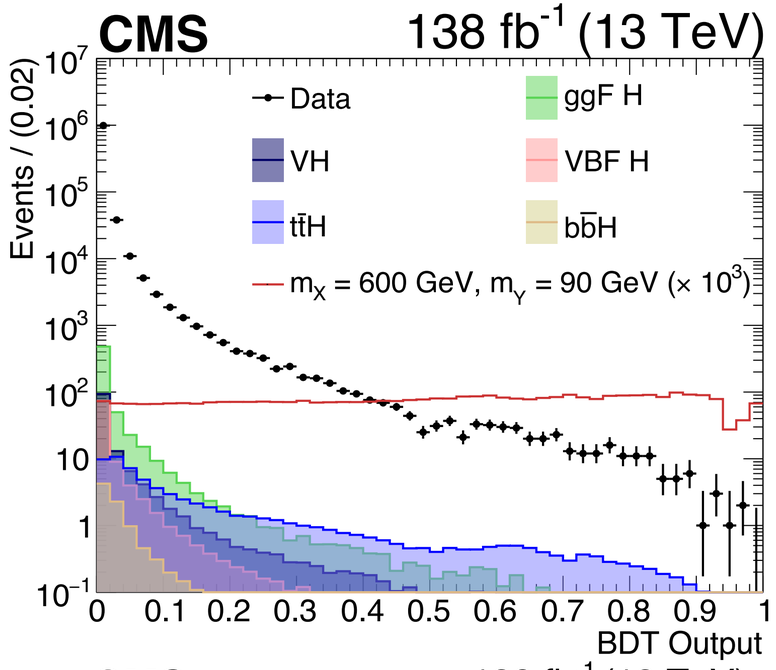
- resonant HH and HY production
- X: mass range [260, 1000] GeV, spin 0/2
- Y: mass range [90, 800] GeV, spin 0

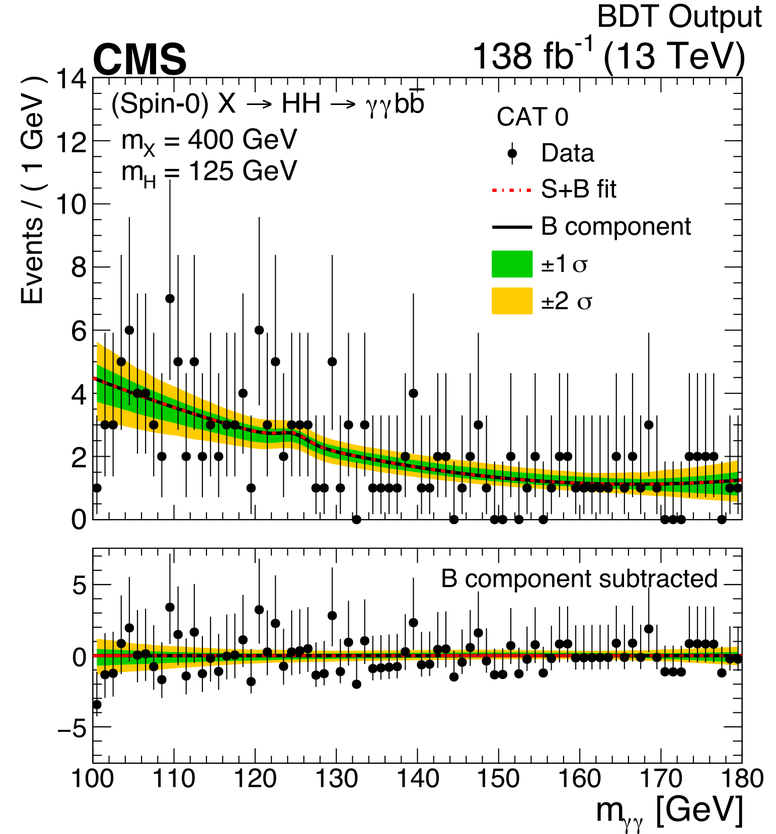
Phase space

- H to γγ, H/Y to bb decays
- backgrounds: γ(γ) + jets, single H

Strategy

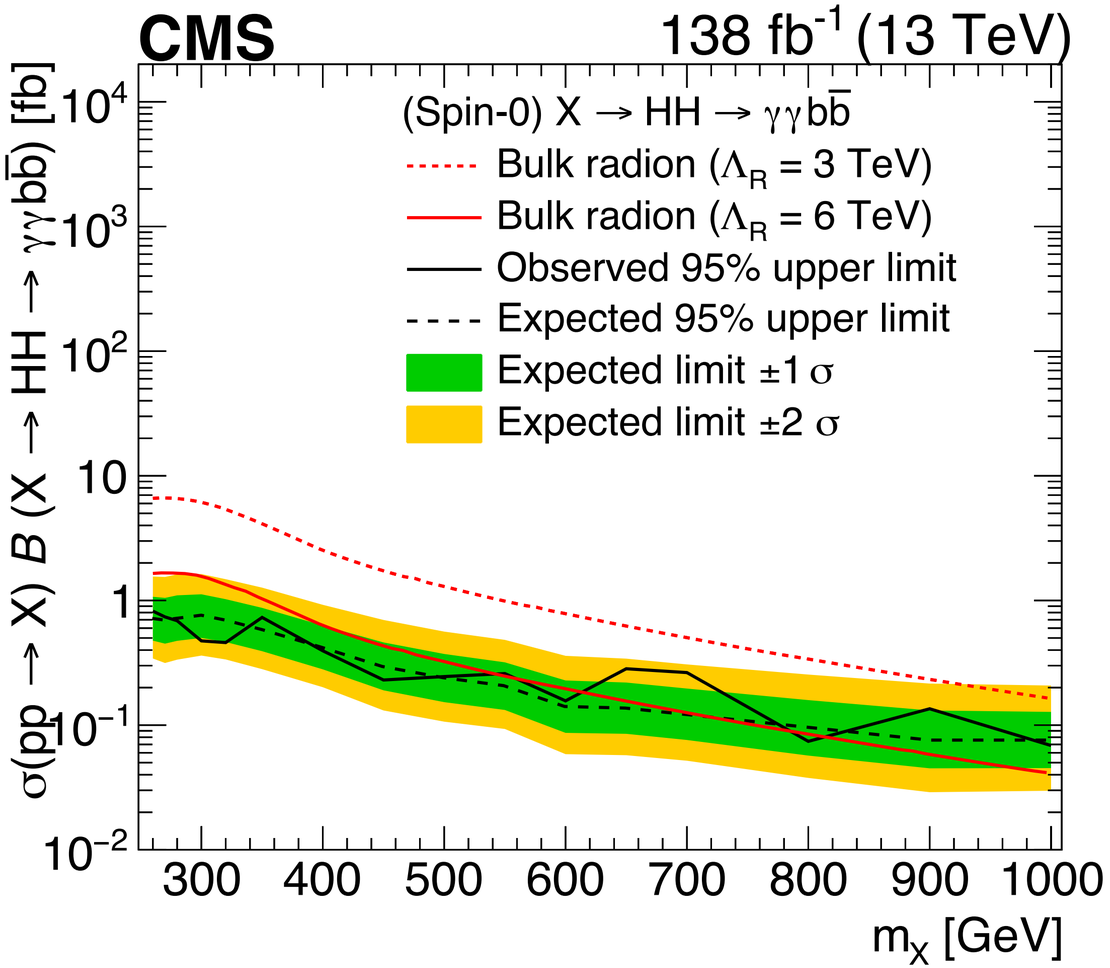
- categories based on m_X and m_Y
- BDT per category, sub-categorise on BDT score
- parametric fit in $m_{\gamma\gamma}$ and m_{jj} plane



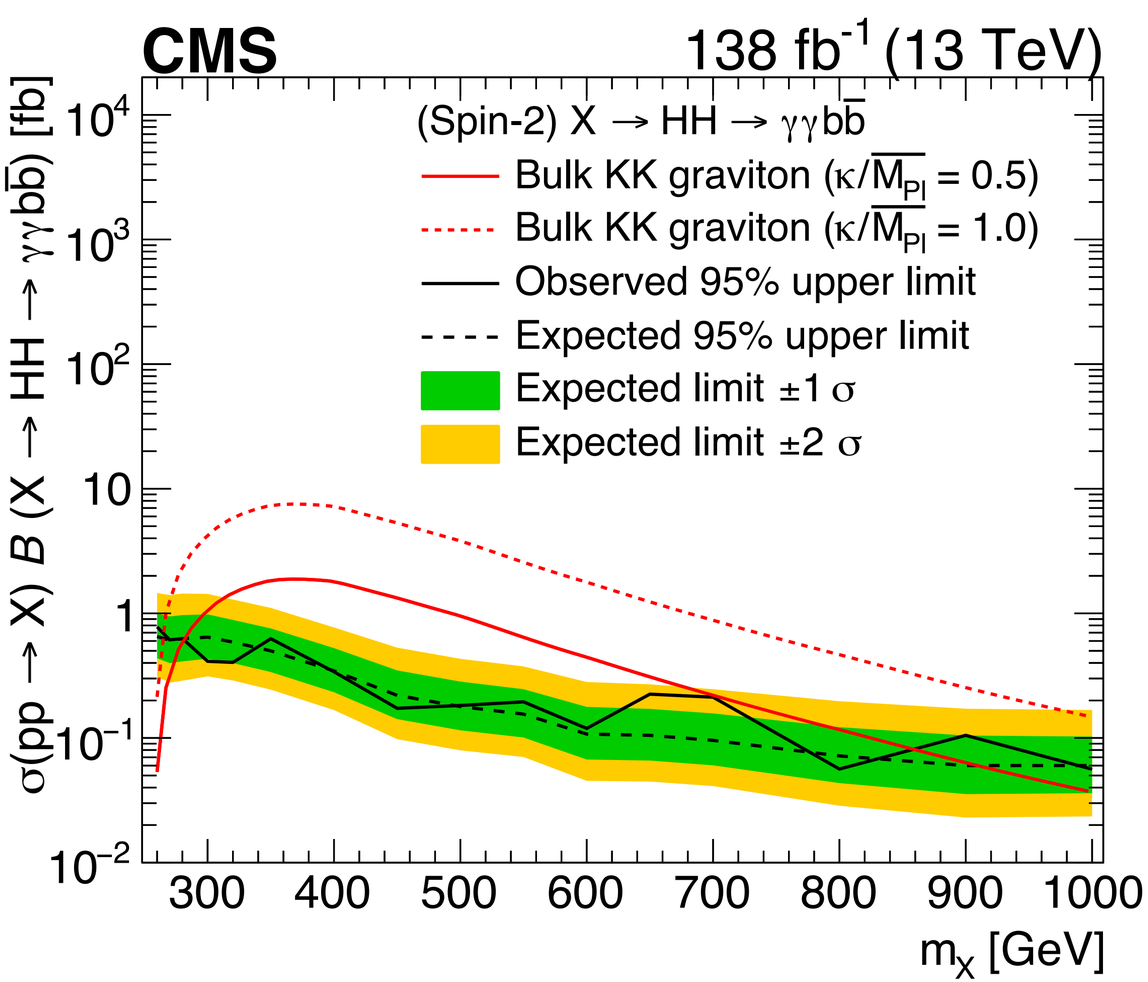


X→HH→γγbb results

spin 0



spin 2



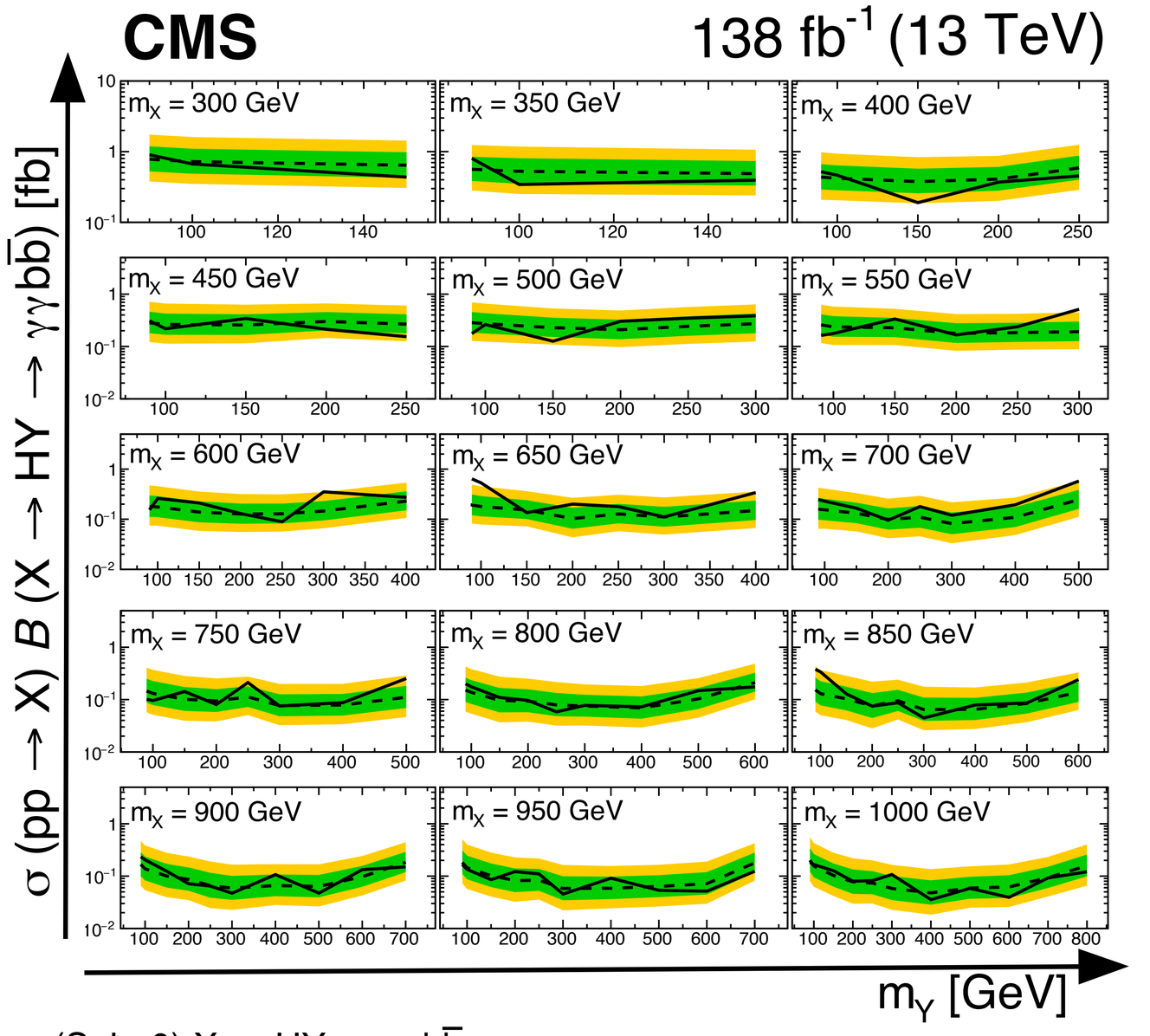
- limits on cross section x branching fraction:

  0.82 fb - 0.07 fb (spin 0)

  0.78 fb - 0.06 fb (spin 2)

X→HY→γγbb results

- limits from 0.79 - 0.05 fb over range of m_X and m_Y
- local 3.8σ excess at m_X=650 GeV, m_Y=90 GeV (global 2.8σ)



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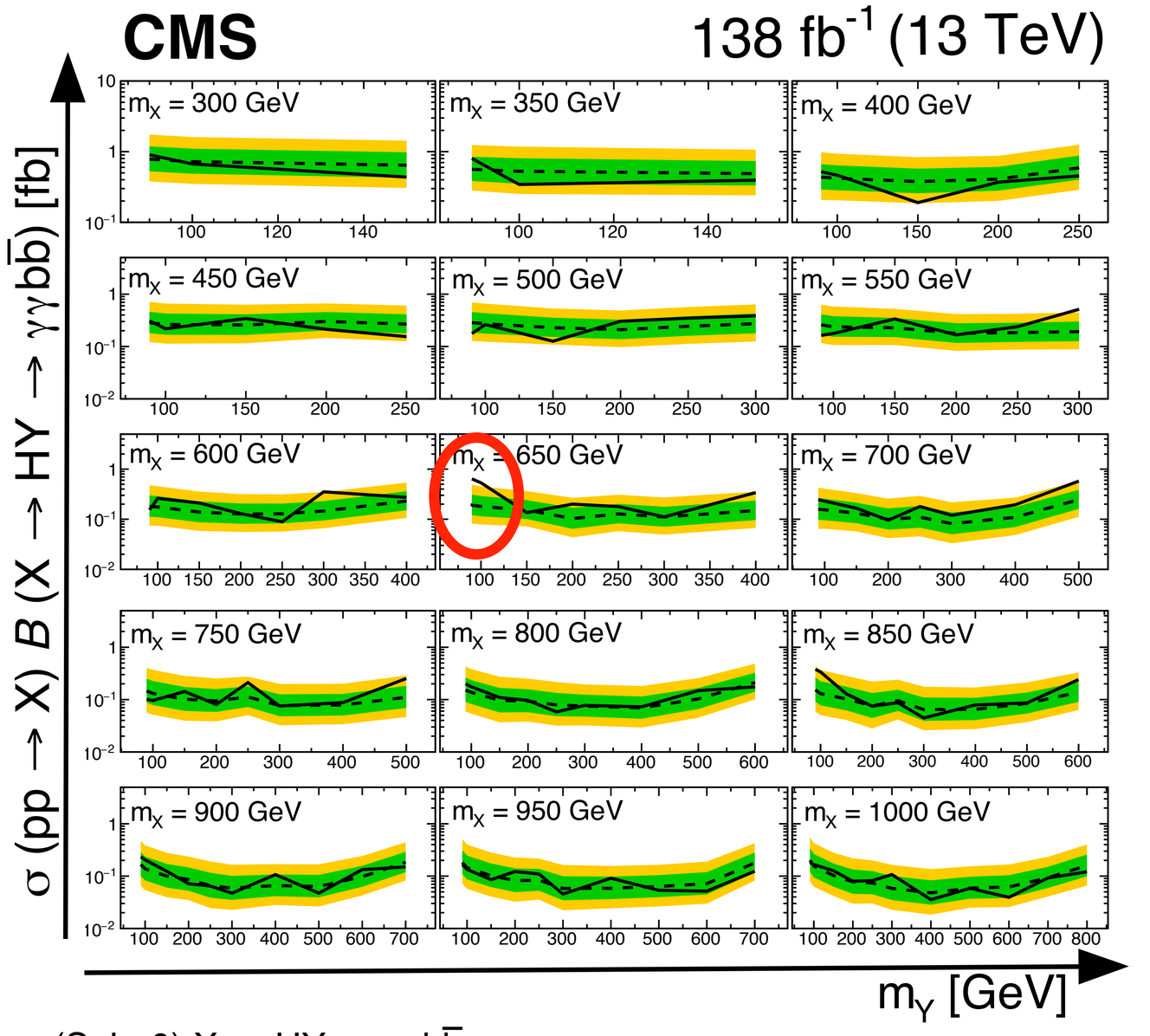


Scope

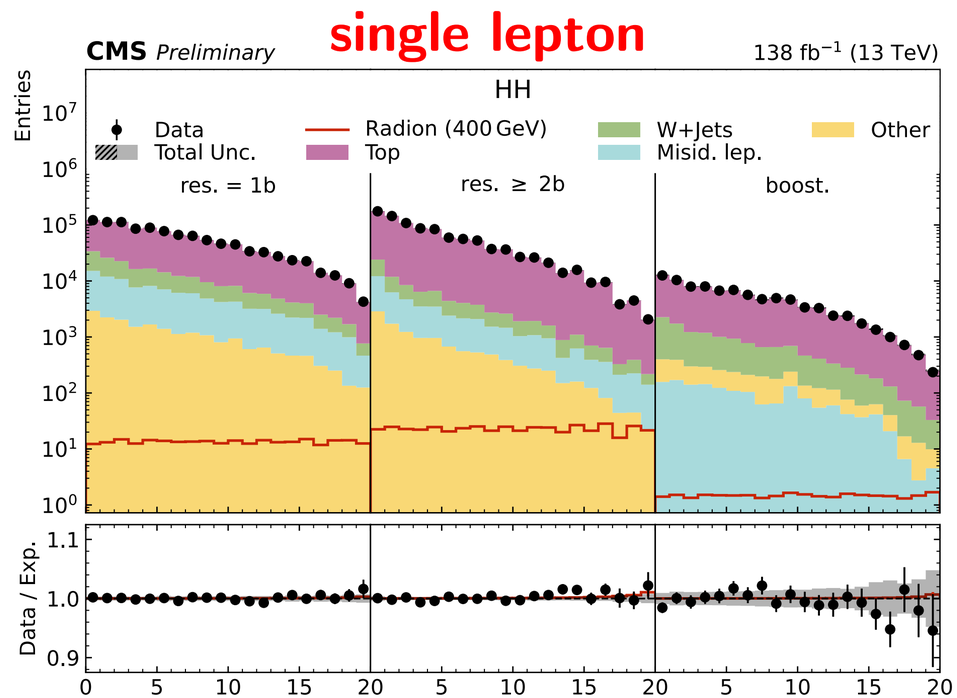
- non-resonant and resonant HH production
- X: mass range [250, 900] GeV, spin 0/2

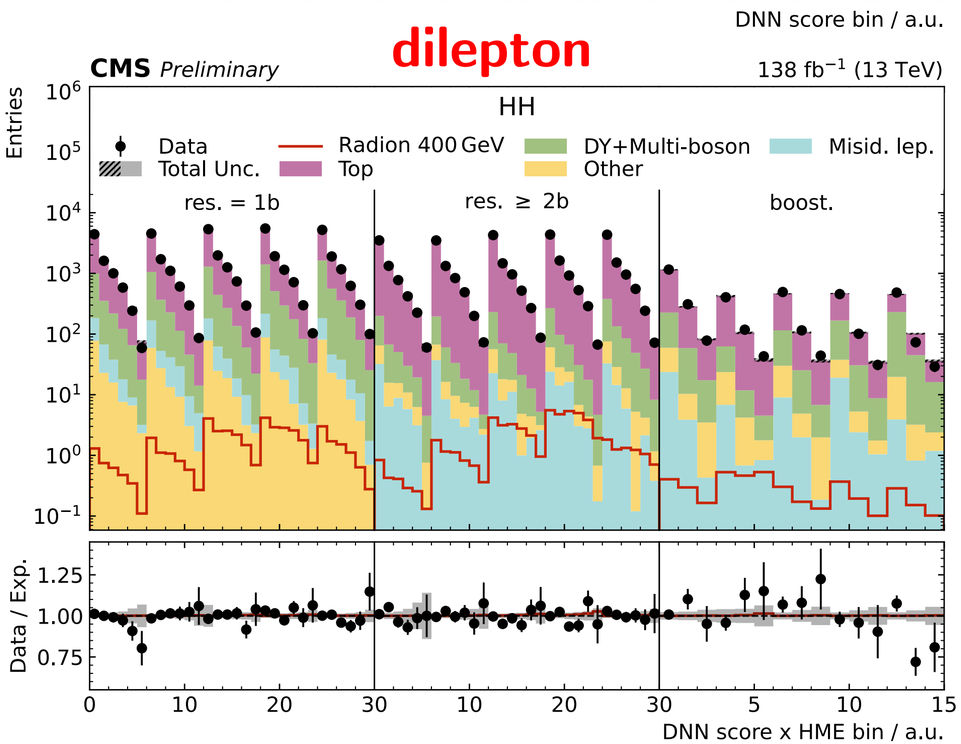
Phase space

- ≥ 1 W decaying to e/μ
- backgrounds: Top, W, DY, Multiboson

Strategy

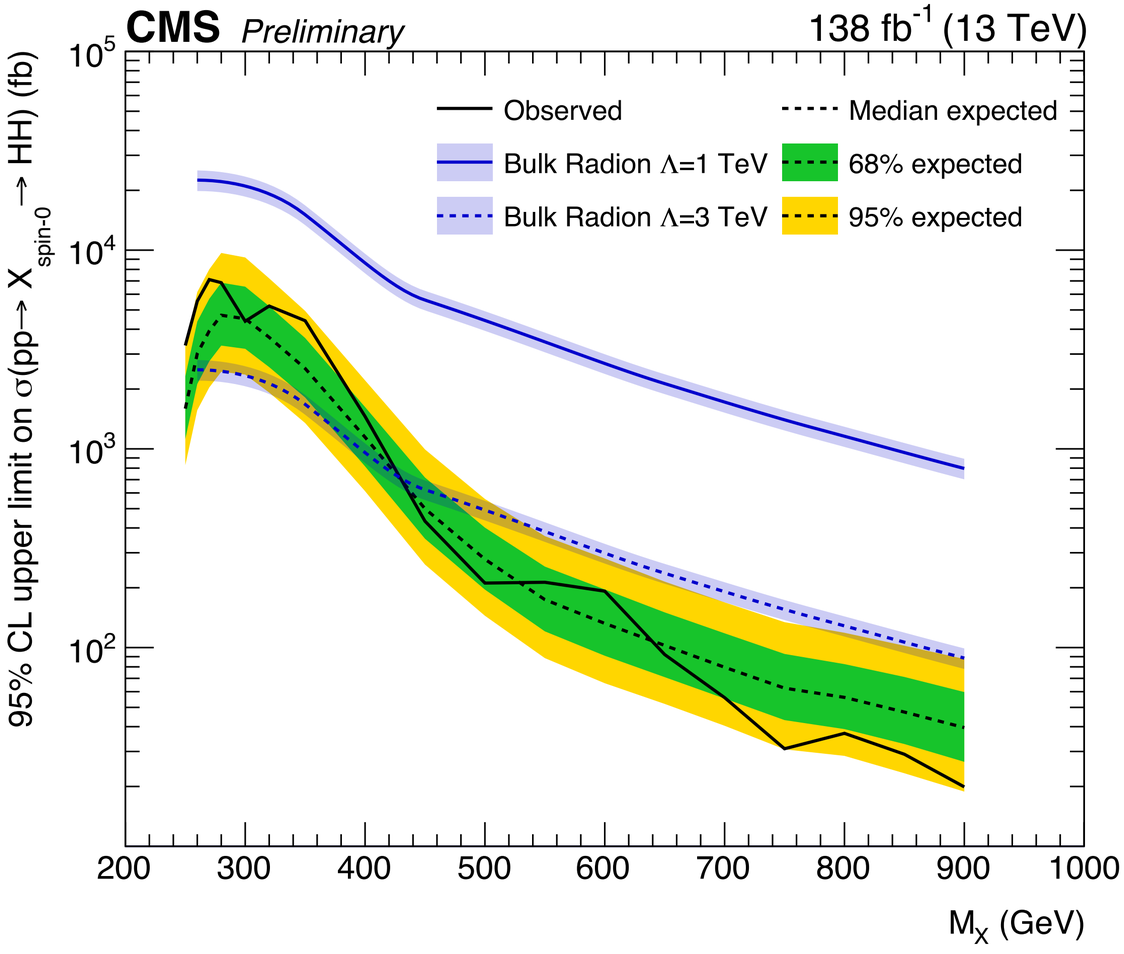
- resolved 1b/2b and boosted categories
- sub-categories based on parameterised multi-class DNN
- fit to DNN (x HME) in the sub-categories



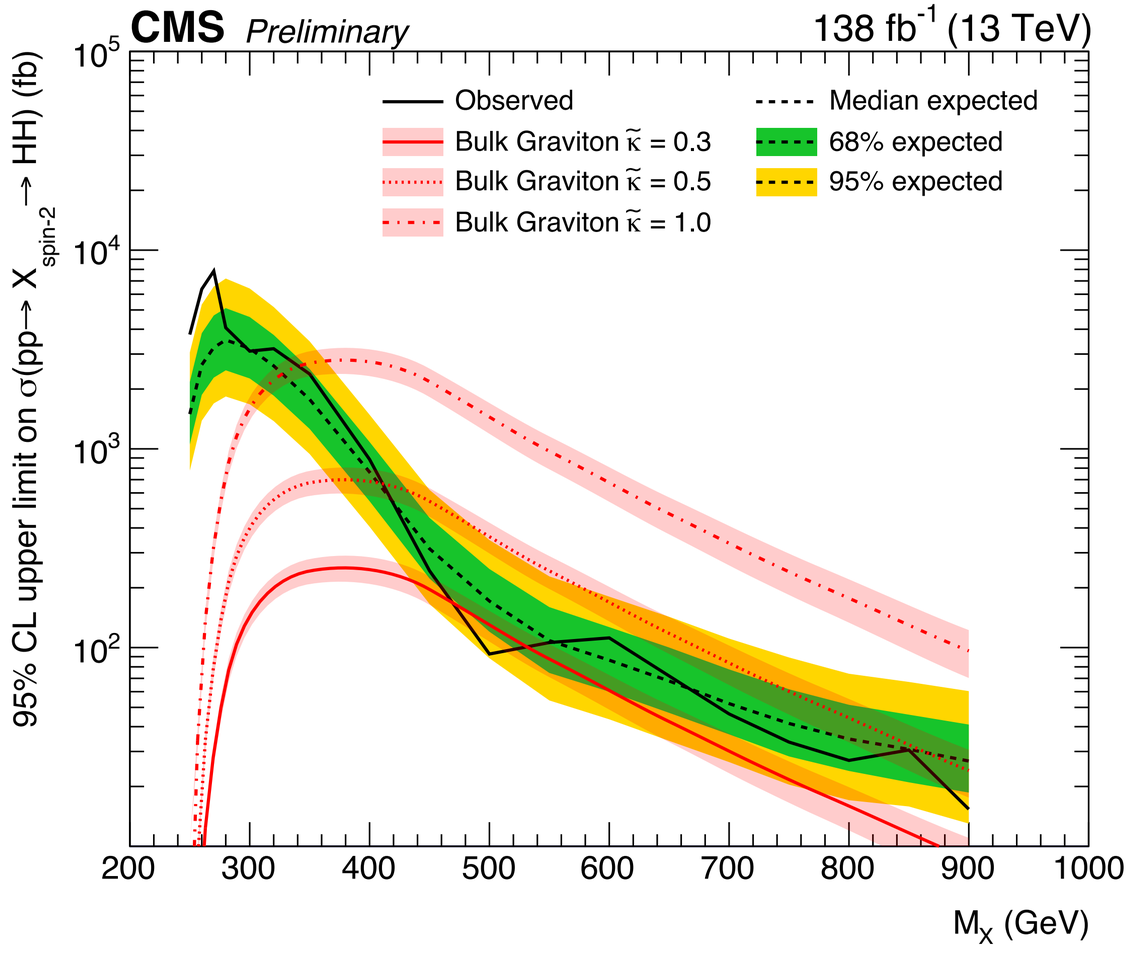


X→HH→bbWW results

spin 0



spin 2



- limits range over 2 orders of magnitude (~10^4 fb to <10^2 fb)

Scope

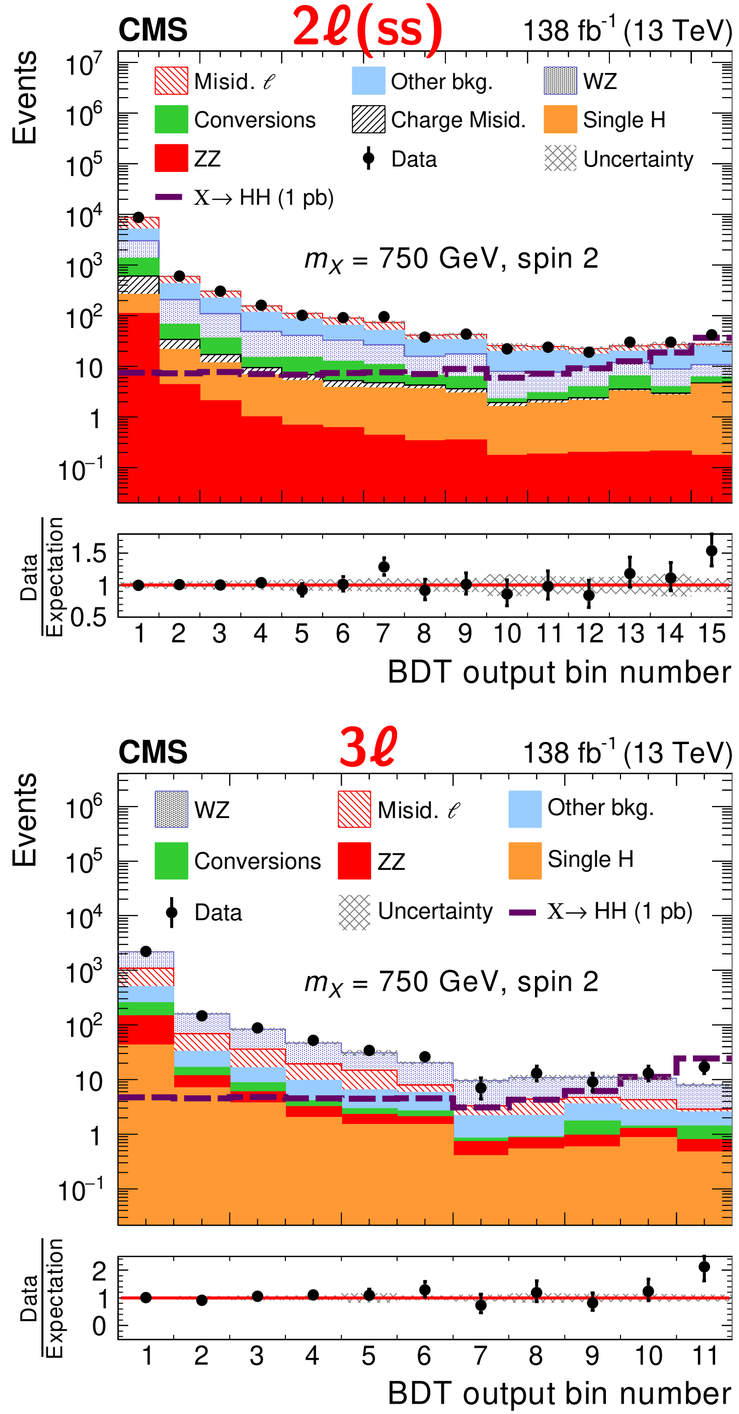
- non-resonant and resonant HH production
- X: mass range [250, 1000] GeV, spin 0/2

Phase space

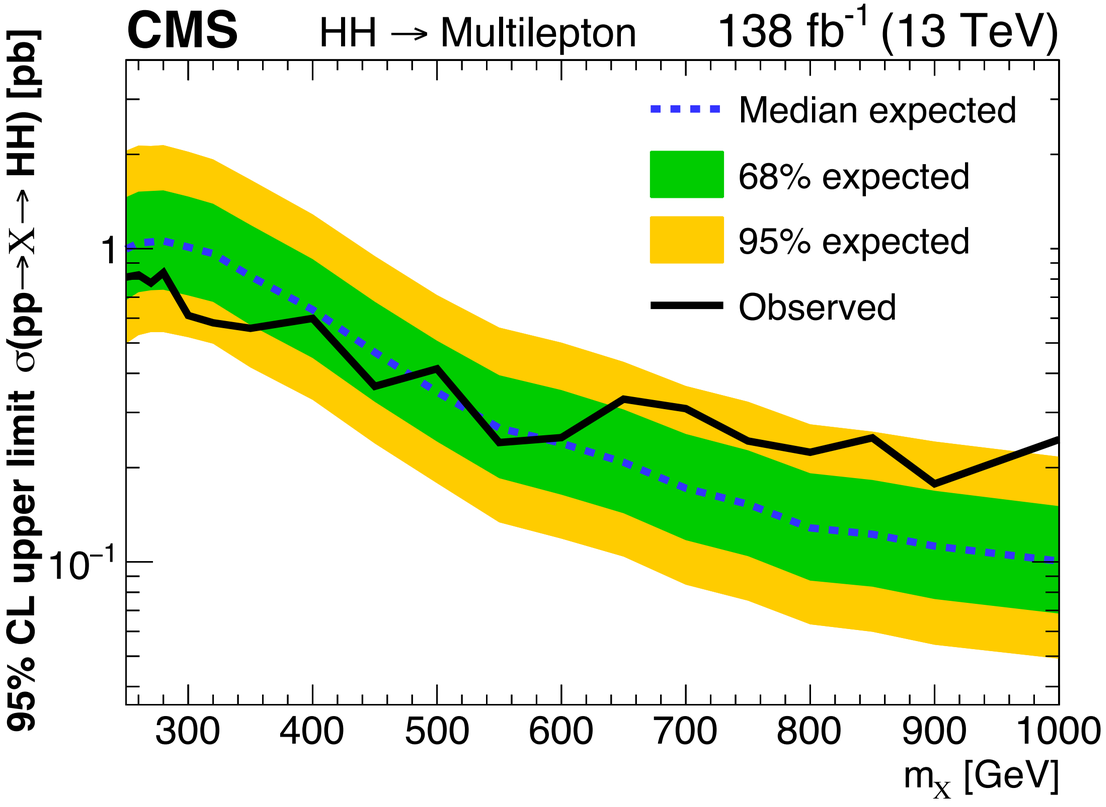
- HH→4W/2W2τ/4τ
- backgrounds: WZ, ZZ, misidentified leptons

Strategy

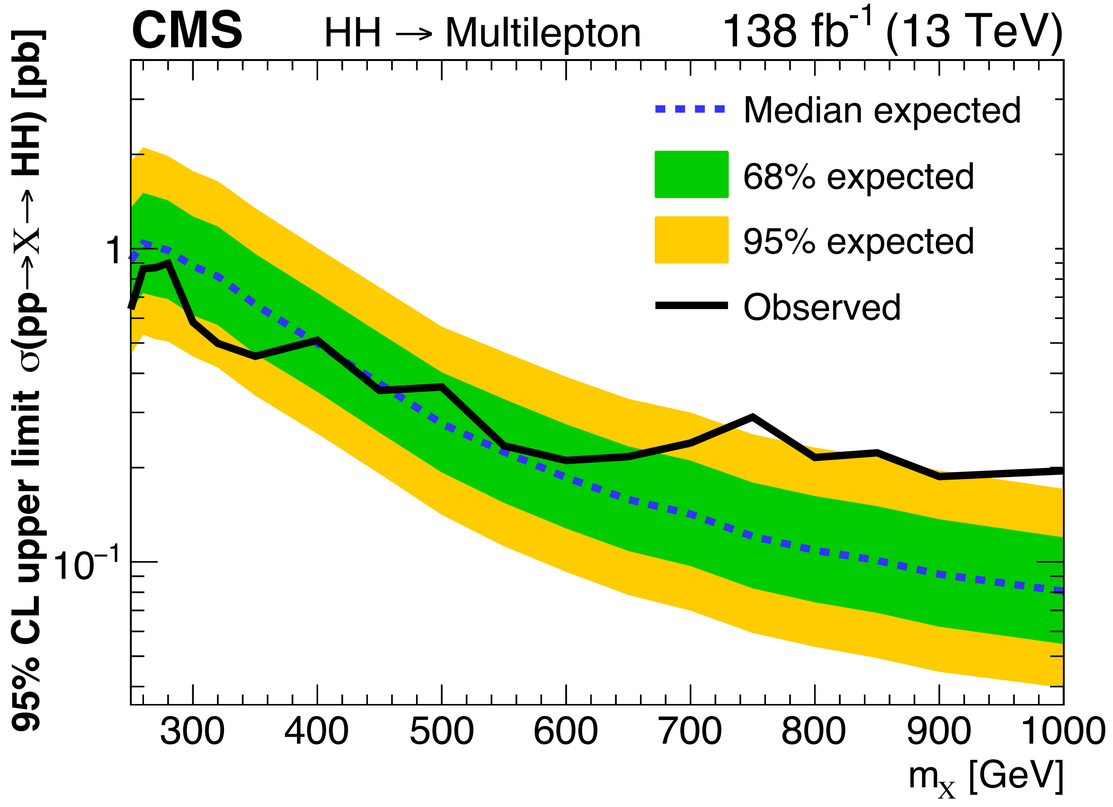
- 7 channels targeting W and τ decays:
  - 2ℓ(ss), 3ℓ, $3\ell 1\tau_h$, $2\ell 2\tau_h$, $1\ell 3\tau_h$, 4ℓ, $4\tau_h$
- parameterised BDTs per channel and spin
- fit to BDT outputs, WZ (m_T) and ZZ ($m_{4\ell}$) regions



spin 0



spin 2



- observed (expected) limits range from 0.18 to 0.90 pb (0.08 to 1.06 pb)
- especially good sensitivity at low masses due to low lepton momentum thresholds

Scope

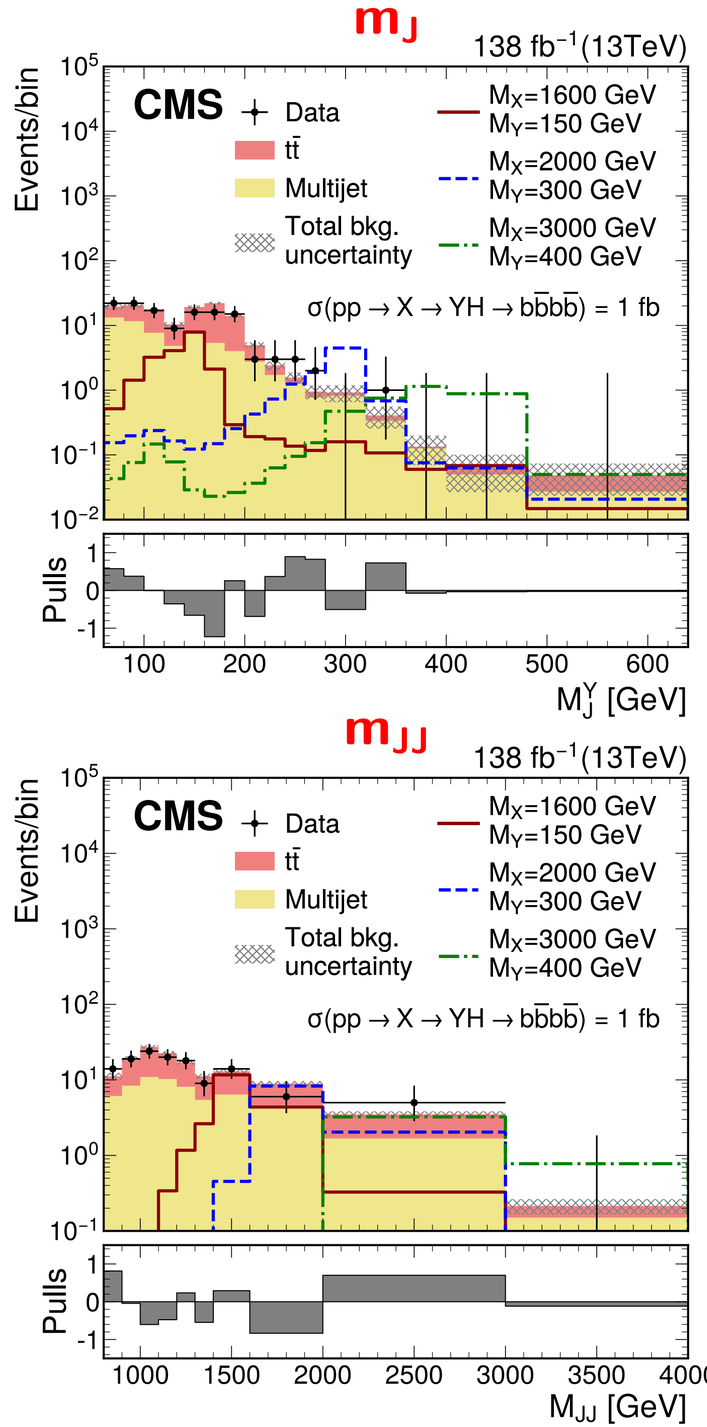
- X: mass range [0.9, 4] TeV, spin 0
- Y: mass range [60, 600] GeV, spin 0

Phase space

- 2 central large-radius jets
- H/Y selection based on jet mass
- backgrounds: QCD, $t\bar{t}$

Strategy

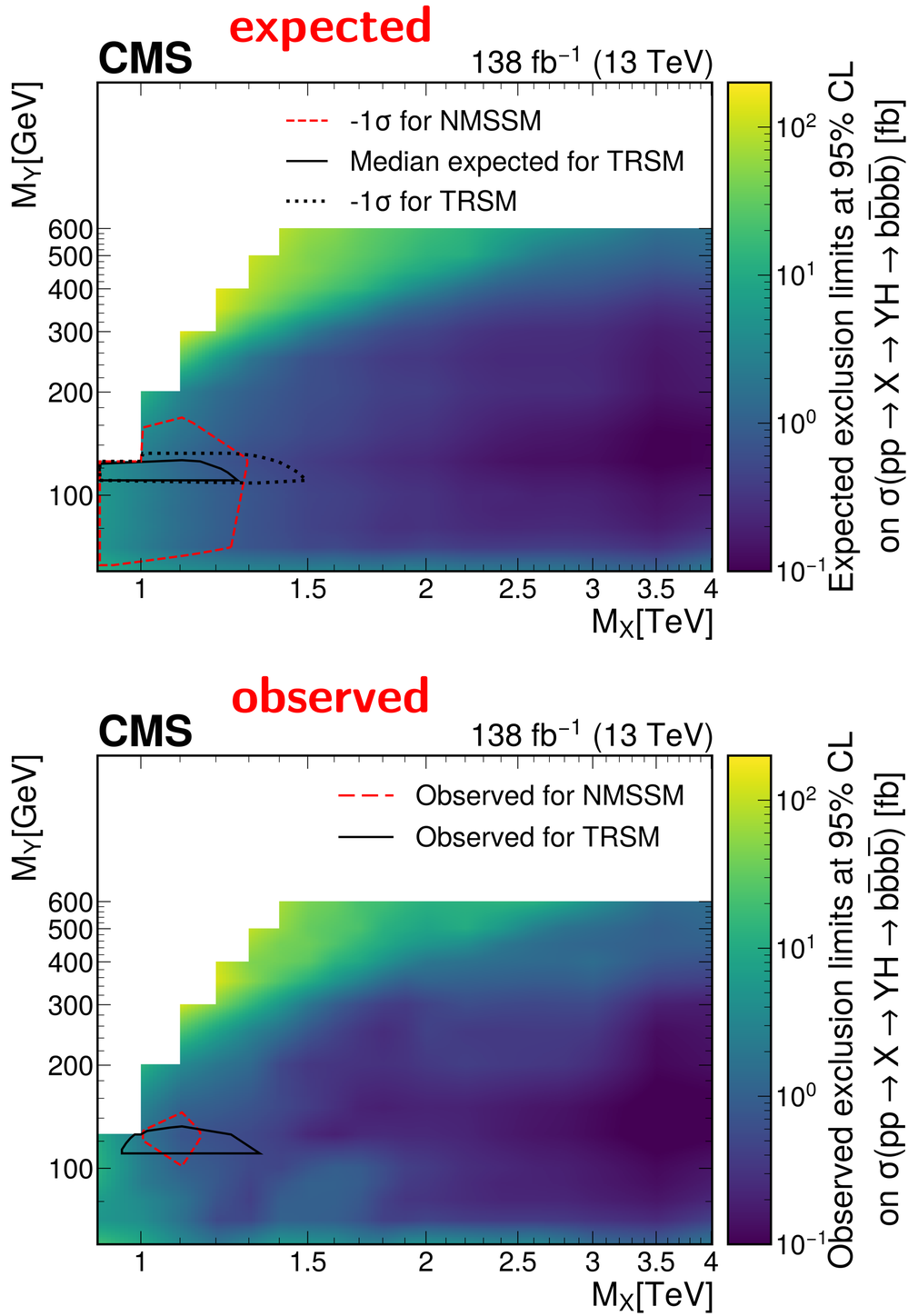
- graph convolutional NN tagger (ParticleNet) to separate signal from background
- signal categories based on ParticleNet score
- fit on m_J and m_{JJ} in signal and background regions



- limits from 0.1 to 150 fb
- highest observed local significance 3.1σ at mX=1.6 TeV, mY=90 GeV (0.7σ global)
- exclude areas assuming maximally allowed cross sections
  - NMSSM:

    m_X [1.00, 1.15] TeV, m_Y [101, 145] GeV
  - TRSM:

    m_X [0.95, 1.33] TeV, m_Y [110, 132] GeV



Scope

- resonant HH production
- X: mass range [1, 3] TeV, spin 0/2

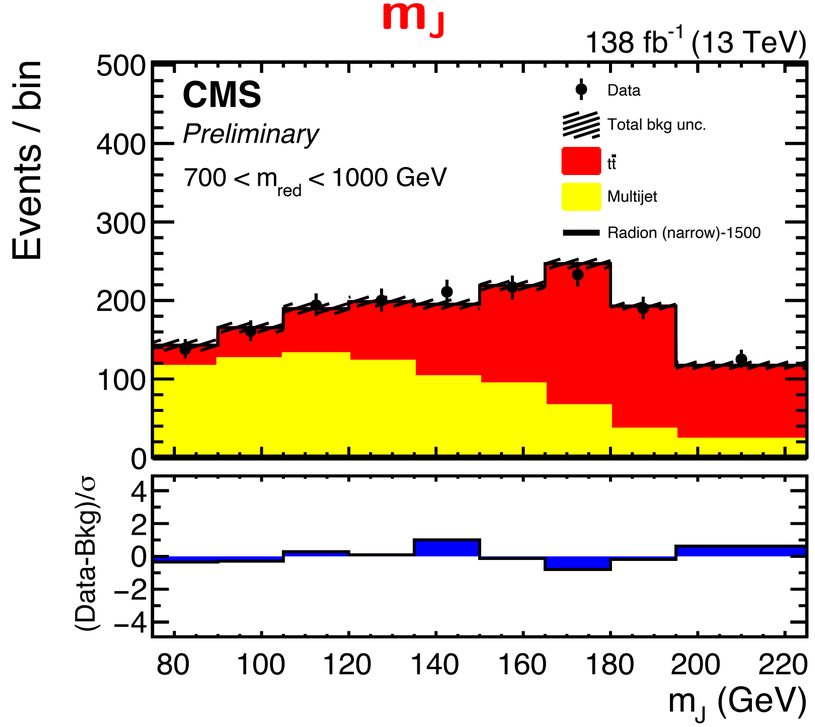
Phase space

- HH→4b, at least one b pair overlapping
- backgrounds: QCD, $t\bar{t}$

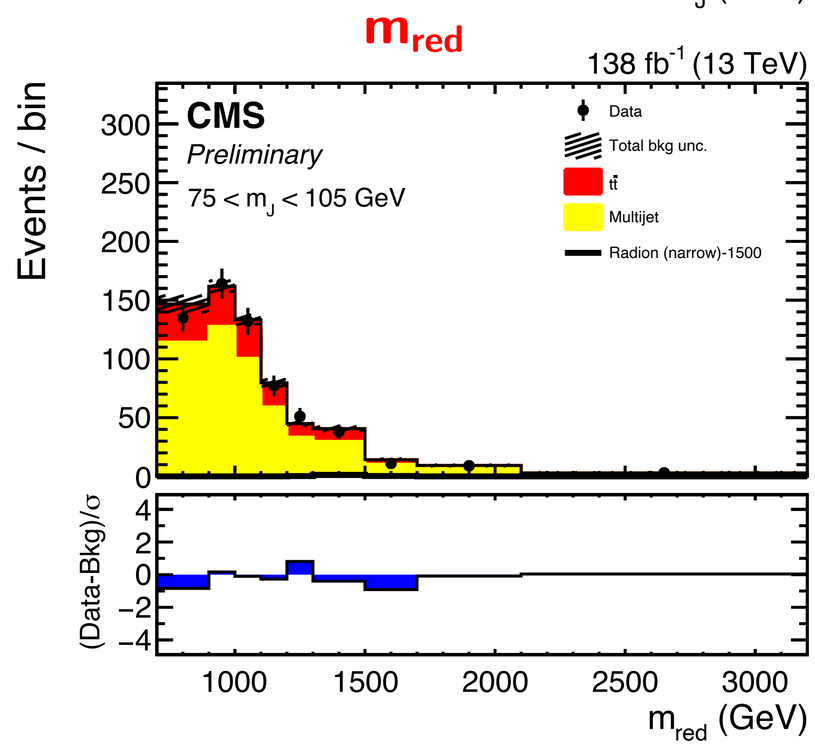
Strategy

- boosted: both H reconstructed as large-radius jets
- semi-resolved: 1 large-radius, 2 small-radius jets
- sub-categories based on mass decorrelated H→bb tagger (DeepAK8) and mass of the H candidates
- fit on estimated mass of X (m_{red}) and m_J

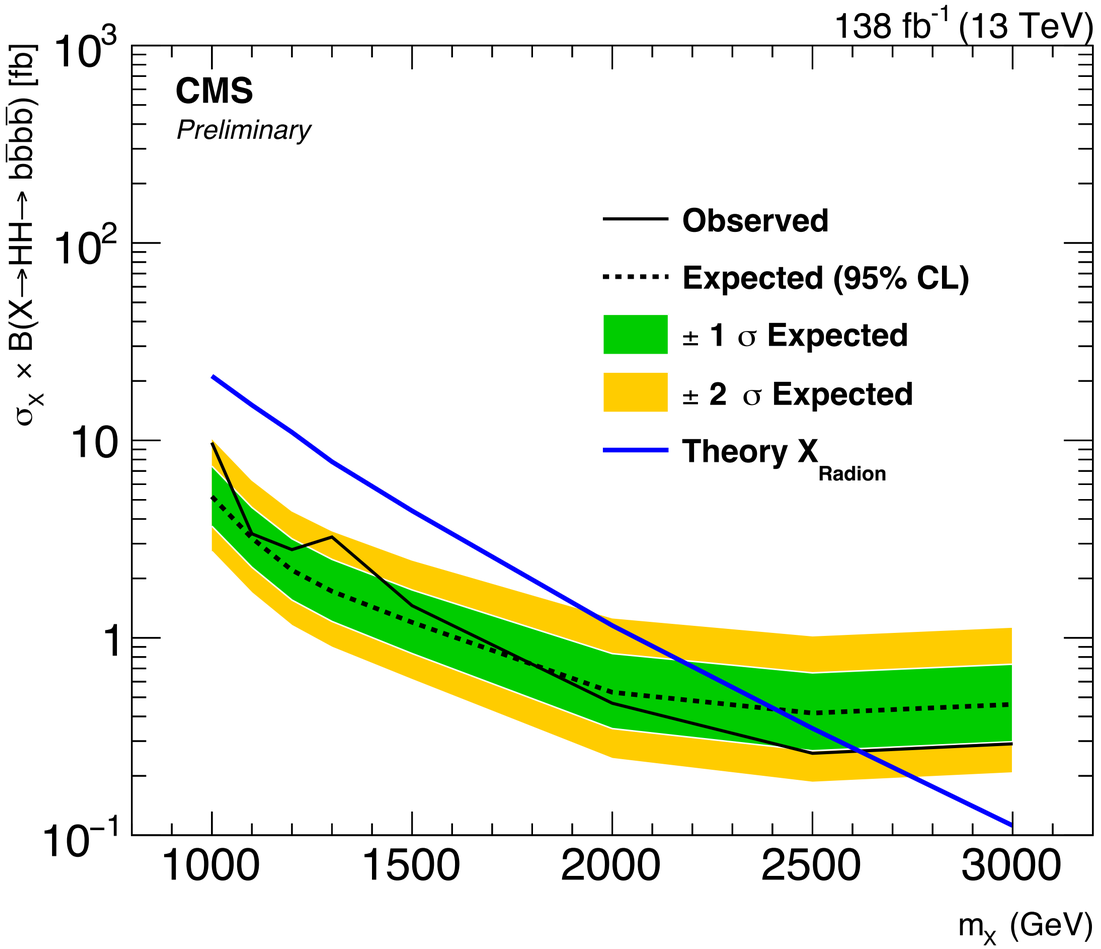
m_J



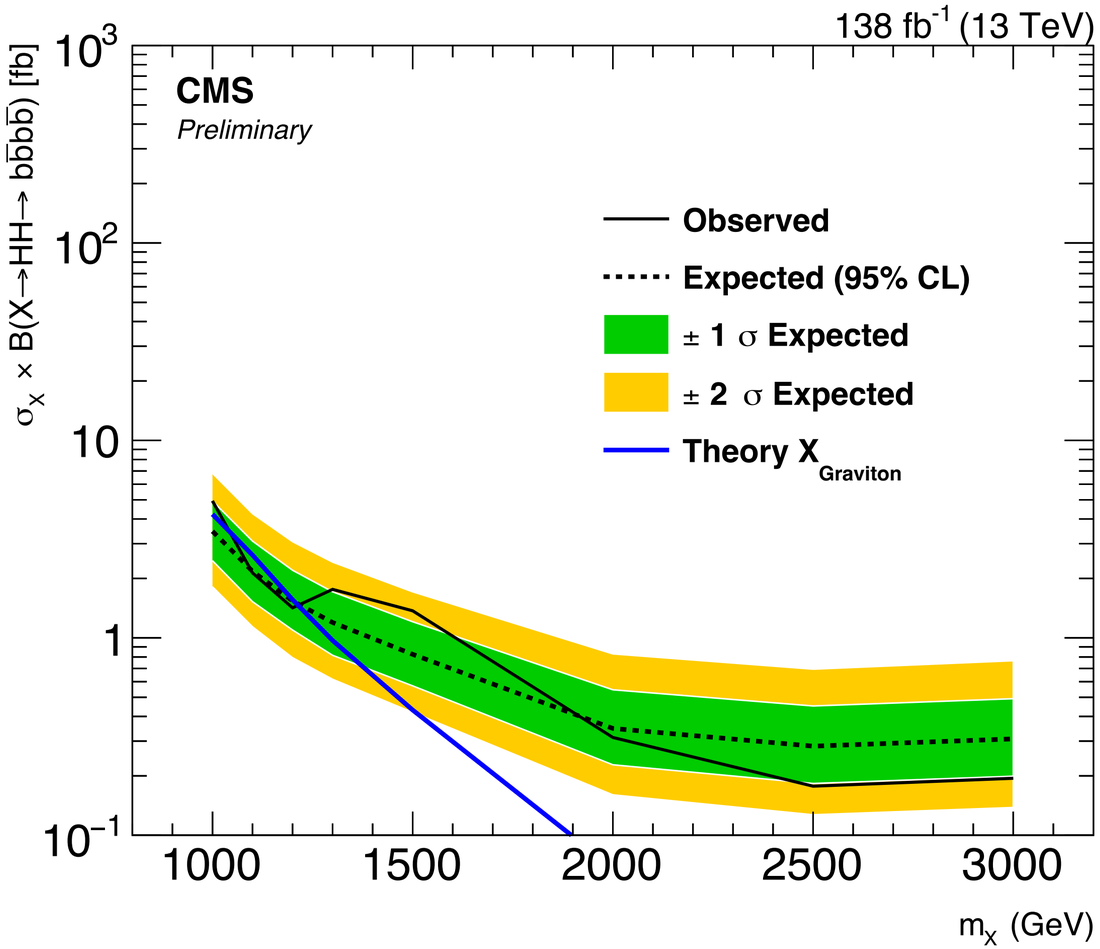
m_{red}



spin 0



spin 2



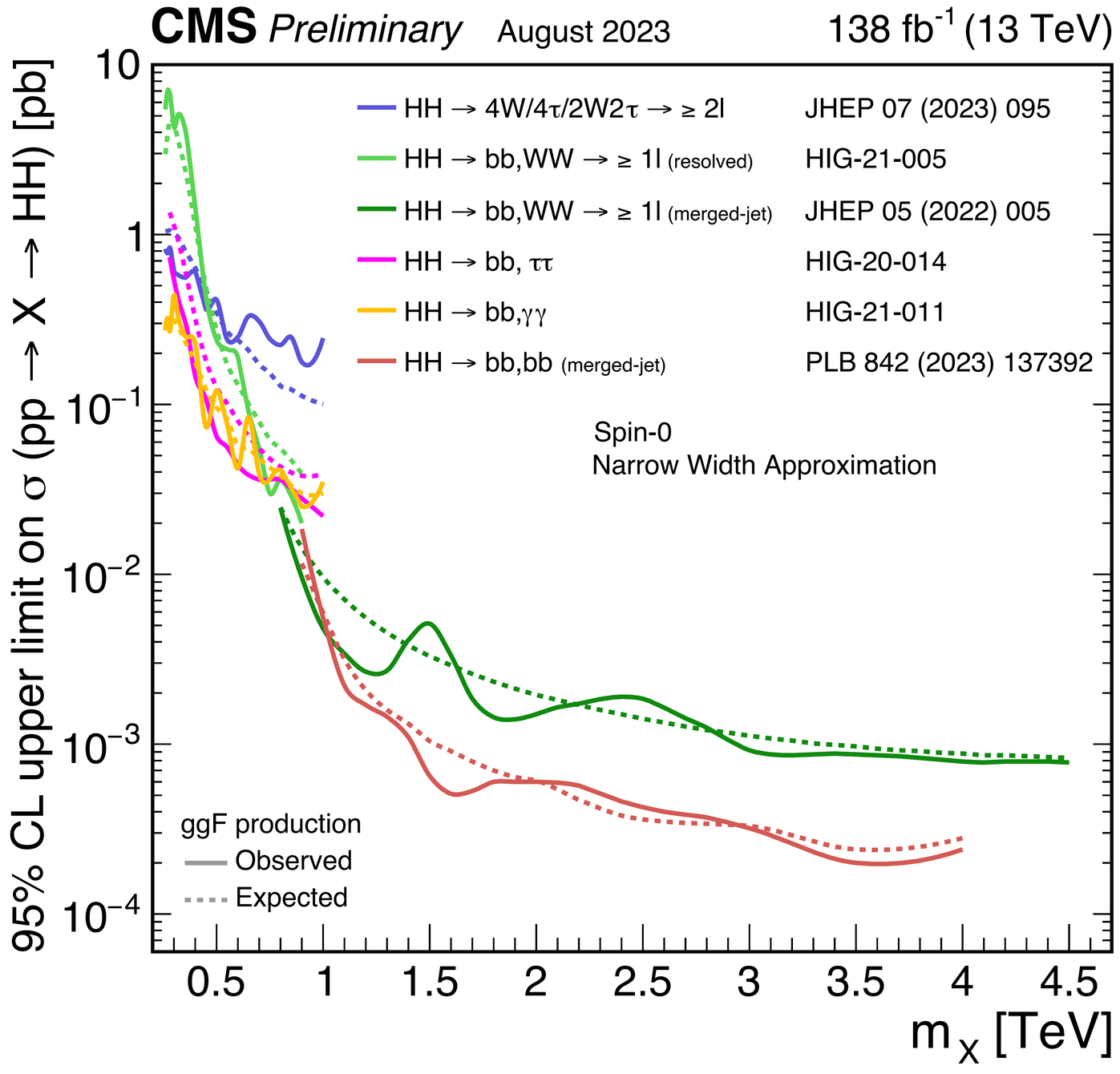
- limits on cross section x branching fraction:

  9.74 fb - 0.29 fb (spin 0)

  4.94 fb - 0.19 fb (spin 2)

- presented the latest full Run 2 resonant HH/HY searches performed by CMS
  - X→HH/HY→γγbb
  - X→HH→bbWW
  - X→HH→Multilepton
  - X→HY→bbbb (boosted)
  - X→HH→bbbb

- more analyses targeting additional HH decay modes as well as a combination on the horizon



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Thank you for your attention