Heavy Higgs Searches from CMS

Brian Pollack
Northwestern University
10/7/15

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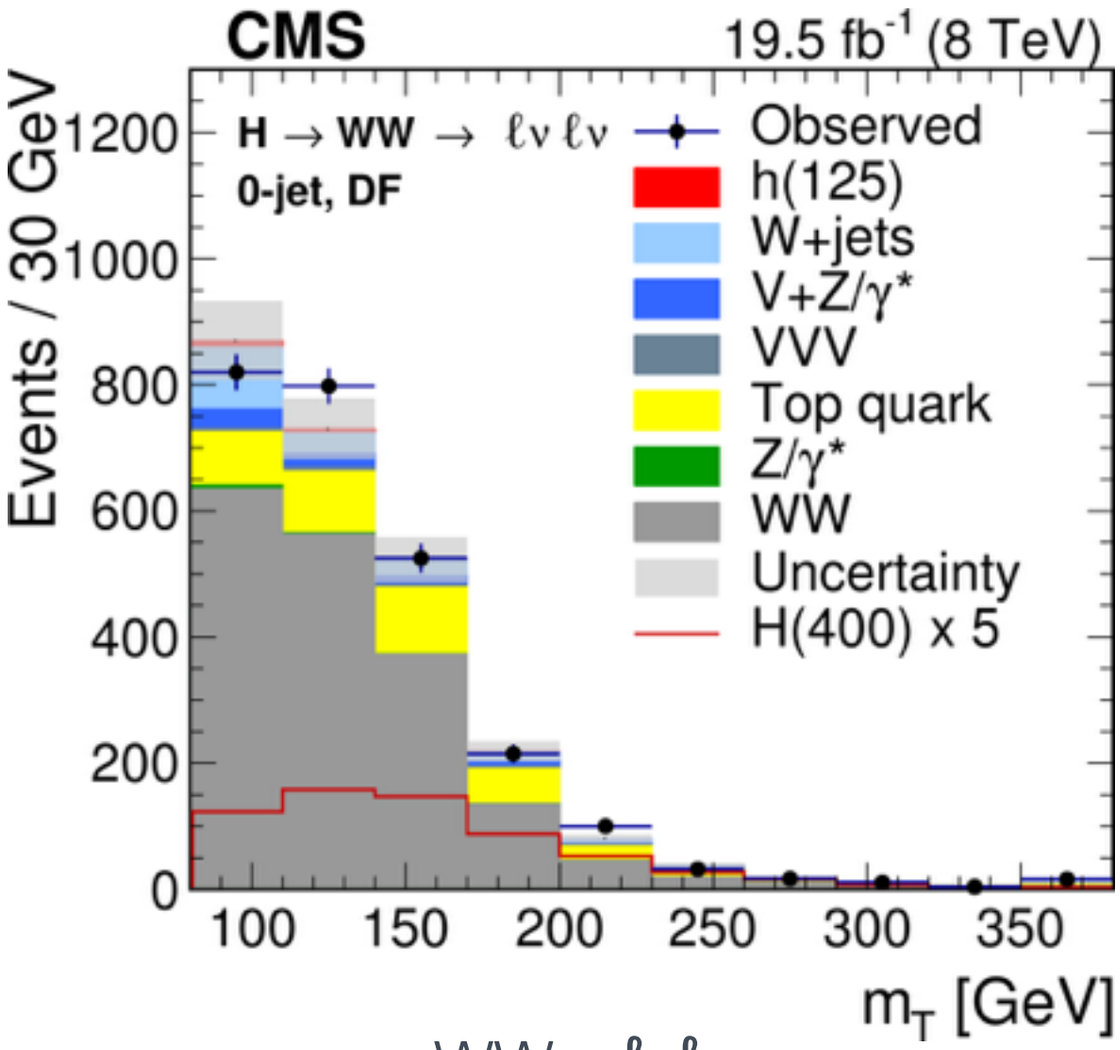
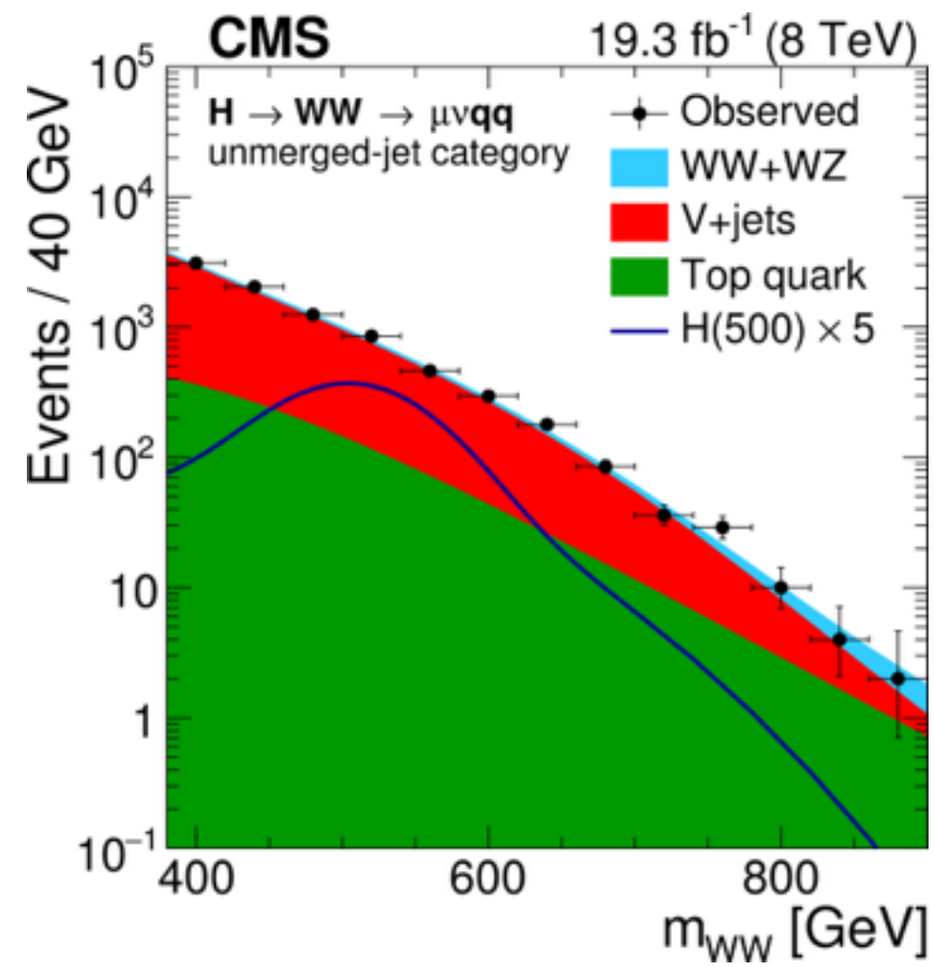
  - WW/ZZ
  - γγ, Zγ
  - Zh, ZA/ZH
  - hh
- ★ **Comparison and Conclusion**

arXiv:1504.00936

H→WW/ZZ

5 fb^{-1} @ 7 TeV + 20 fb^{-1} @ 8TeV





WW→ℓνℓν

ee,μμ,eμ

Higher sensitivity for

low mass

WW→ℓνjj (ℓνJ)

eνjj,μνjj

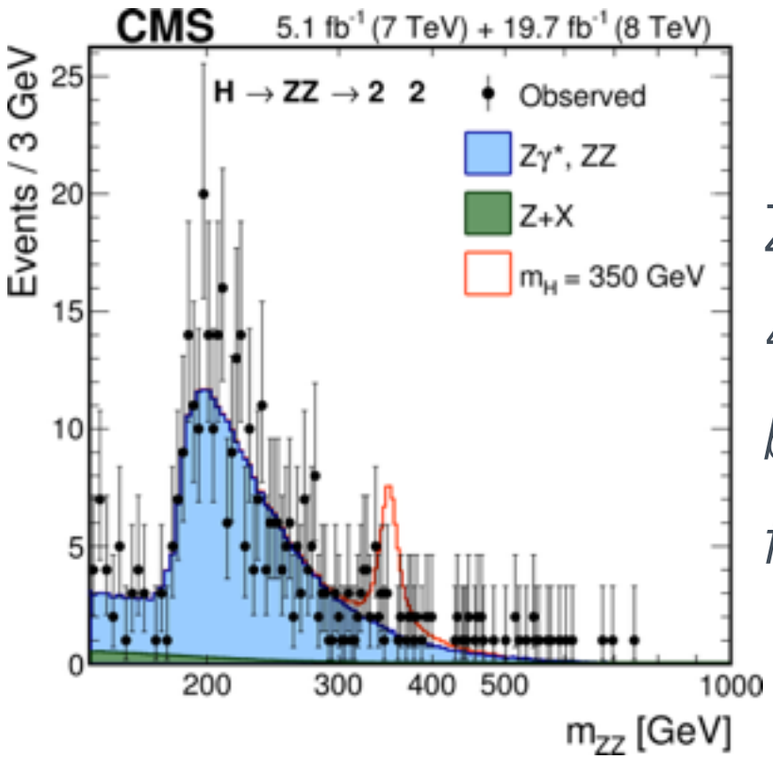
eνJ,μνJ

J: merged jets

arXiv:1504.00936

H→WW/ZZ

5 fb^{-1} @ 7 TeV + 20 fb^{-1} @ 8TeV



ZZ→ℓℓℓℓ

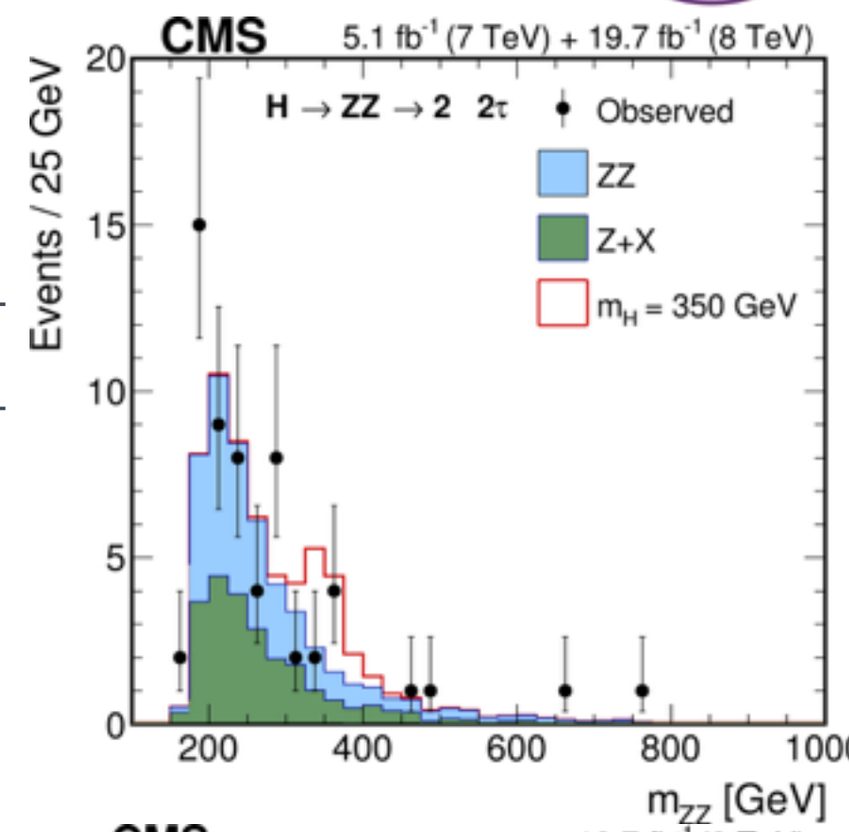
4e,4μ,2e2μ

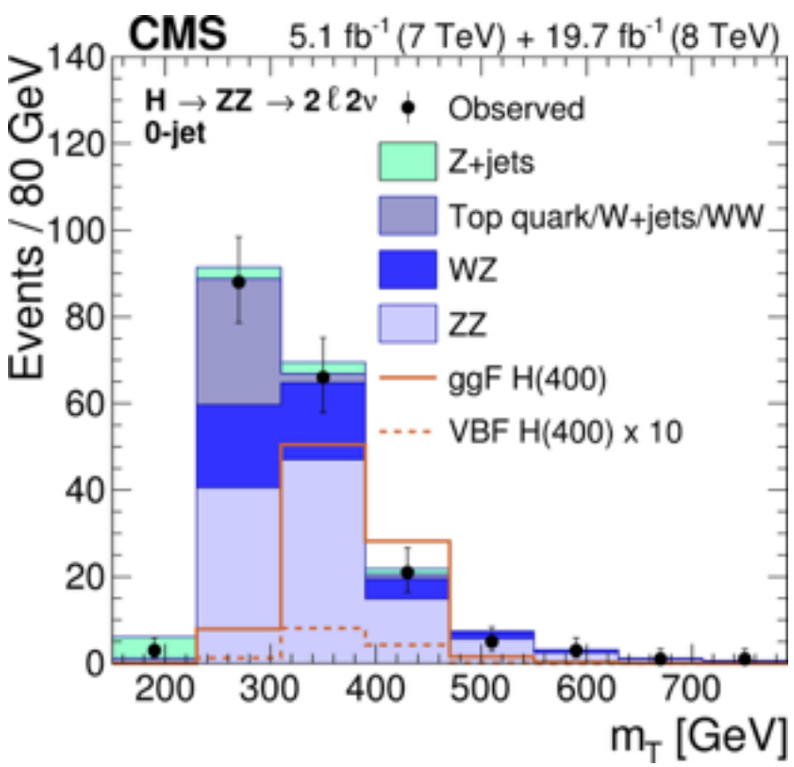
best sensitivity

for lower masses

ZZ→ℓℓττ

eeττ,μμττ





ZZ→ℓℓνν

eeνν,μμνν

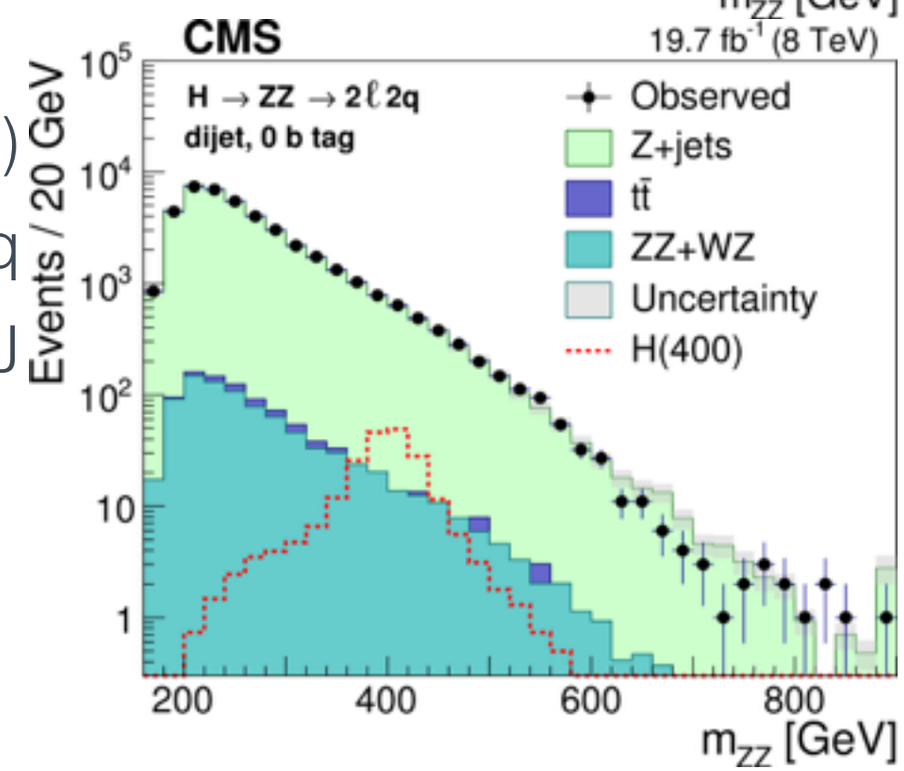
best sensitivity

for higher masses

ZZ→ℓℓqq(ℓℓJ)

eeqq,μμqq

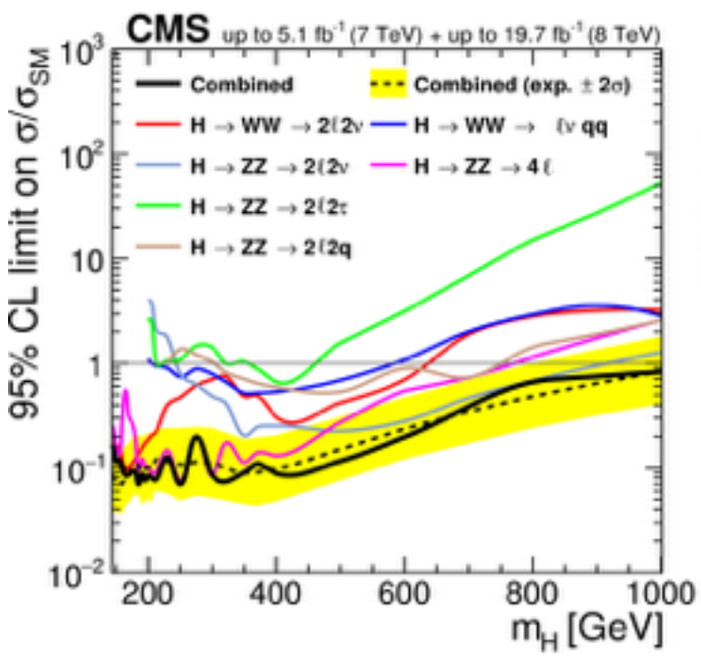
eeJ,μμJ

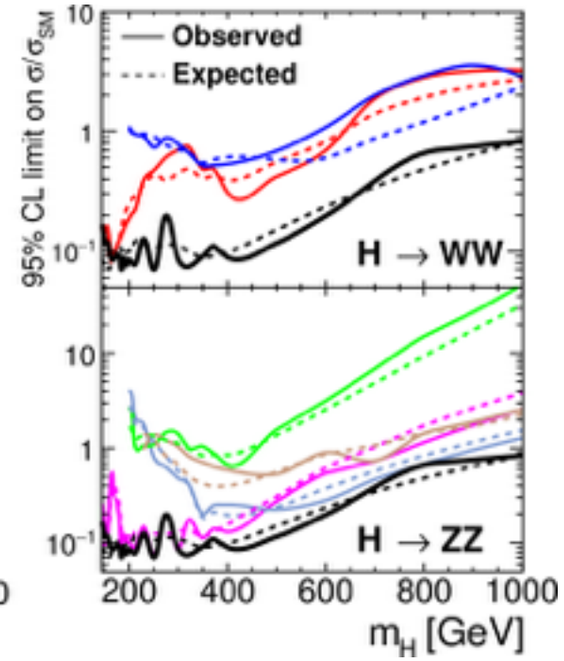


H→WW/ZZ

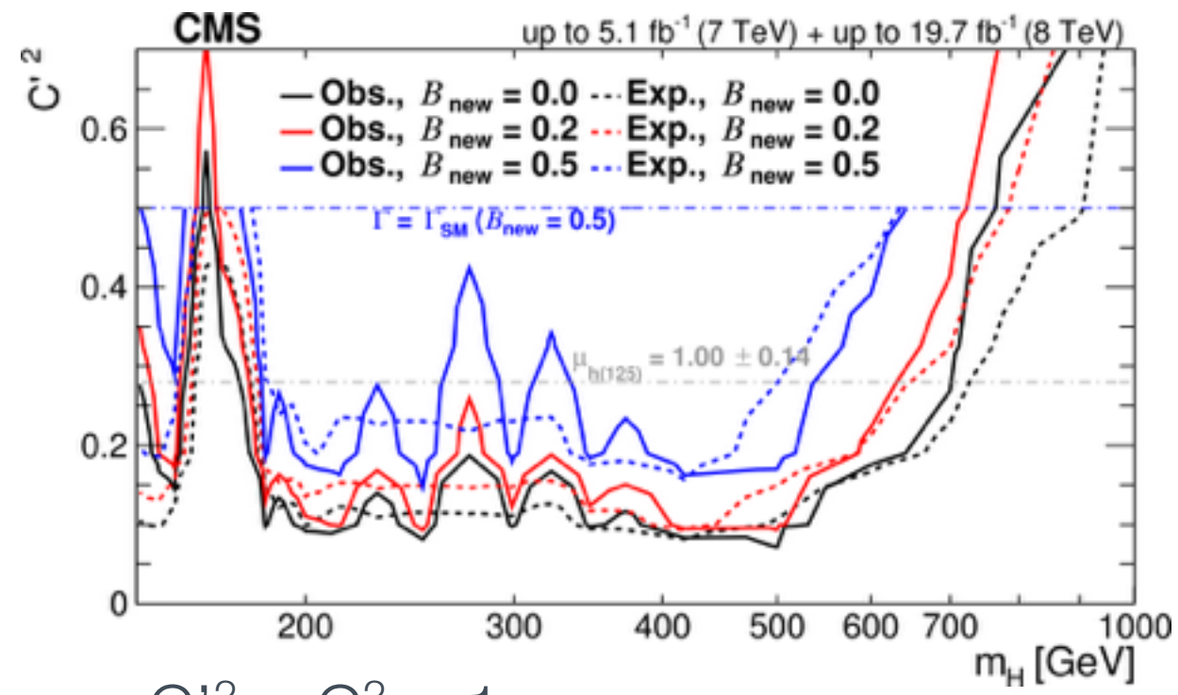
arXiv:1504.00936

Limits for SM h coupling



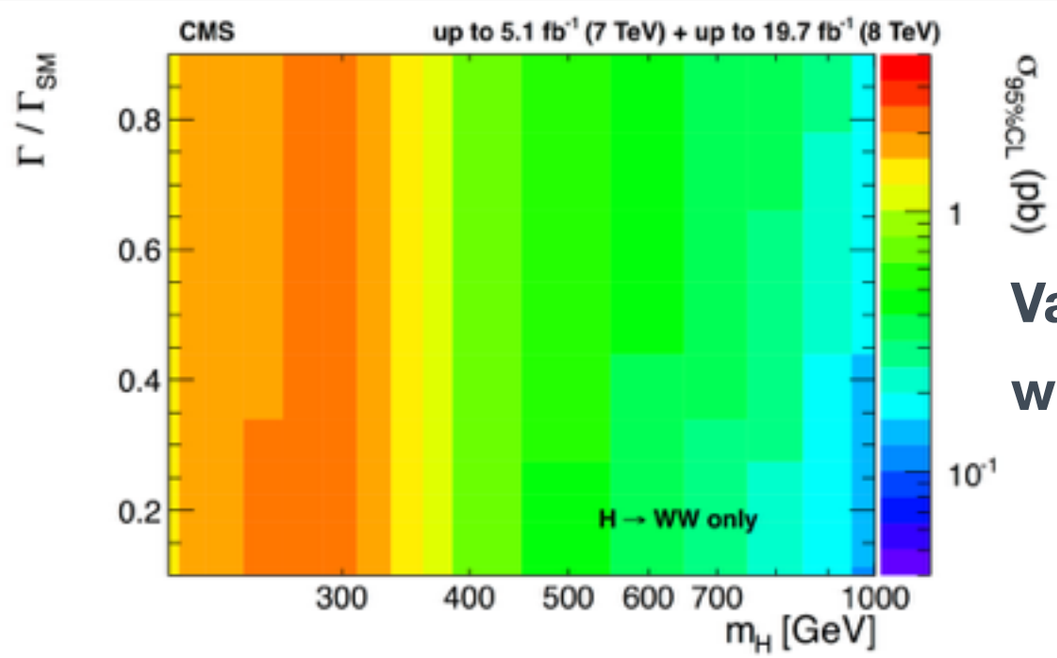


Limits for EWK Singlet C'

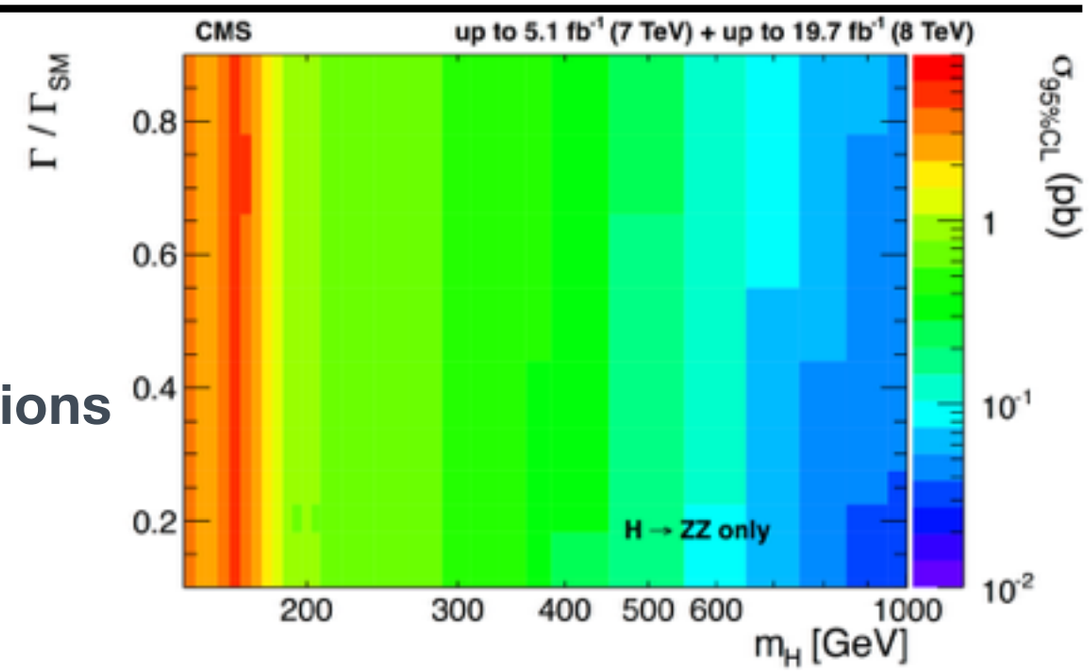


$C'^2 + C^2 = 1$,

C (C') → coupling for h (H) to V



Varying signal width assumptions



cds.cern.ch/record/1997885

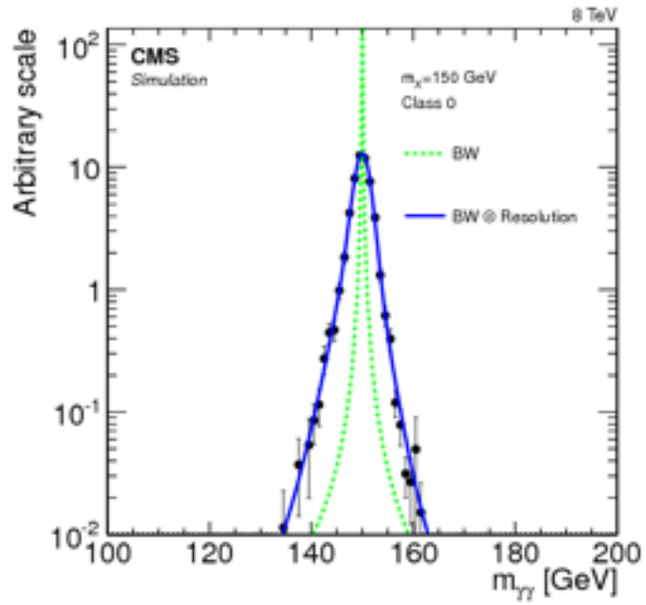
arXiv:1506.02301

$X \rightarrow \gamma\gamma / Z\gamma$

$X \rightarrow \gamma\gamma$

20 fb^{-1} @ 8TeV

$X \rightarrow Z\gamma$



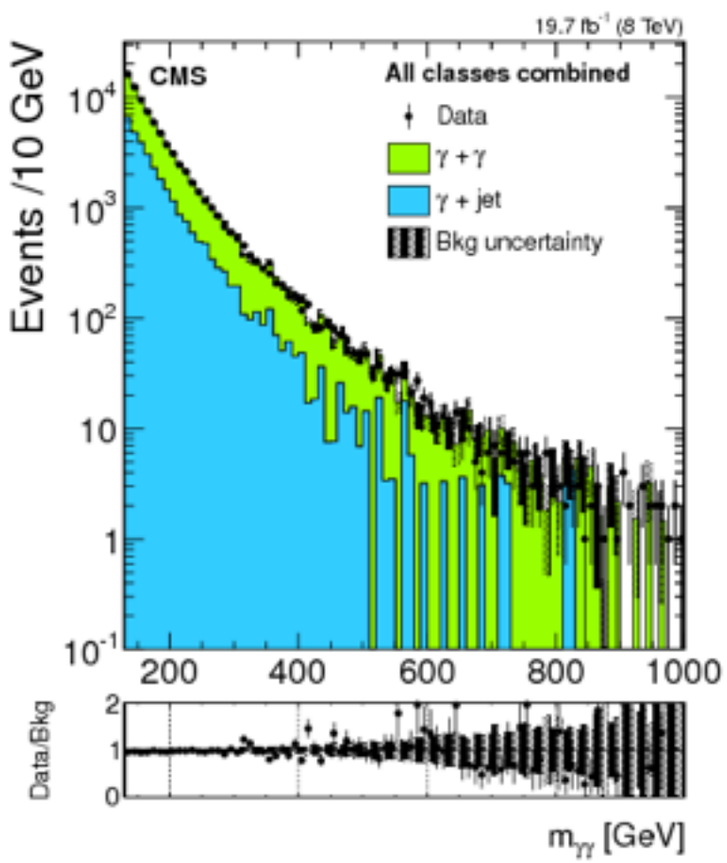
Signal Width: Narrow to broad widths investigated.

Spin 0 and spin 2 signals.

Narrow (0.1 GeV), Broad (10% m_X)

Spin 0 only

Narrow (1% m_X), Broad (Γ_h^{SM})

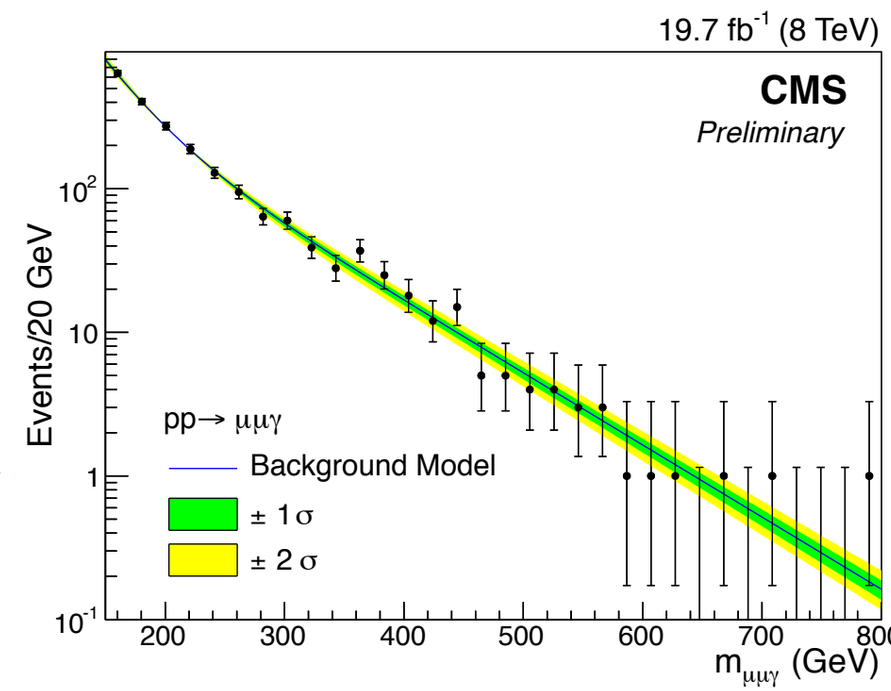


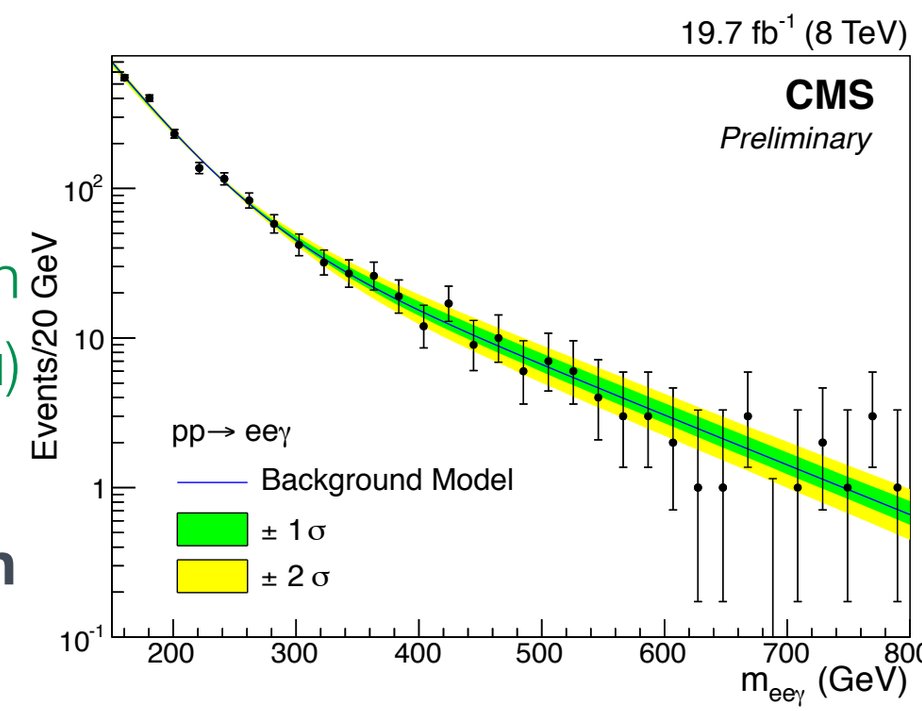
Event Categorization

Events categorized w.r.t γ shower shape and η_γ.

Events categorized w.r.t lepton flavor (ee, μμ)

Backgrounds estimated through parametric data driven techniques.

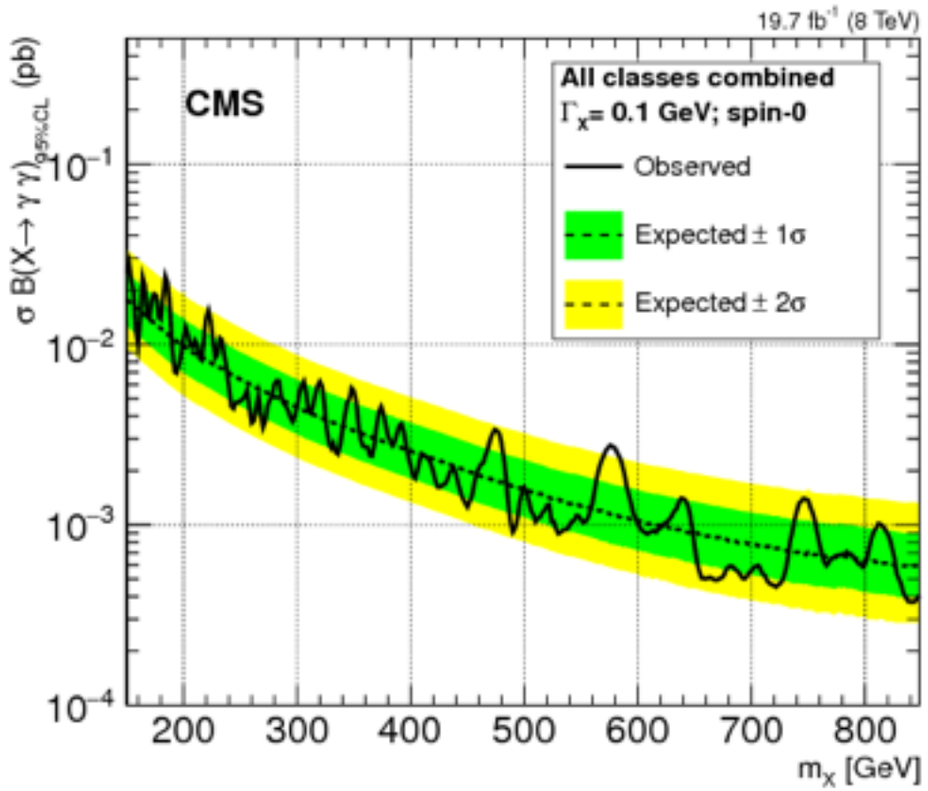




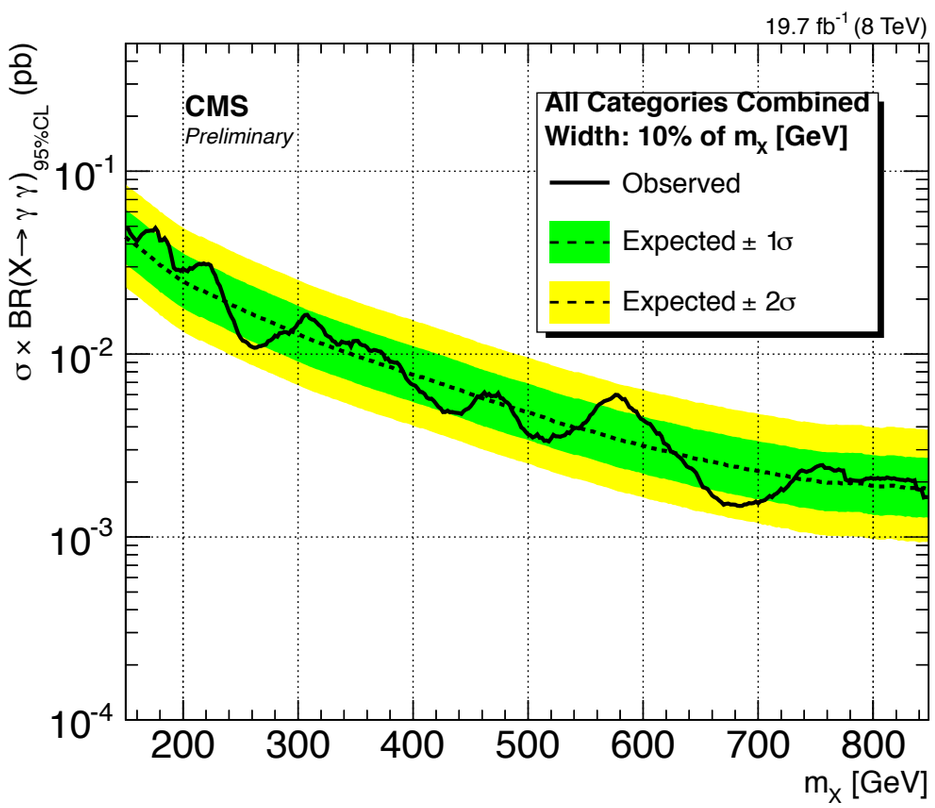
cds.cern.ch/record/1997885

arXiv:1506.02301

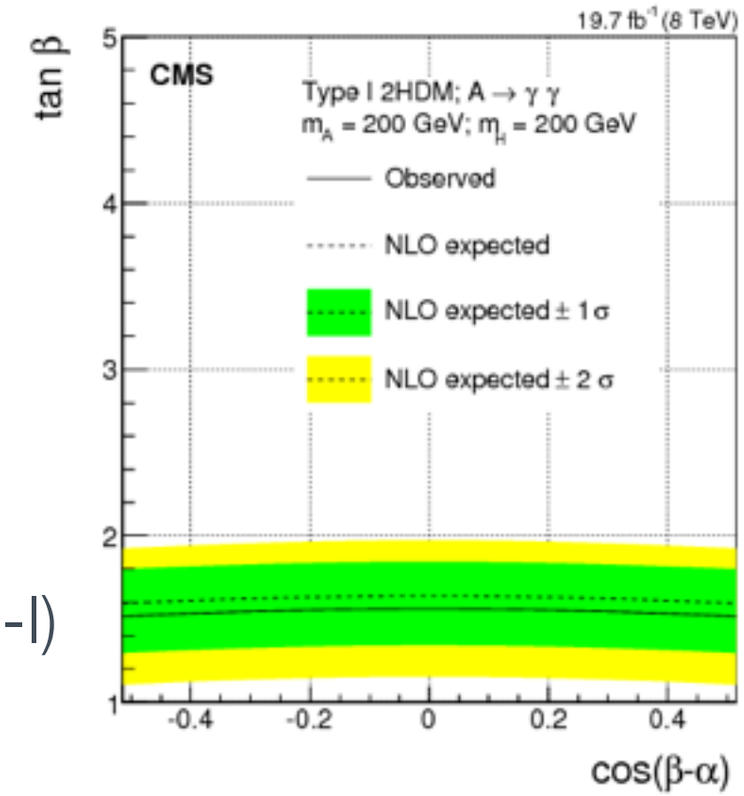
$X \rightarrow \gamma\ \gamma\ /Z\ \gamma$



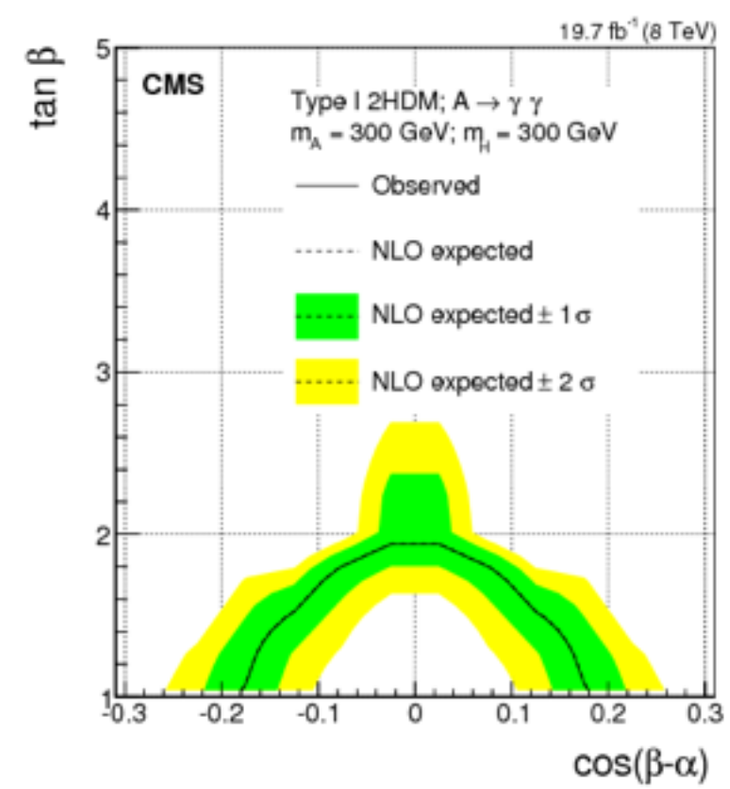
Spin-0 Limits, Narrow Width



Spin-0 Limits, Broad Width



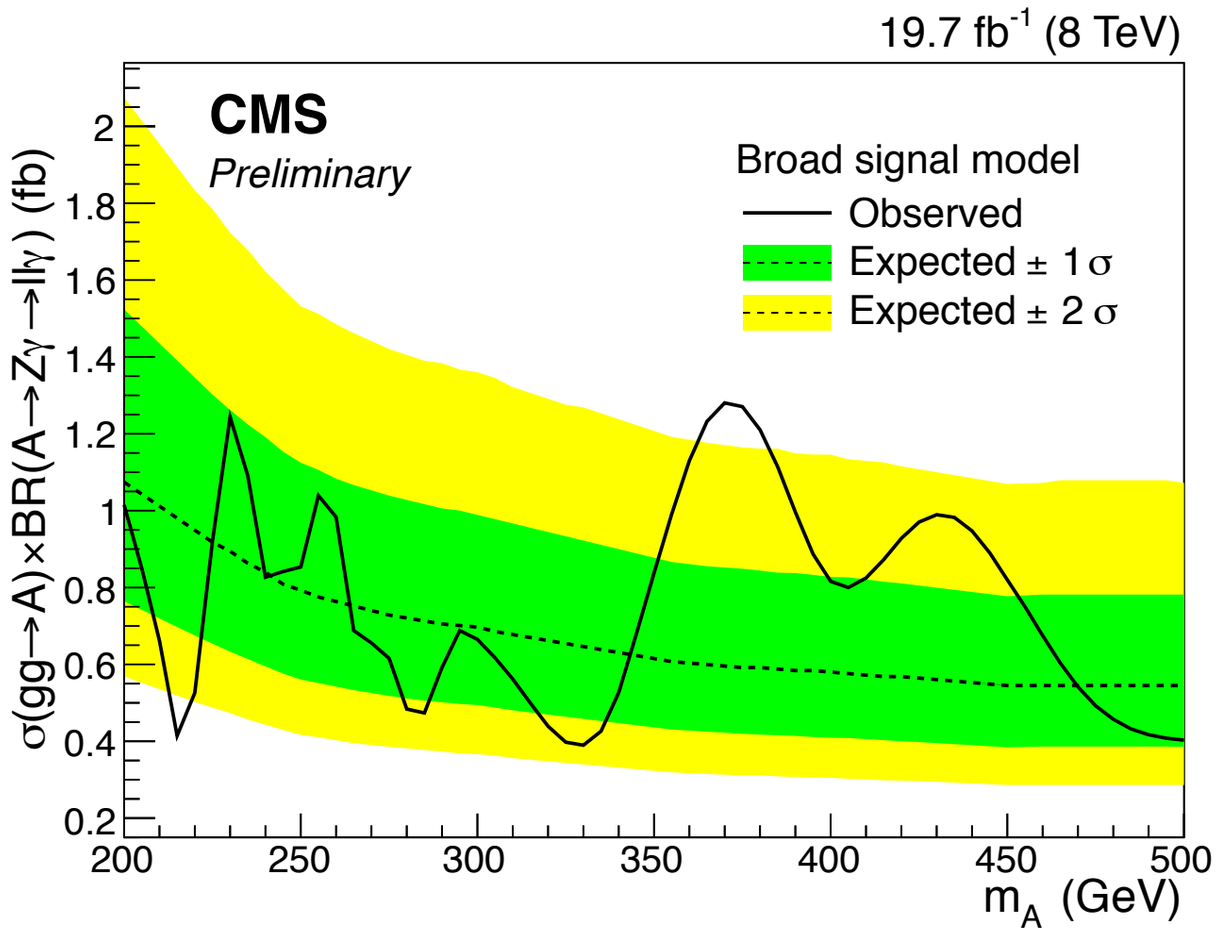
2HDM (Type-I) Parameter space limits



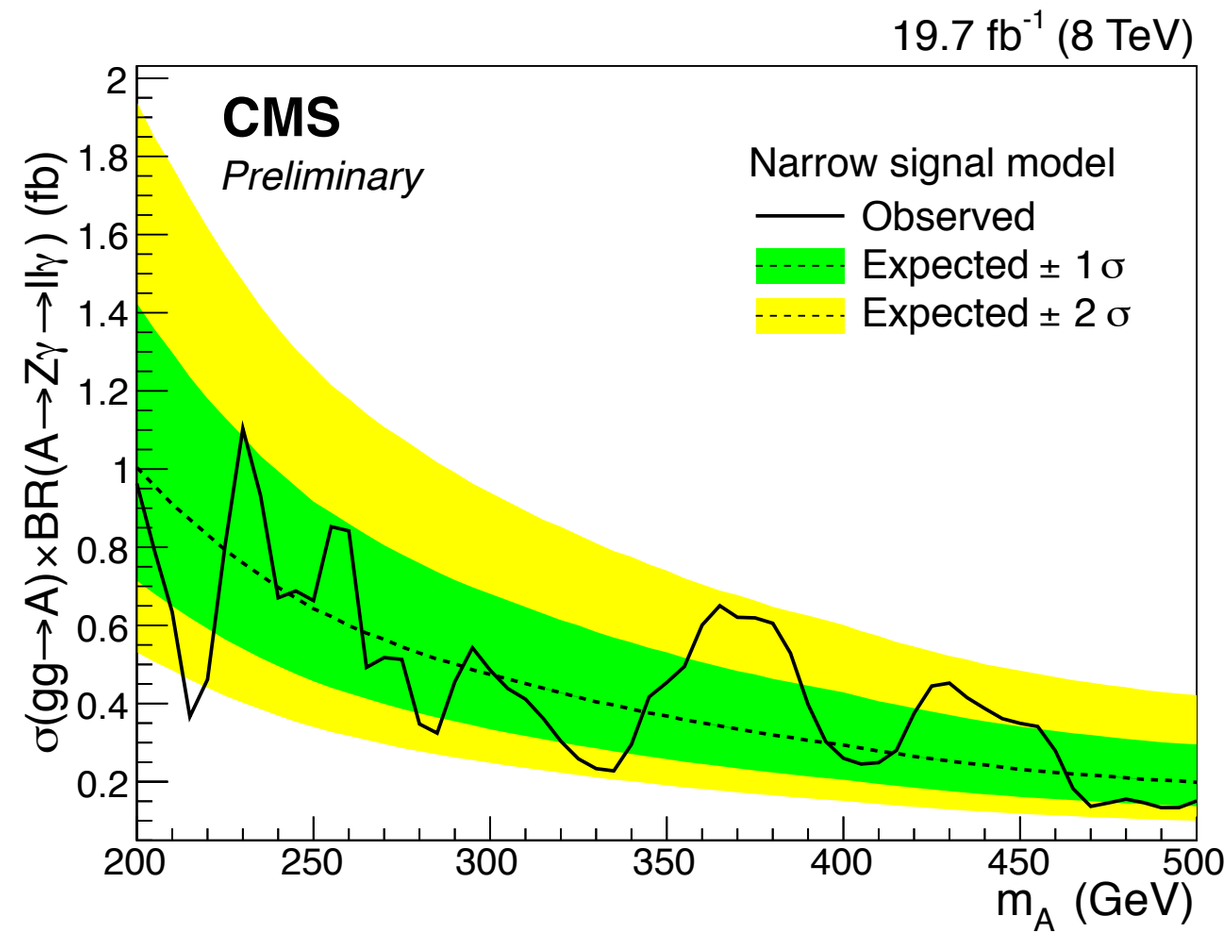
cds.cern.ch/record/1997885

arXiv:1506.02301

$X \rightarrow \gamma\gamma / Z\gamma$



Broad signal width



Narrow signal width

Zh/ZH/ZA

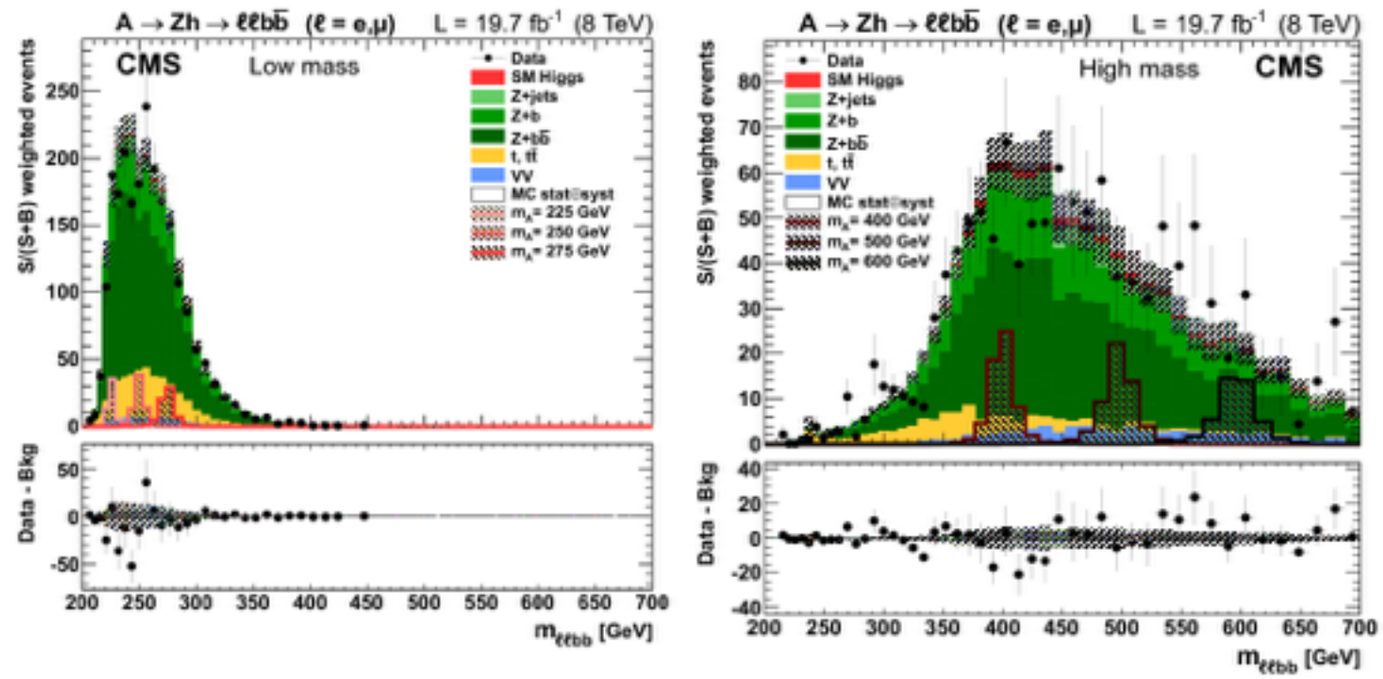
cds.cern.ch/record/2014119

arXiv:1504.04710

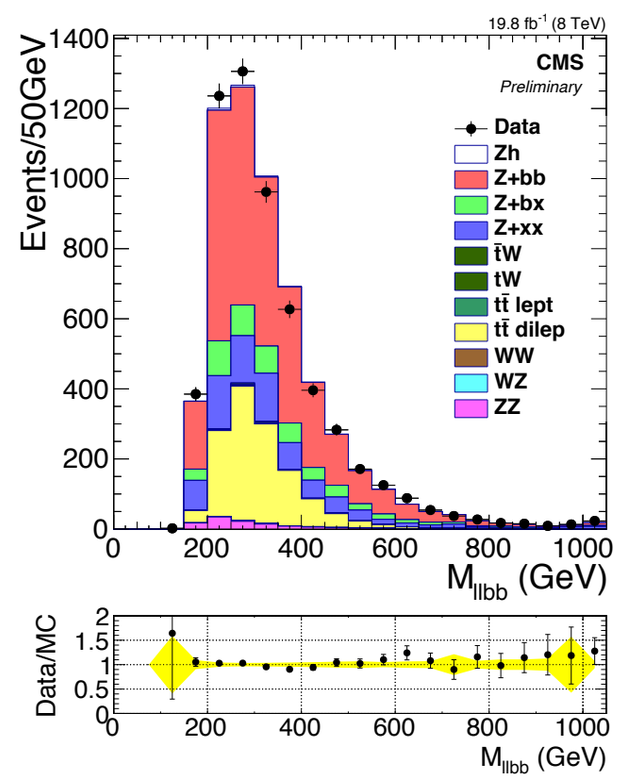
Motivated by 2HDM.

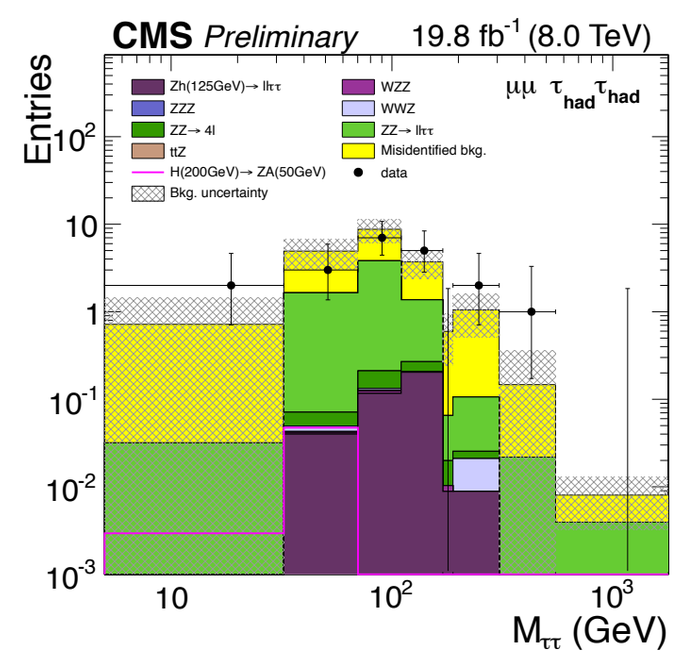
- ★ **A→Zh→ℓℓbb, SM h**
  - **BDT optimized for low, intermediate, high mass regions**

20 fb^{-1} @ 8TeV



- ★ **H(A)→A(H)Z→ℓℓbb(ττ), Heavy H,A**
  - **ττ→eμ,eτ$_h$,μτ$_h$,τ$_h$τ$_h$**
- ★ **Large phase space in m_A, m_H**

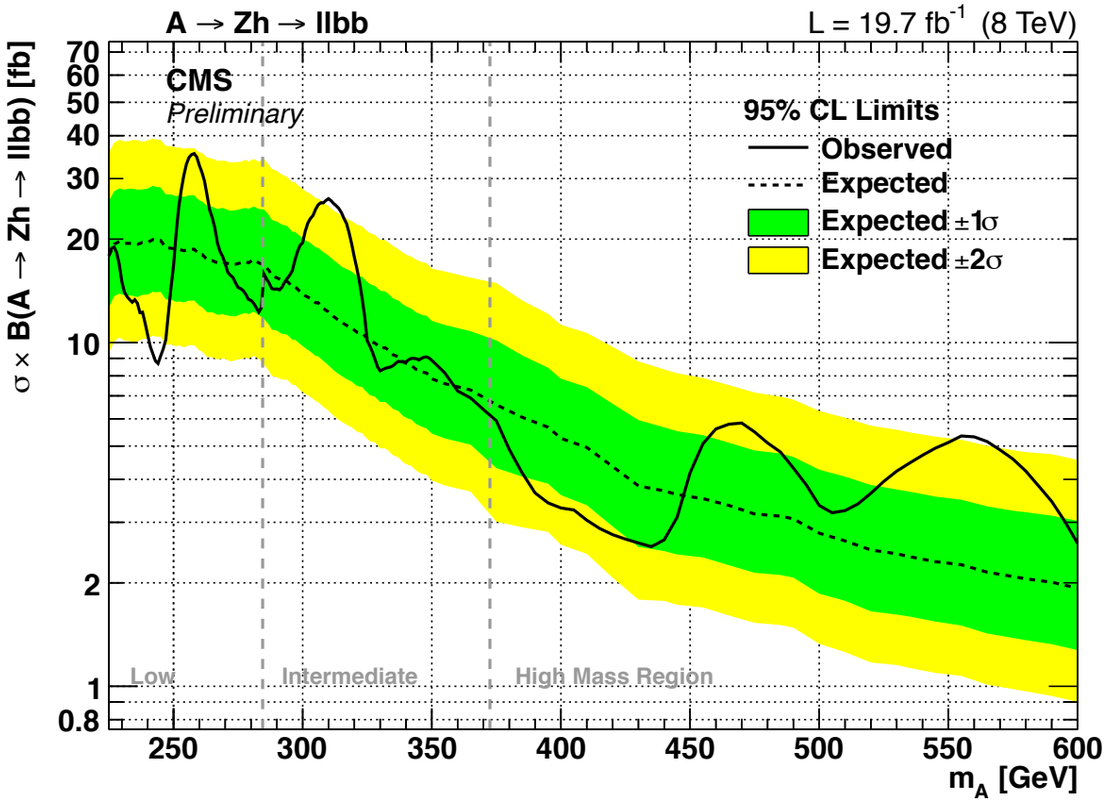




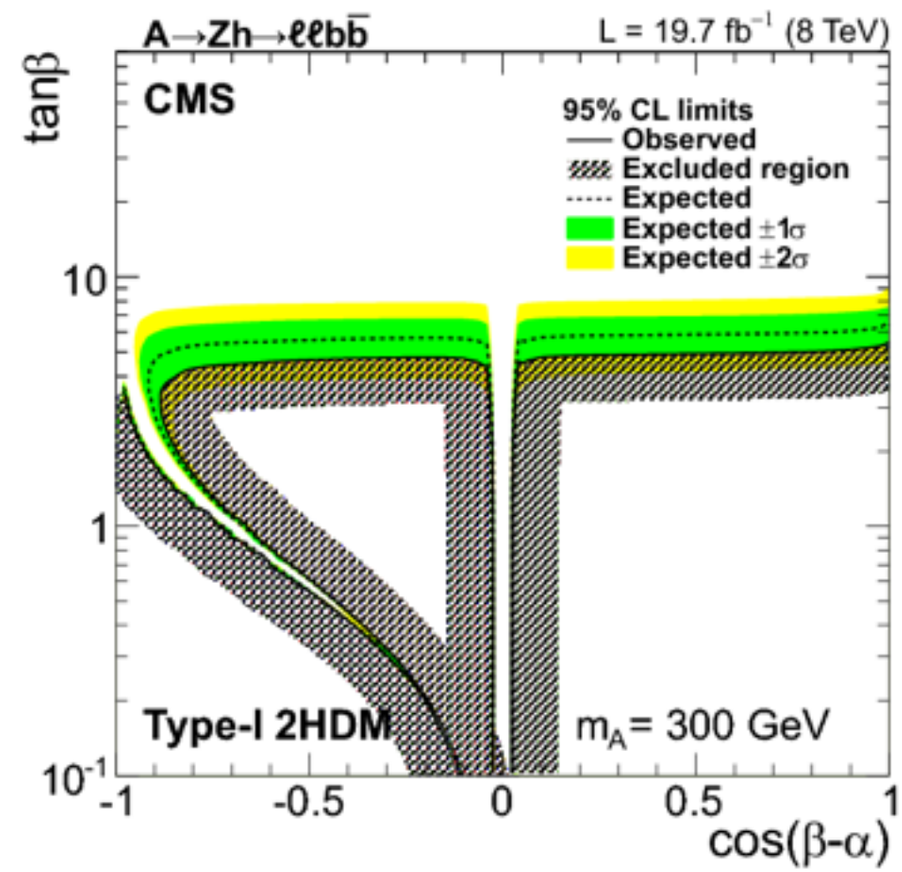
Zh/ZH/ZA

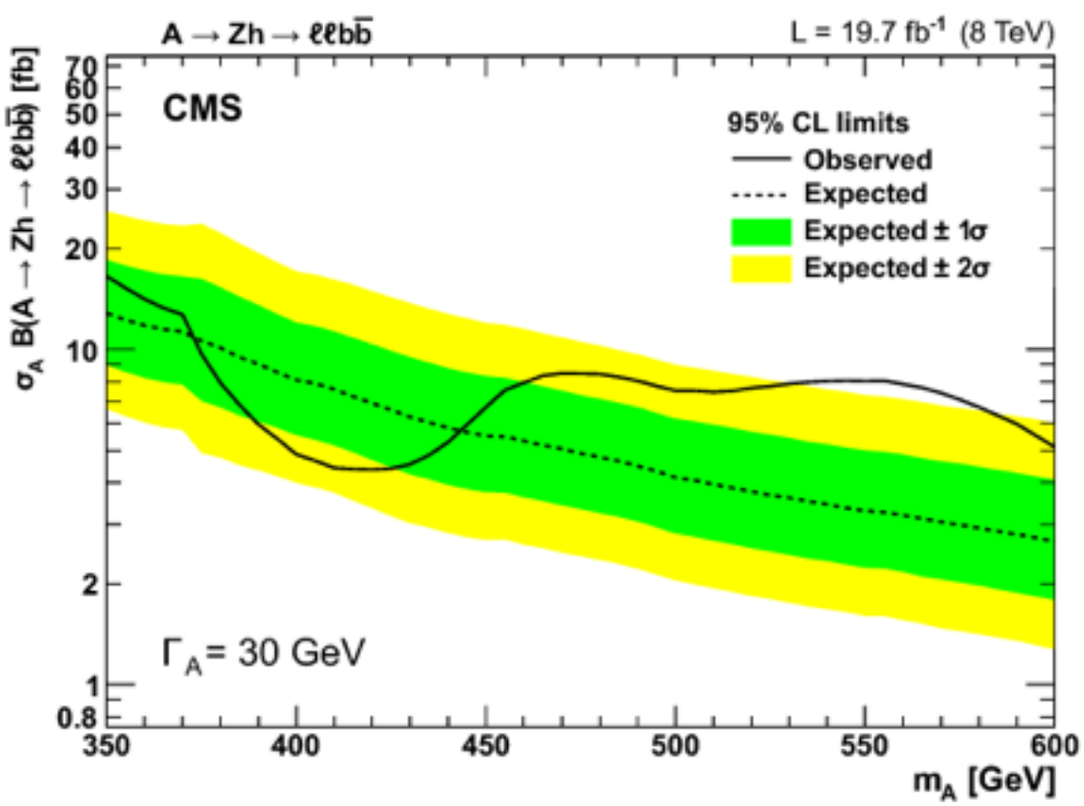
cds.cern.ch/record/2014119

arXiv:1504.04710



Narrow Width Signal (0.1 GeV)



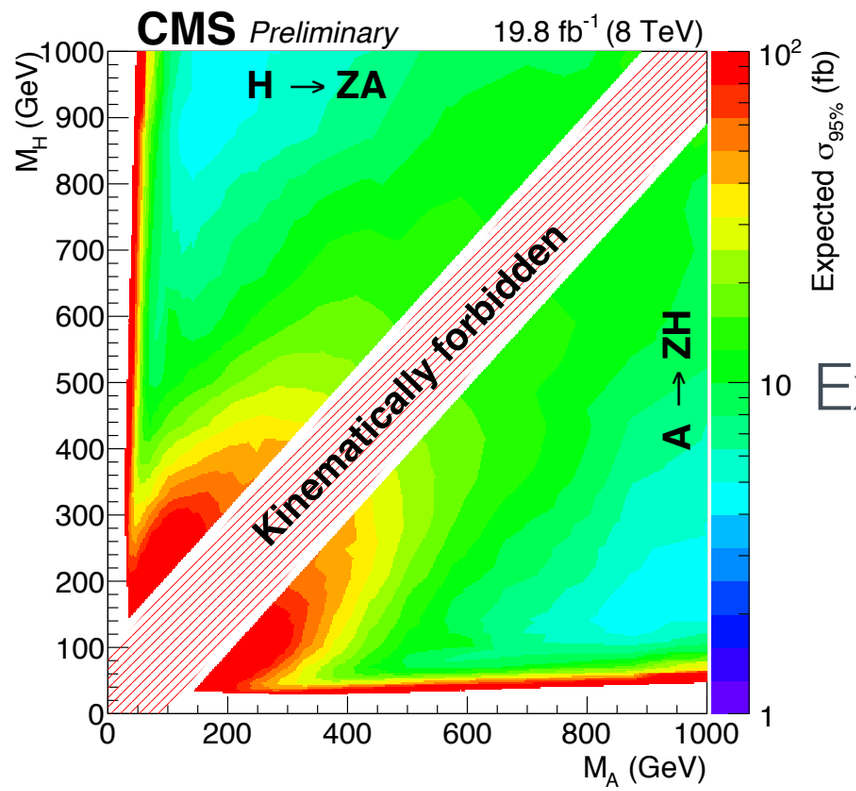


Broad Width Signal (30 GeV)

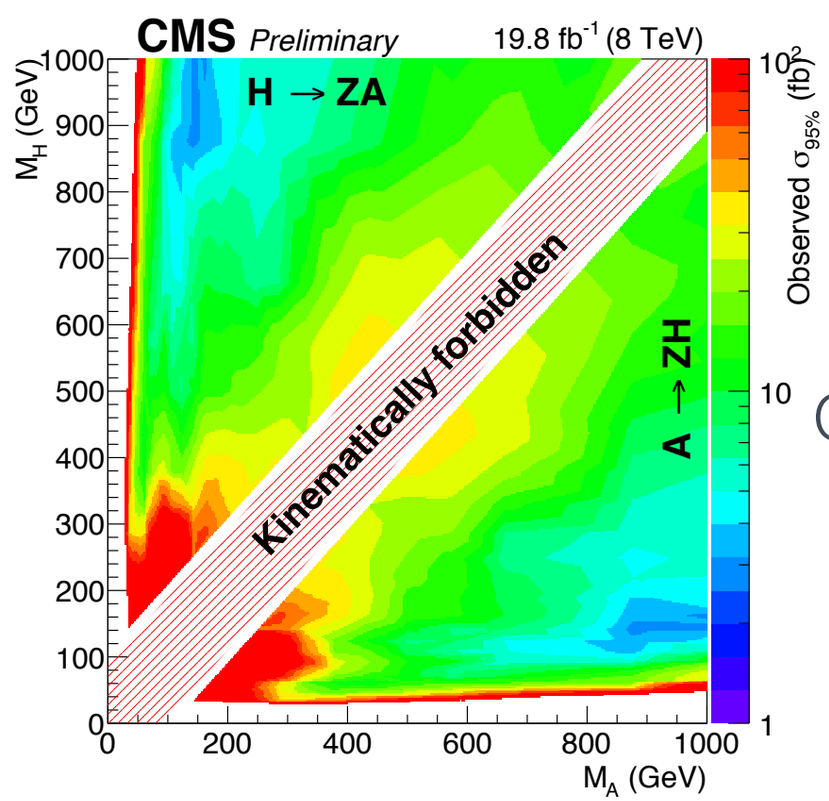
Zh/ZH/ZA

cds.cern.ch/record/2014119

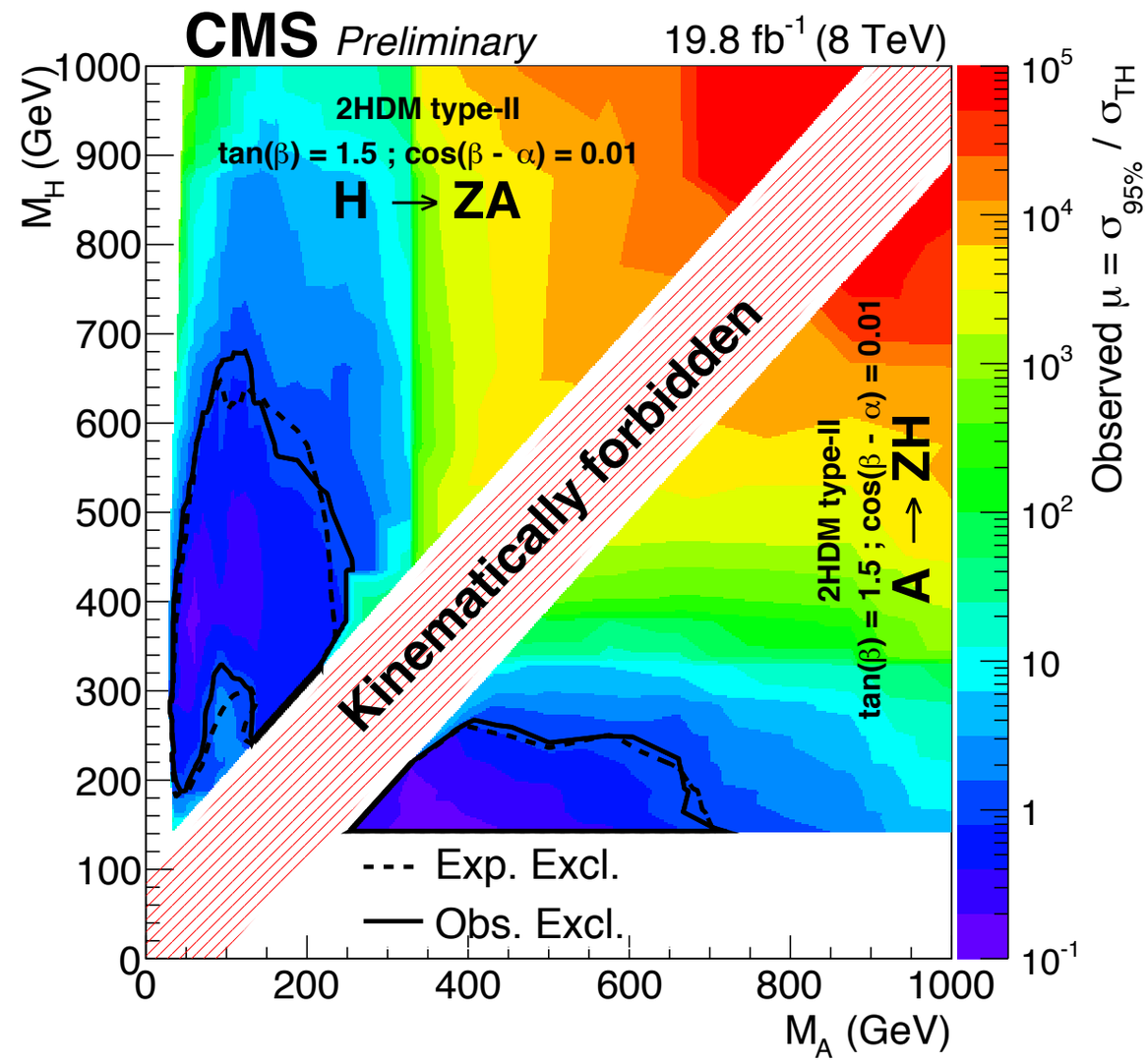
arXiv:1504.04710



Expected Limits



Observed Limits



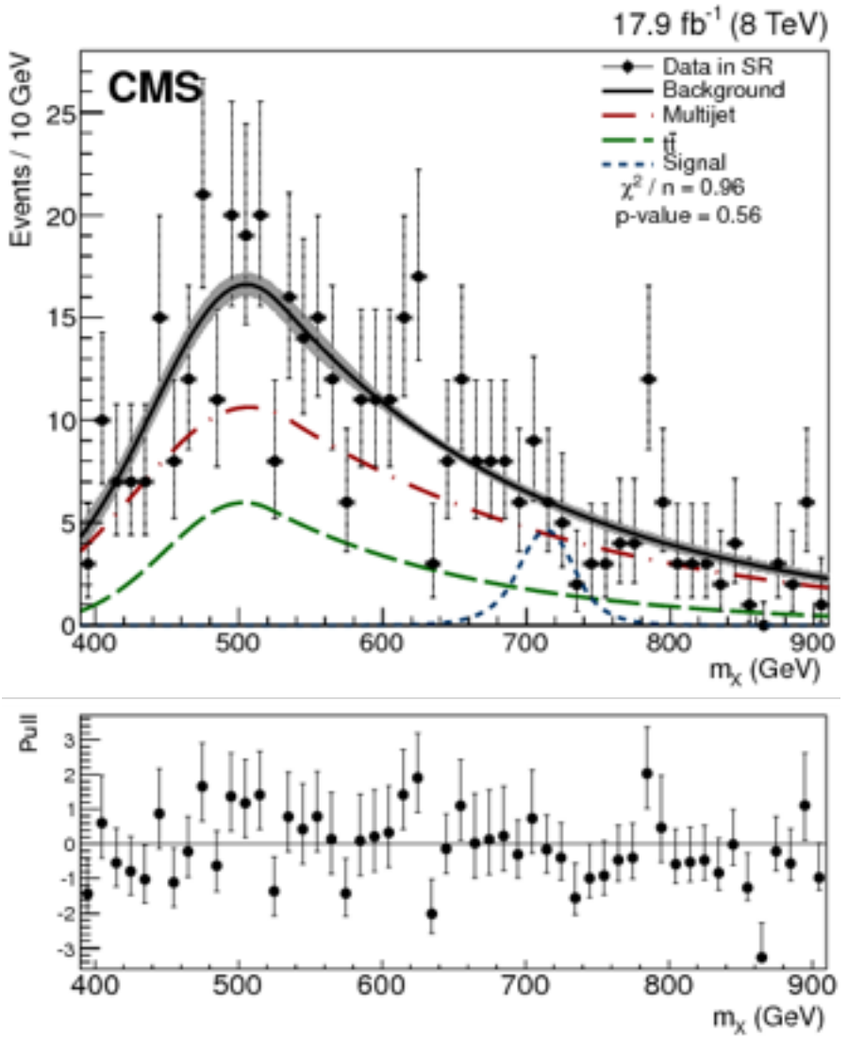
2HDM type-II

(alignment limit benchmarch)

arXiv:1503.04114

X→hh→bbbb

18 fb^{-1} @ 8TeV

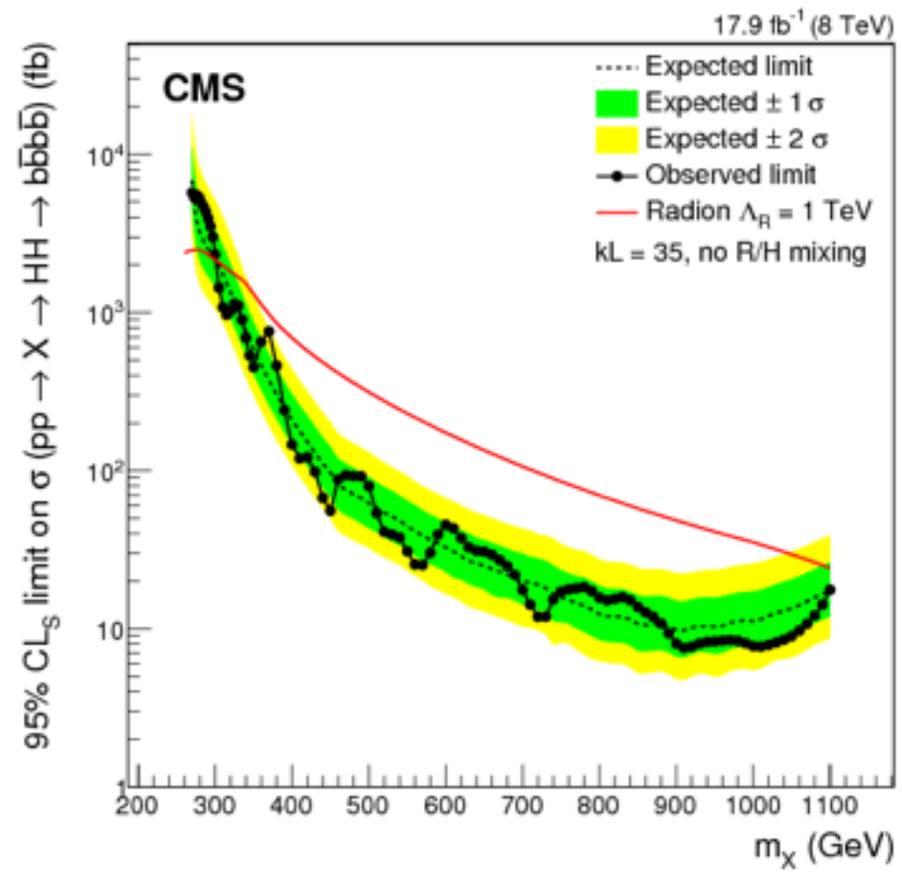


Intermediate Mass Region

Spin-0 and Spin-2 narrow resonances tested.

Events broken into 3 regions (low, intermediate, high mass) due to changing kinematics.

Data-driven BG estimation, multiple control regions.



Spin-0 limits

Radion comparison

Model Independent Comparison

95% CL upper limits on σ×BR

Assuming narrow signal models (resolution is detector-limited)

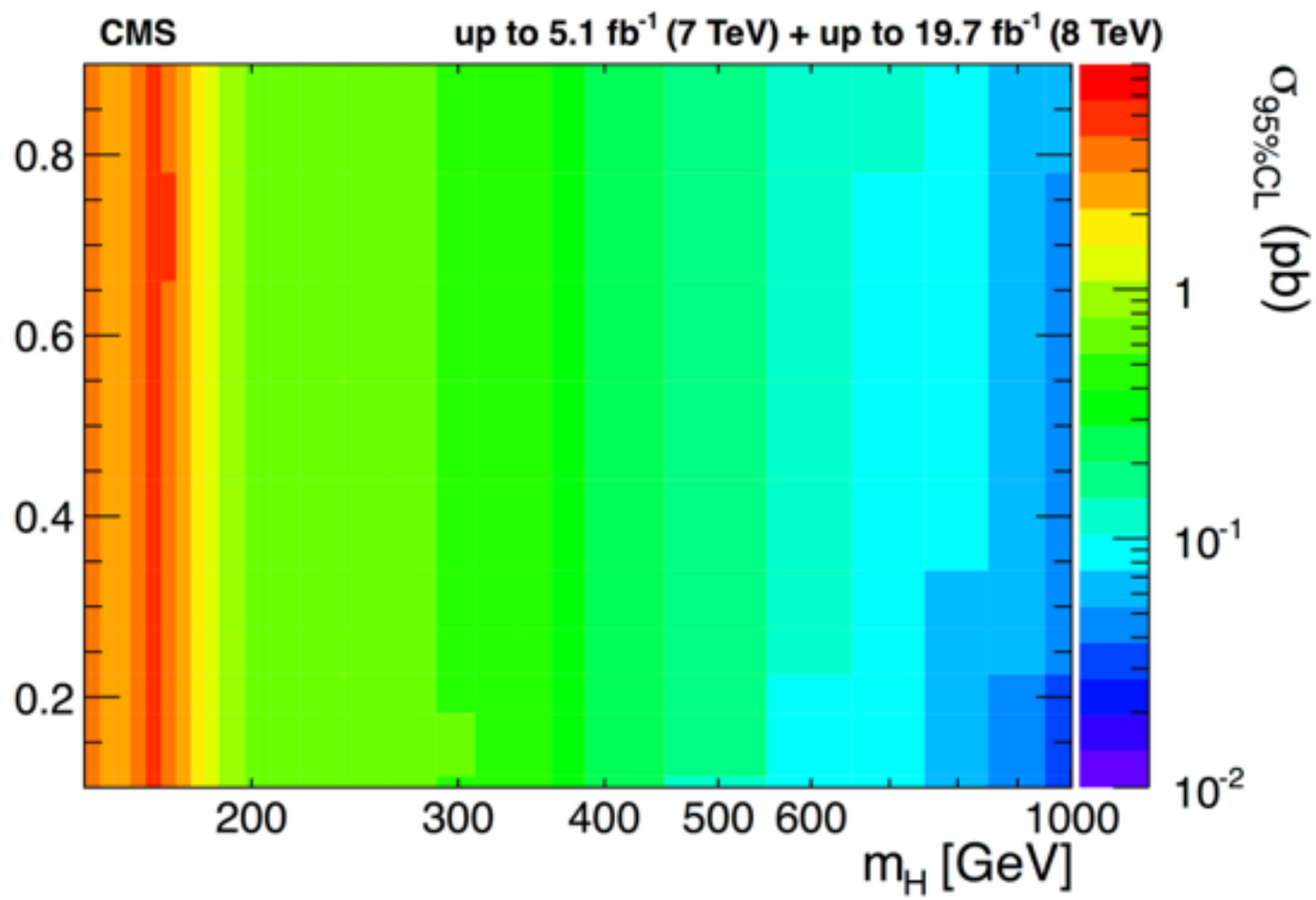
σ×BR: X→	250 GeV	500 GeV	800 GeV
WW	~2000 fb	~400 fb	~200 fb
ZZ	~1000 fb	~200 fb	~40 fb
γγ	~7 fb	~2 fb	~0.6 fb
Zγ	~7 fb	~2 fb	-
Zh	~350 fb	~50 fb	-
hh	-	~200 fb	~30 fb

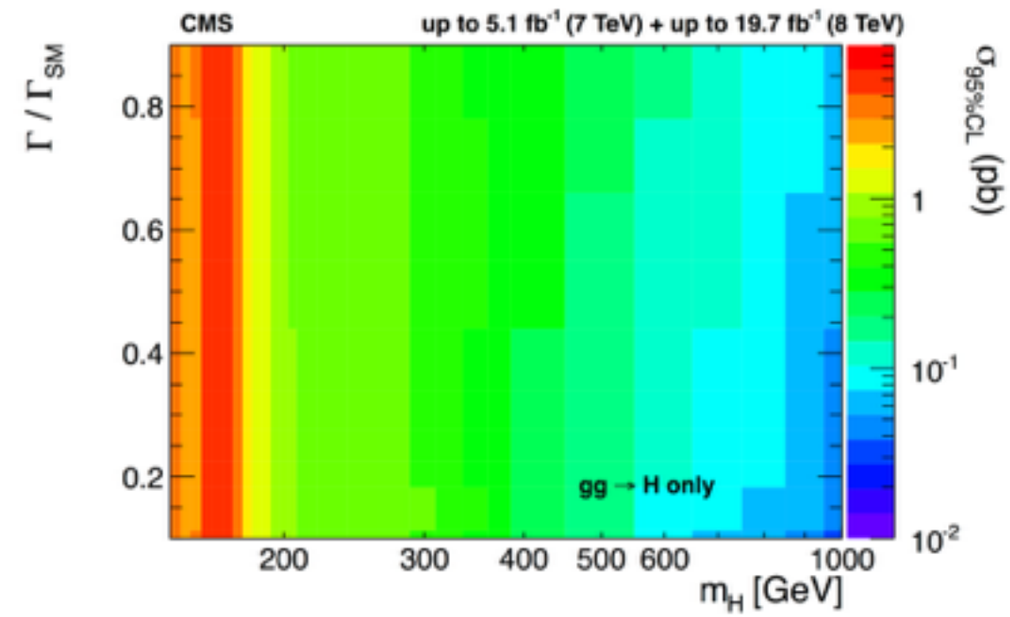
Summary

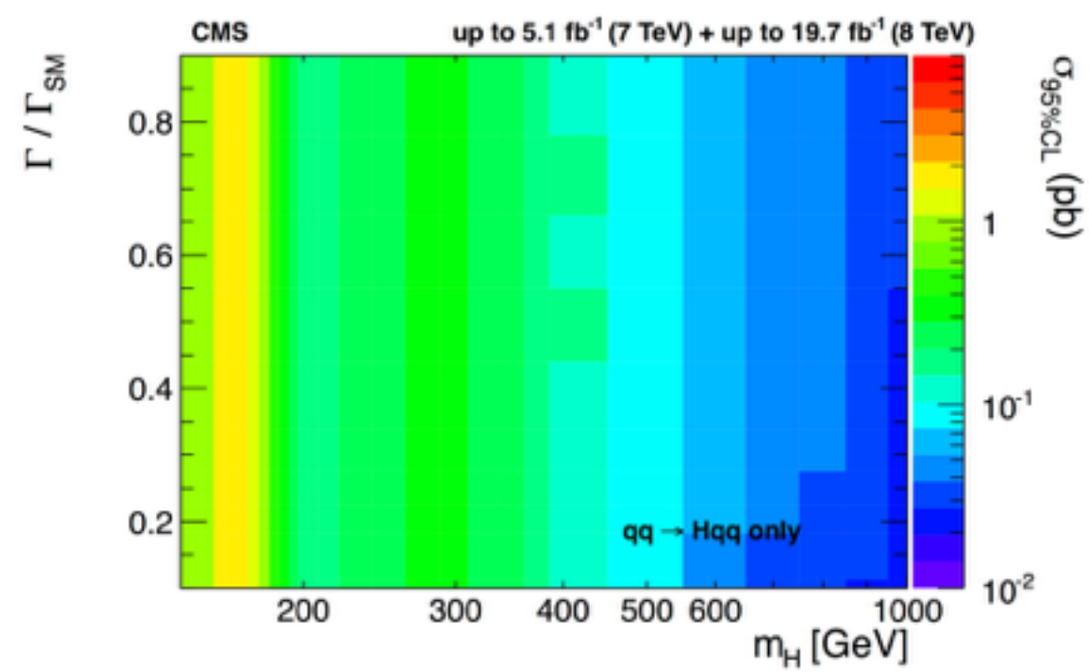
- ★ **Heavy Higgs-like searches have been performed in numerous channels at CMS:**
  - ZZ, WW, γγ, Zγ, Zh, ZX, hh.
- ★ **No appreciable excess has yet to be seen.**
  - However, upper limits place strong constraints on BSM models.
- ★ **All analyses will be conducted on 13 TeV data.**
  - These are important channels for probing new physics, and will benefit greatly from increased energies and integrated luminosity.

Backup

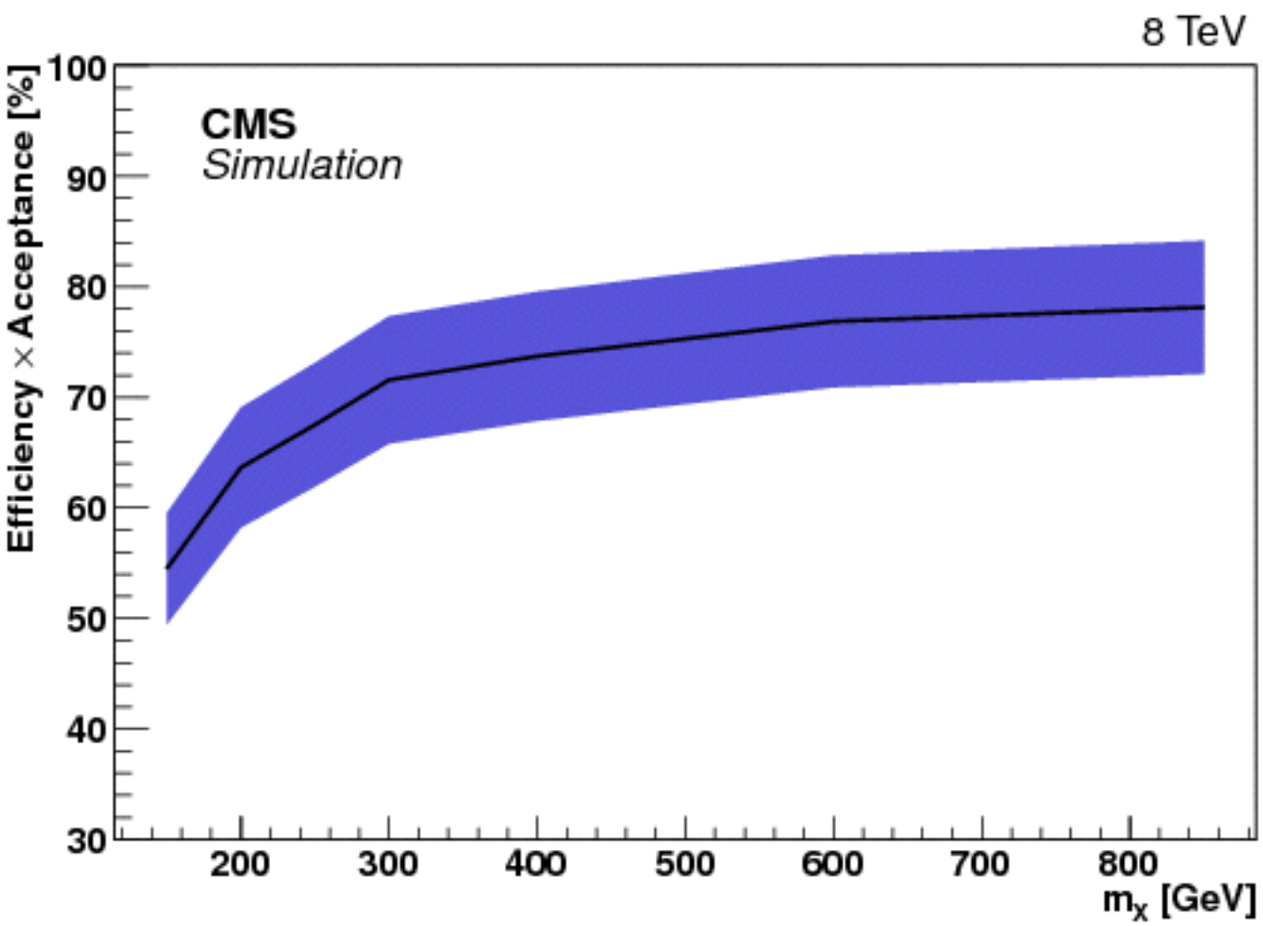
WW/ZZ

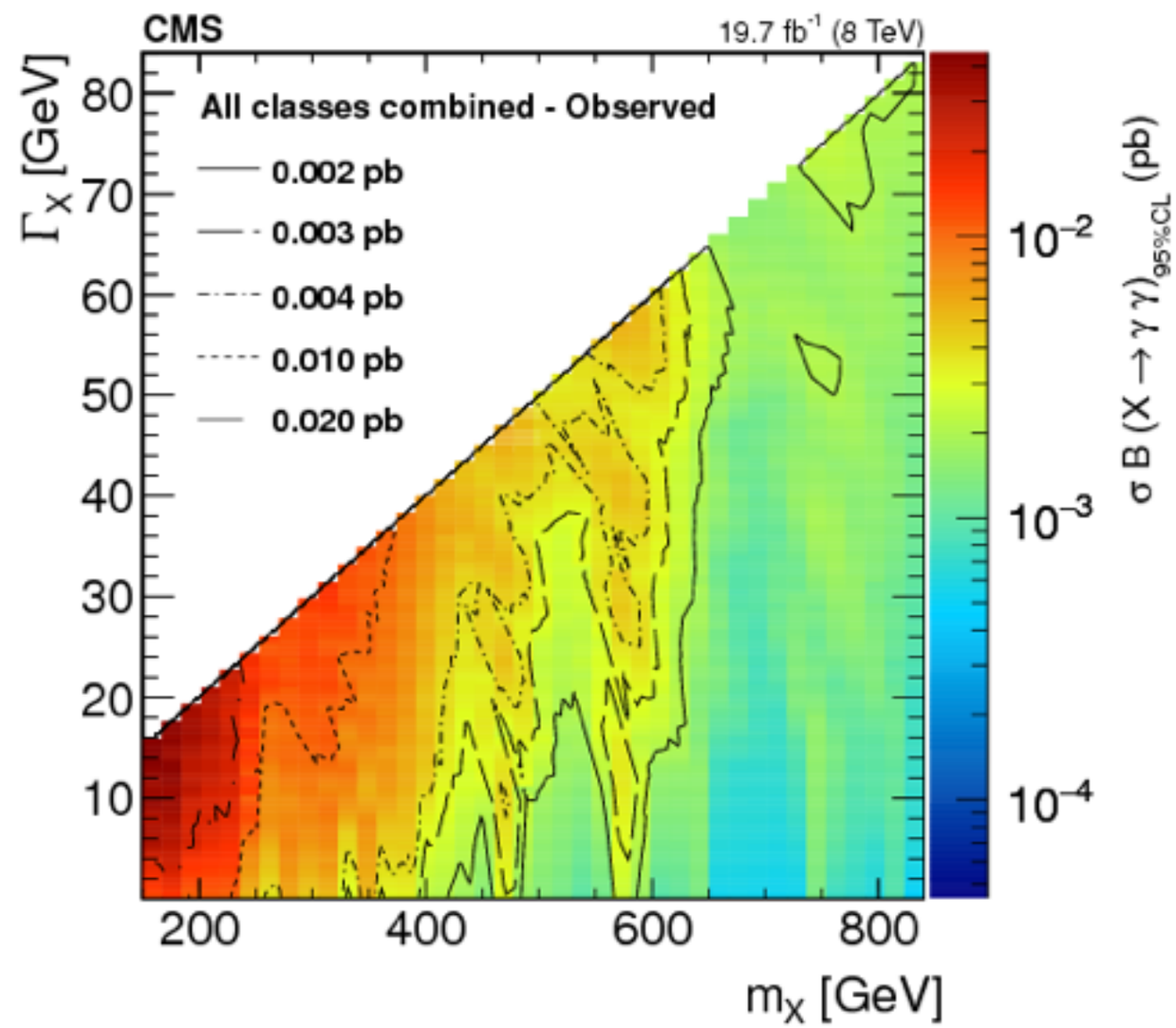

CMS
up to 5.1 fb^{-1} (7 TeV) + up to 19.7 fb^{-1} (8 TeV)
0.8
0.6
0.4
0.2
200
300
400
500
600
1000
m_H [GeV]
1
10^{-1}
10^{-2}
$\sigma_{95\%CL}$ (pb)


CMS
up to 5.1 fb^{-1} (7 TeV) + up to 19.7 fb^{-1} (8 TeV)
Γ / Γ_{SM}
0.8
0.6
0.4
0.2
gg → H only
200
300
400
500
600
1000
m_H [GeV]
1
10^{-1}
10^{-2}
$\sigma_{95\%CL}$ (pb)


CMS
up to 5.1 fb^{-1} (7 TeV) + up to 19.7 fb^{-1} (8 TeV)
Γ / Γ_{SM}
0.8
0.6
0.4
0.2
qq → Hqq only
200
300
400
500
600
1000
m_H [GeV]
1
10^{-1}
10^{-2}
$\sigma_{95\%CL}$ (pb)

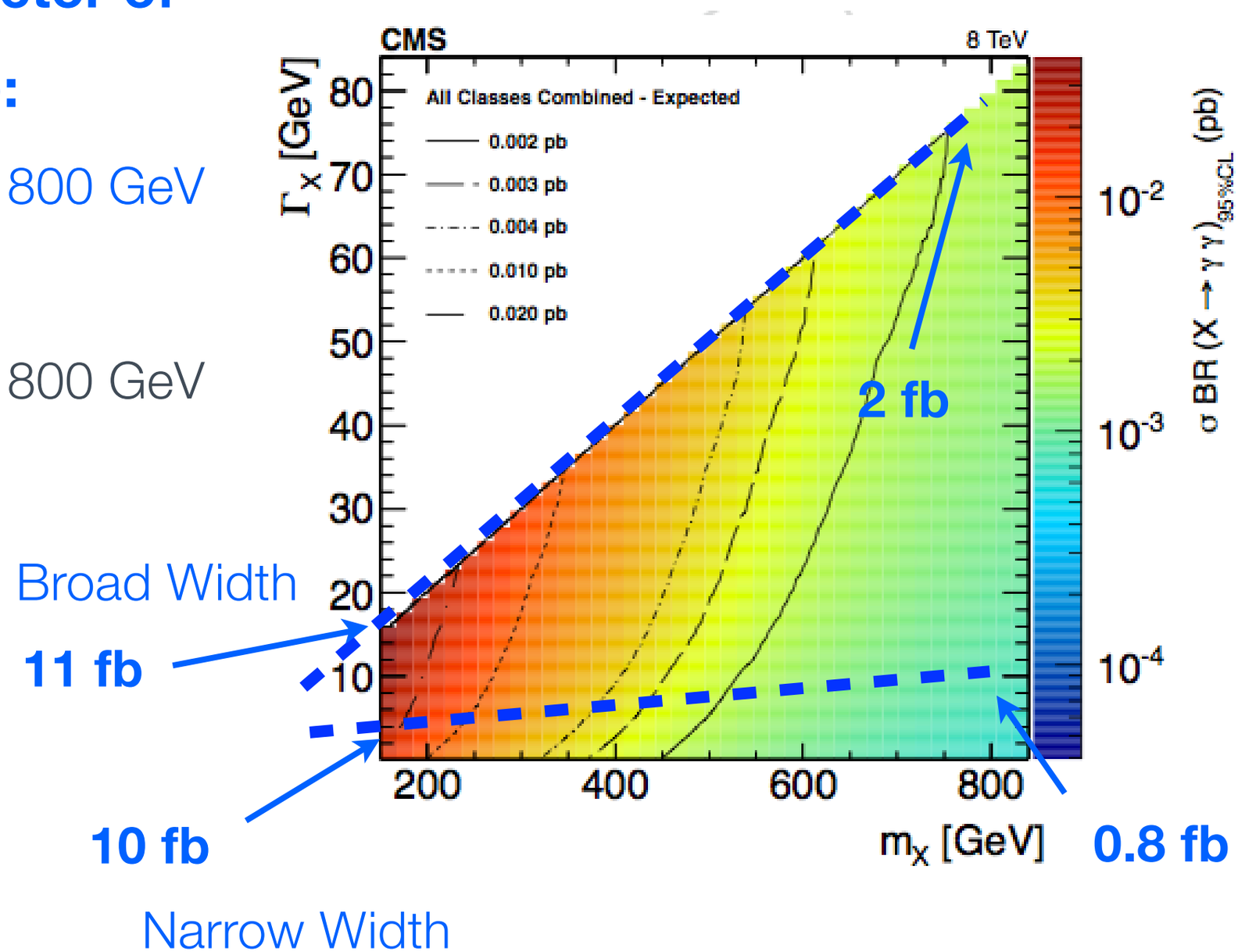
$\gamma \quad \gamma$



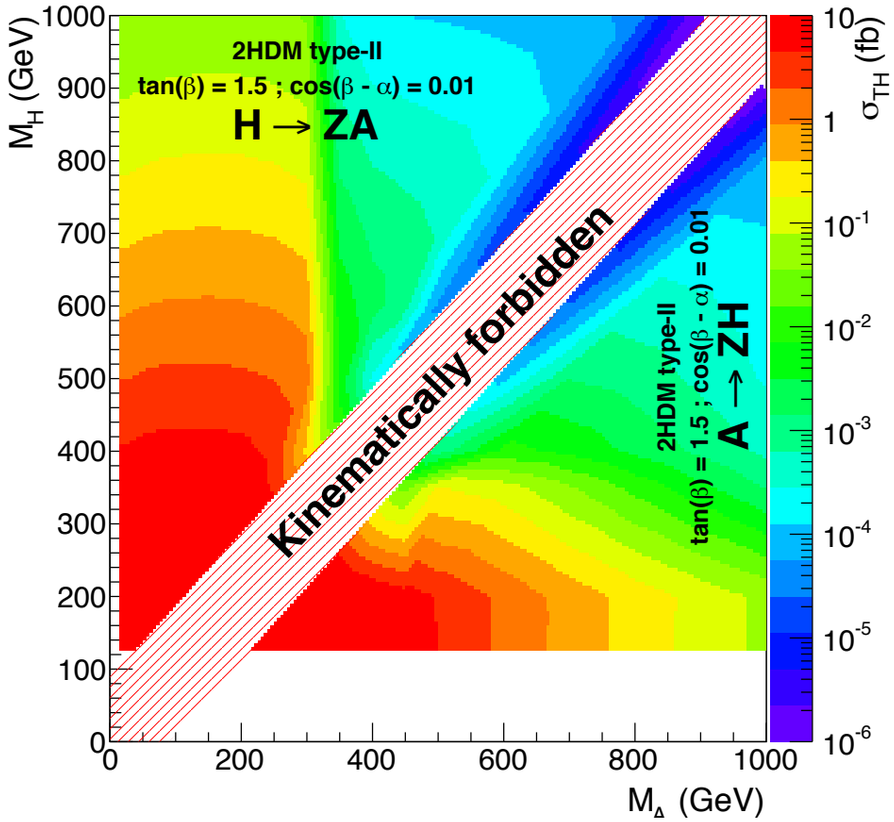


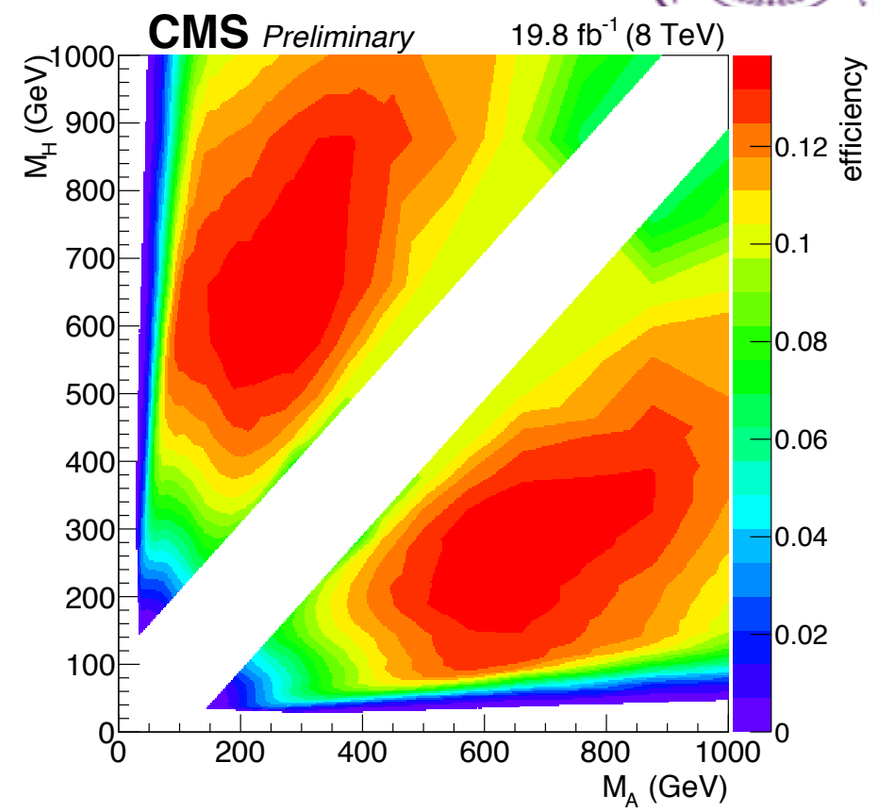
$\gamma\ \gamma\ /Z\ \gamma$

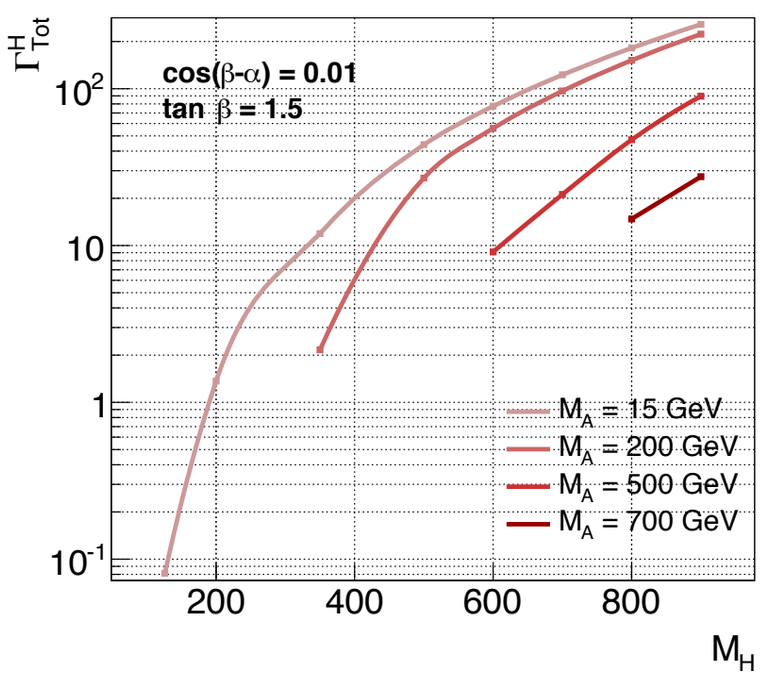
- ★ **A->Zγ (multiplied by a factor of ~10 to account for Z BR):**
  - ~**10** fb @ 200 GeV, ~**1** fb @ 800 GeV
- ★ **A->γγ:**
  - ~**30** fb @ 200 GeV, ~**1** fb @ 800 GeV

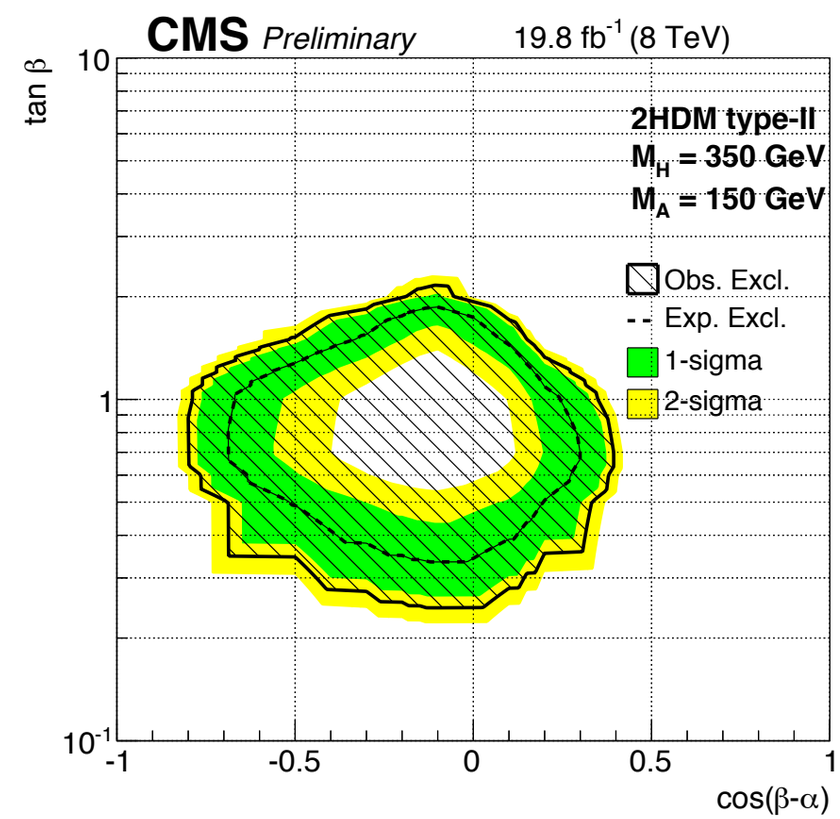


ZH/ZA

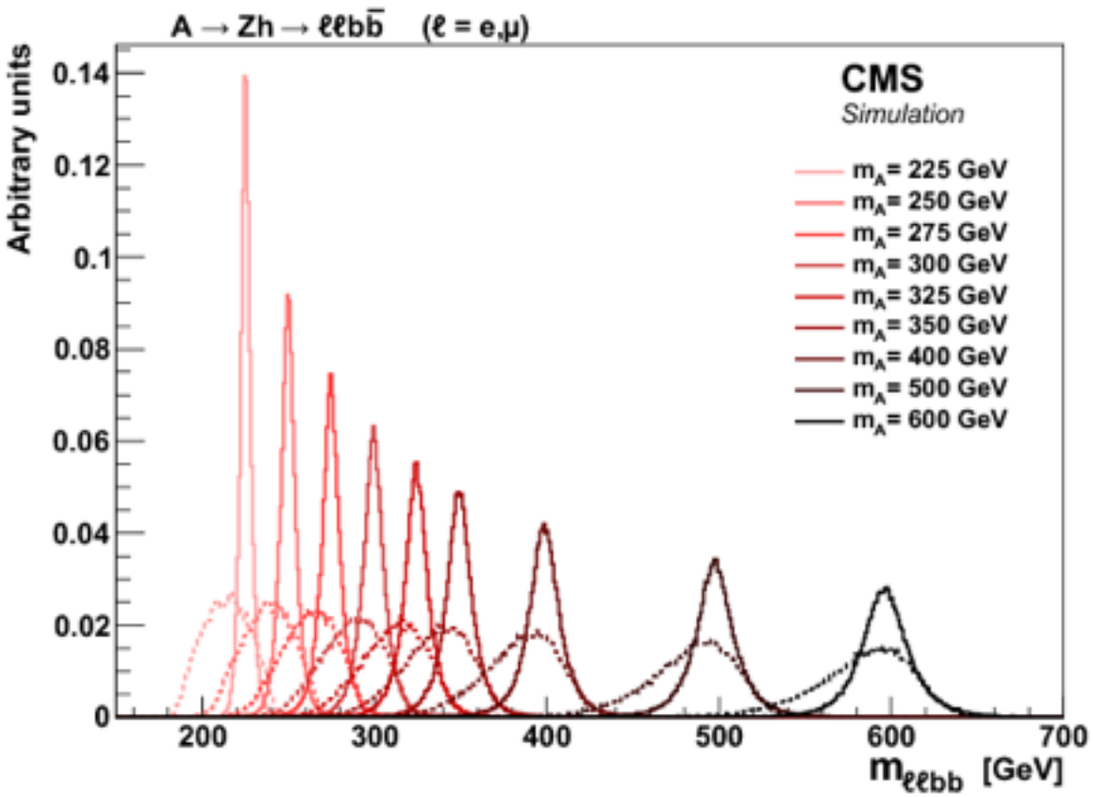

2HDM type-II
tan(β) = 1.5 ; cos(β - α) = 0.01
H → ZA
Kinematically forbidden
2HDM type-II
tan(β) = 1.5 ; cos(β - α) = 0.01
A → ZH
M_H (GeV)
M_A (GeV)
σ_TH (fb)

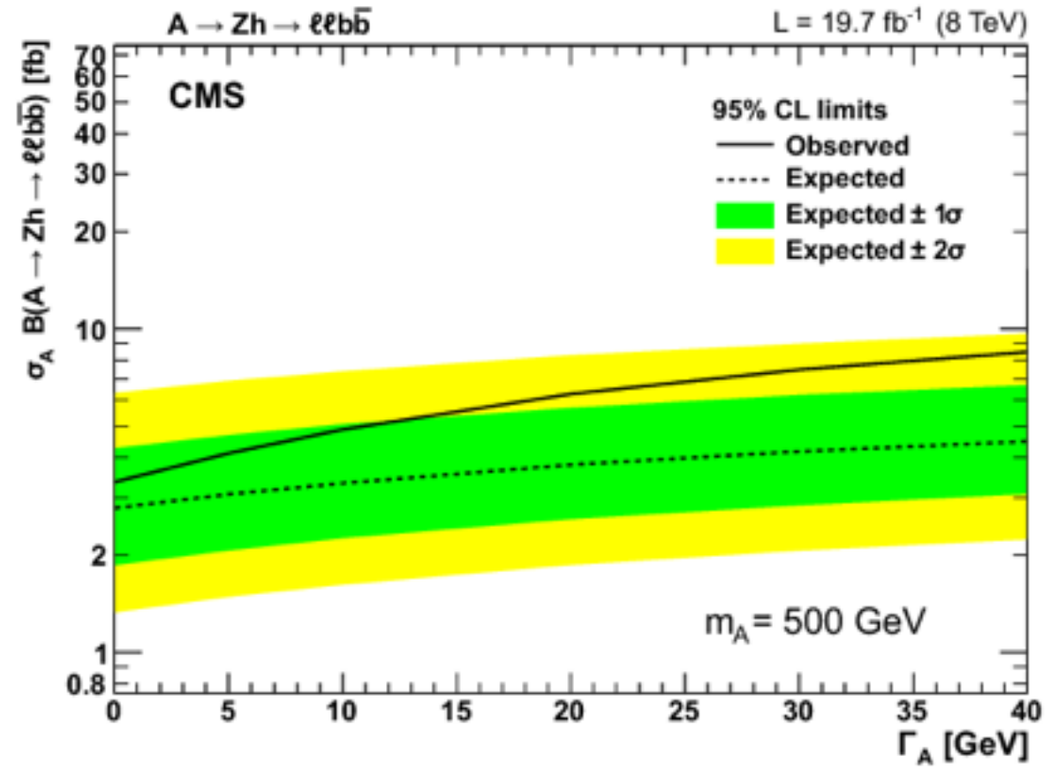

CMS Preliminary
19.8 fb-1 (8 TeV)
M_H (GeV)
M_A (GeV)
efficiency

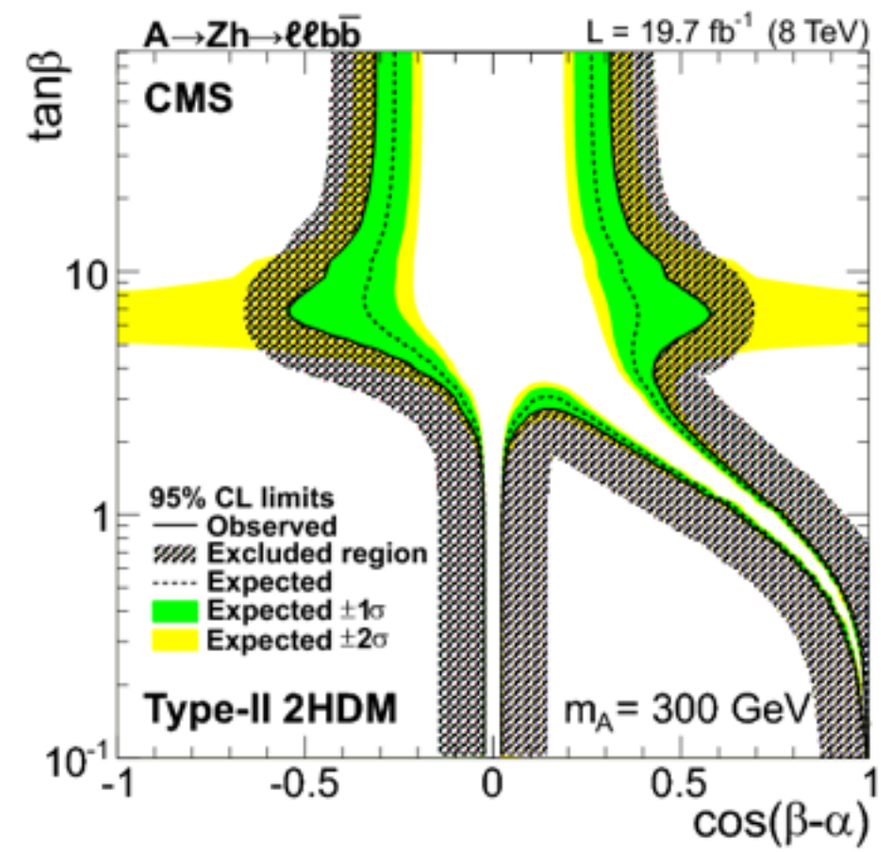

cos(β-α) = 0.01
tan β = 1.5
M_A = 15 GeV
M_A = 200 GeV
M_A = 500 GeV
M_A = 700 GeV
Γ^H_Tot
M_H


CMS Preliminary
19.8 fb-1 (8 TeV)
2HDM type-II
M_H = 350 GeV
M_A = 150 GeV
Obs. Excl.
Exp. Excl.
1-sigma
2-sigma
tan β
cos(β-α)

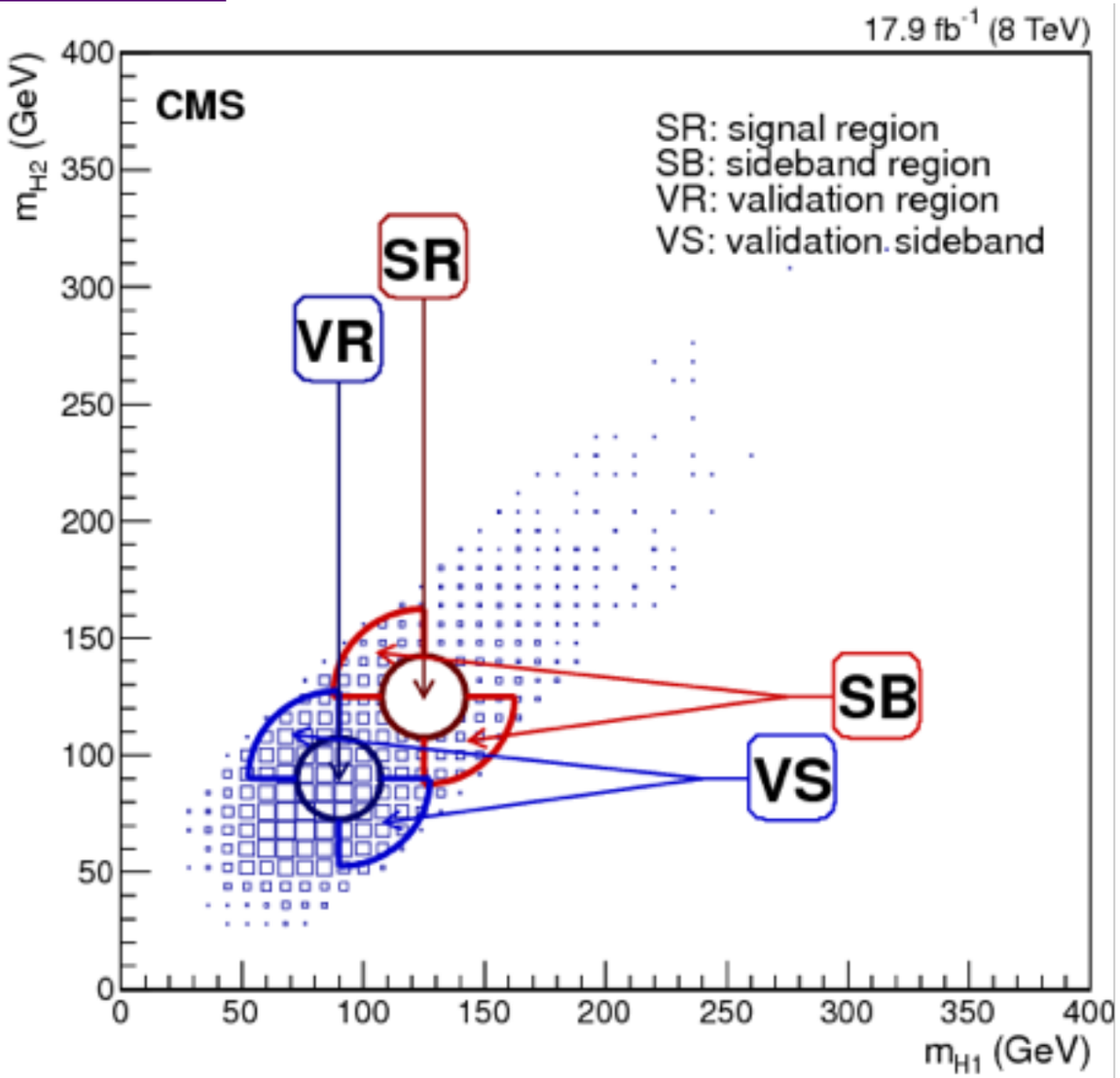
Zh

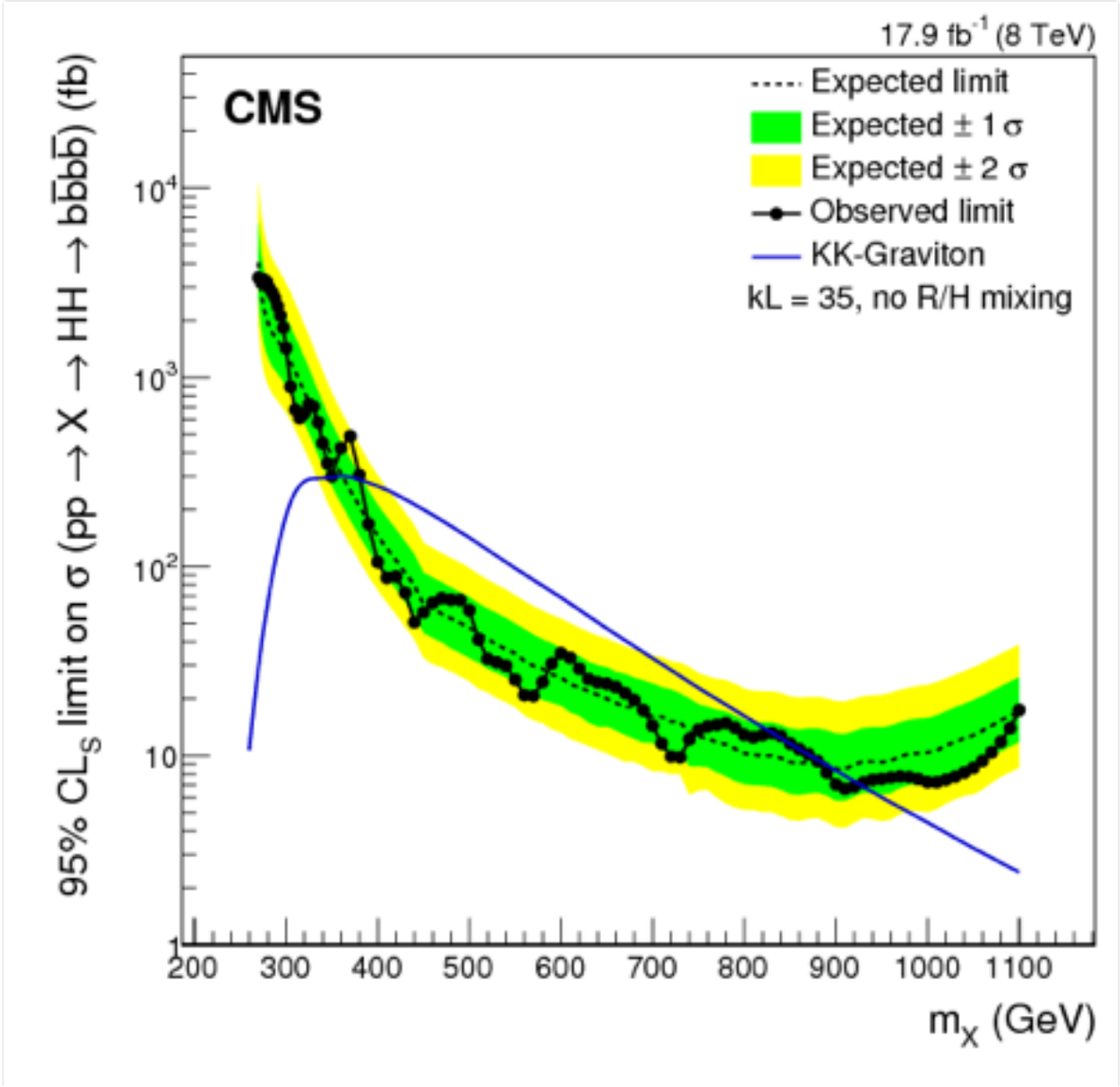

A → Zh → ℓℓbb̄ (ℓ = e,μ)
CMS
Simulation
m_A = 225 GeV
m_A = 250 GeV
m_A = 275 GeV
m_A = 300 GeV
m_A = 325 GeV
m_A = 350 GeV
m_A = 400 GeV
m_A = 500 GeV
m_A = 600 GeV
Arbitrary units
m_ℓℓbb [GeV]


A → Zh → ℓℓbb̄
L = 19.7 fb⁻¹ (8 TeV)
CMS
95% CL limits
Observed
Expected
Expected ± 1σ
Expected ± 2σ
m_A = 500 GeV
σ_A B(A → Zh → ℓℓbb̄) [fb]
Γ_A [GeV]


A→Zh→ℓℓbb̄
L = 19.7 fb⁻¹ (8 TeV)
CMS
95% CL limits
Observed
Excluded region
Expected
Expected ±1σ
Expected ±2σ
Type-II 2HDM
m_A = 300 GeV
tanβ
cos(β-α)

hh


17.9 fb^{-1} (8 TeV)
CMS
SR: signal region
SB: sideband region
VR: validation region
VS: validation sideband
SR
VR
SB
VS
m_{H2} (GeV)
m_{H1} (GeV)


17.9 fb^{-1} (8 TeV)
CMS
Expected limit
Expected ± 1 σ
Expected ± 2 σ
Observed limit
KK-Graviton
kL = 35, no R/H mixing
95% CL_S limit on σ (pp → X → HH → $b\bar{b}b\bar{b}$) (fb)
m_X (GeV)