Search for BSM Higgs

Speaker:

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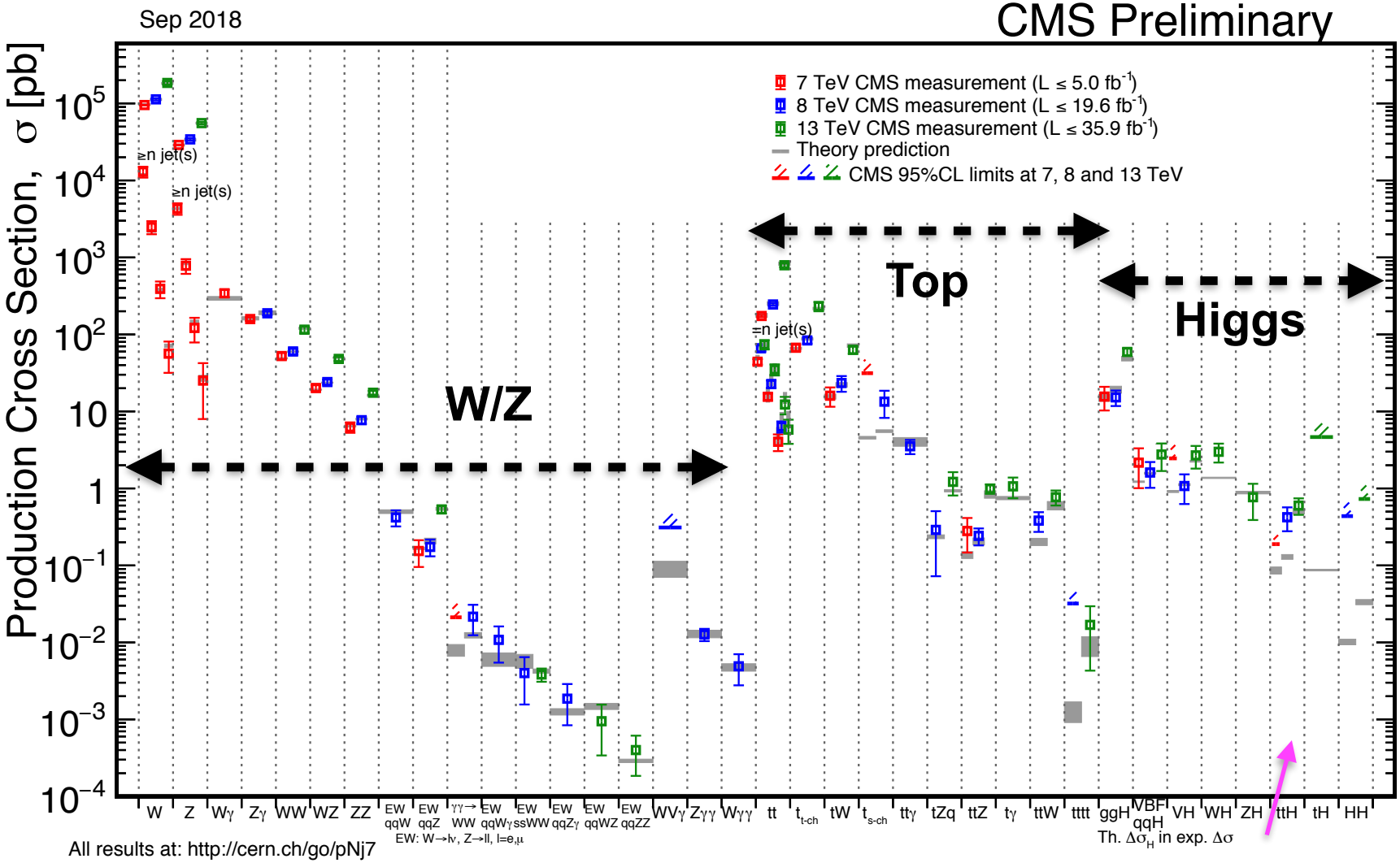
The 4th China Large Hadron Collider Physics Workshop
CCNU, Wuhan

Challenging the SM

Searching for another Higgs boson



Observed ttH (7,8,13 TeV)
CMS: arXiv:1804.02610
ATLAS: arxiv 1806.00425

Theory motivation

✦ Extended phenomenology from theo. models (Higgs SM sector + scalar, doublet, triplet …)

✦ Direct searches @ collider complementary to indirect constraints (b → sγ, g-2) and connected to BSM (i.e. dark matter)

Scalar singlet

They are not charged under the SM symmetries
Direct production of light or from the h_{125} decay

➡ 2HDM + scalar
➡ Theories for light Dark Matter with scalar mediator

Doublet

Two-Higgs Doublet Models (2HDM)

extend the SM by adding one Higgs doublets, lead to 5 Higgs bosons

H^+, H^-, A (CP-odd),
H and h (CP-even)

4 types according to couplings of two Higgs doublets with fermion sector:

Type-I: only one doublet couples to fermions
Type-II: up vs. down
Lepton Specific: quark vs lepton
Flipped Coupling: b enhanced τ suppressed

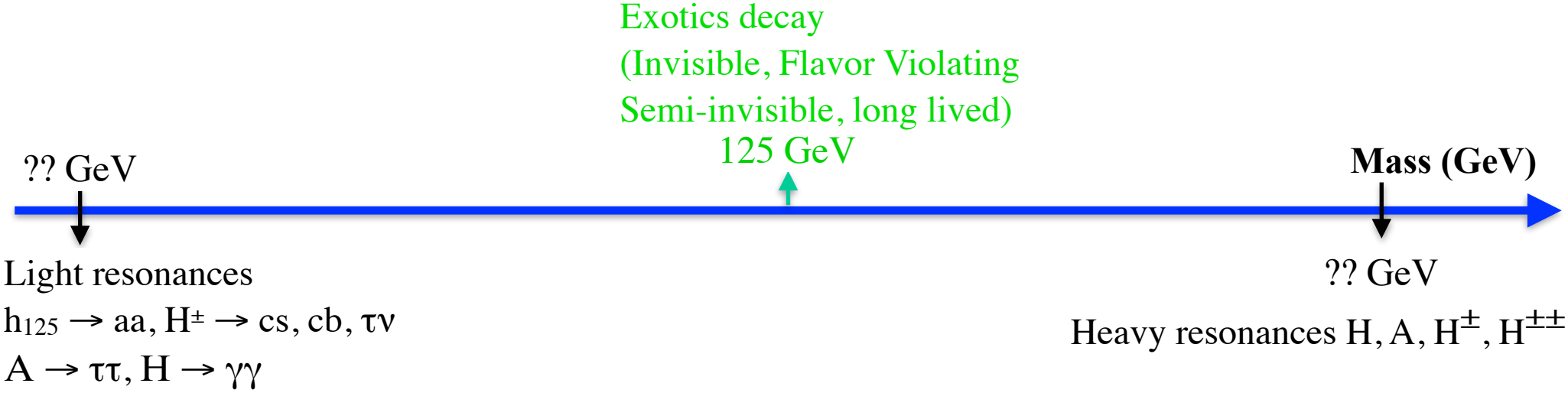
Triplet

Fermiophobic $H^{\pm}$,$H^{\pm\pm}$ bosons appear in Higgs sectors extended by a scalar triplet Φ

➡ couplings to W and Z bosons at tree level
➡ e.g. Georgi-Machacek (GM) model

Exotic Higgs Sector

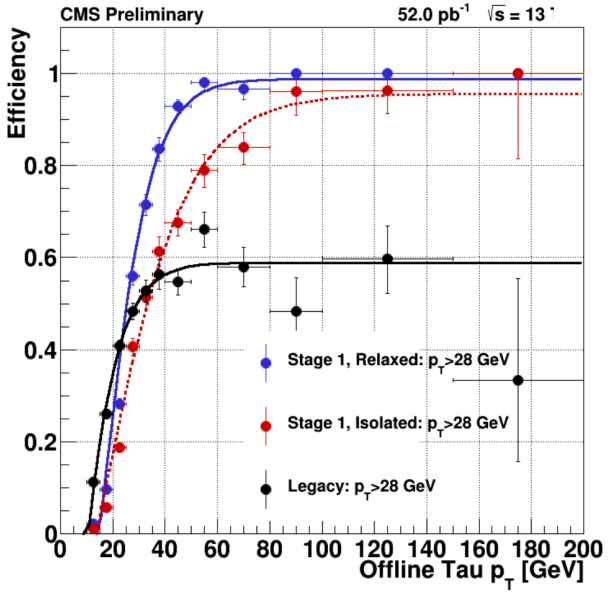
- Full mass coverage is needed to enhance the sensitivity to variety of models
- Extended phenomenology from theoretical models (higgs SM sector+scalar, doublet, triplet …)
- Direct searches @ collider complementary to indirect constraints (b->s γ, g-2) and connected to BSM (i.e. dark matter)
- Multiple analysis techniques (i.e. boosted objects, soft triggers, high p_T b-tagging, mva ...)
- General enhancement of production xsection from PDF at 13TeV
  i.e. exploit different production modes: gluon fusion, VBF, bb/tt radiation, W/Z associated



No golden channel important to cast a wide net

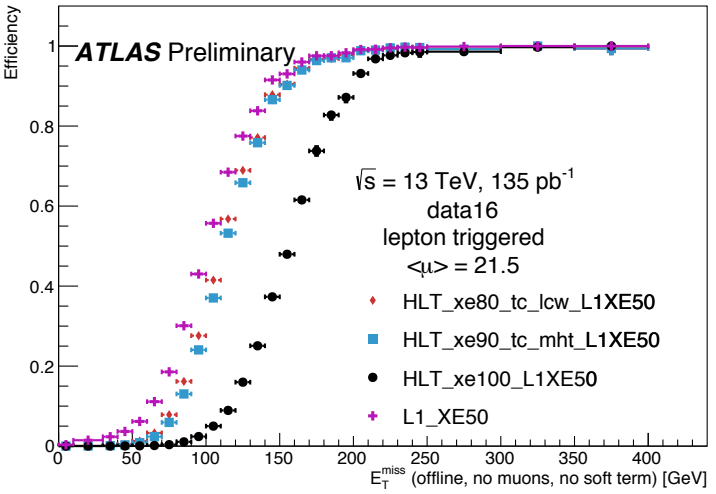
Experimental handles

CMS DP2015/050



MET triggers suffers threshold dictated by the rate

https://twiki.cern.ch/twiki/bin/view/ AtlasPublic/MissingEtTriggerPublicResults

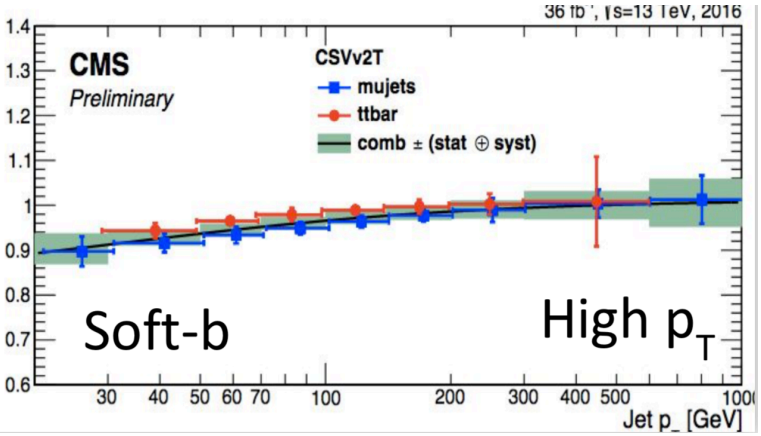


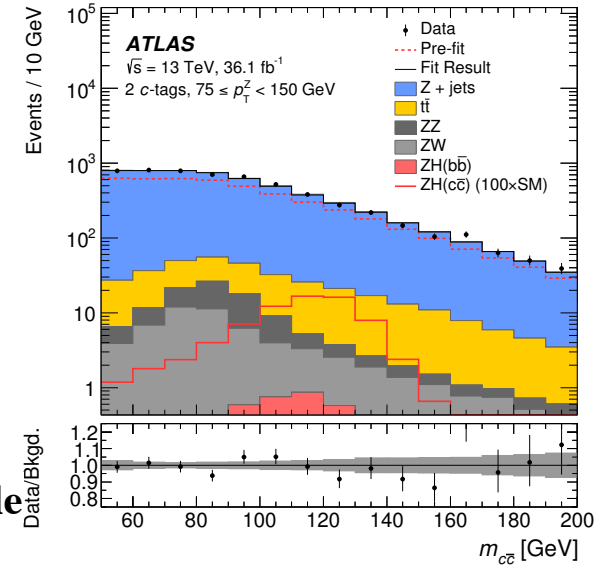
Run 2 major upgrade of the L1 trigger system increases the τ_h collection efficiency.

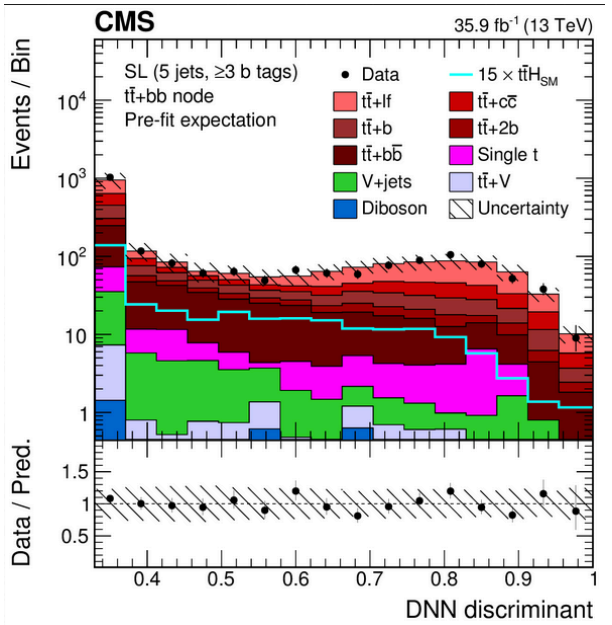
HIGG-2017-01

Multivariate techniques are exploited to find rare signals on top of bkg

Charm tagging giving results.



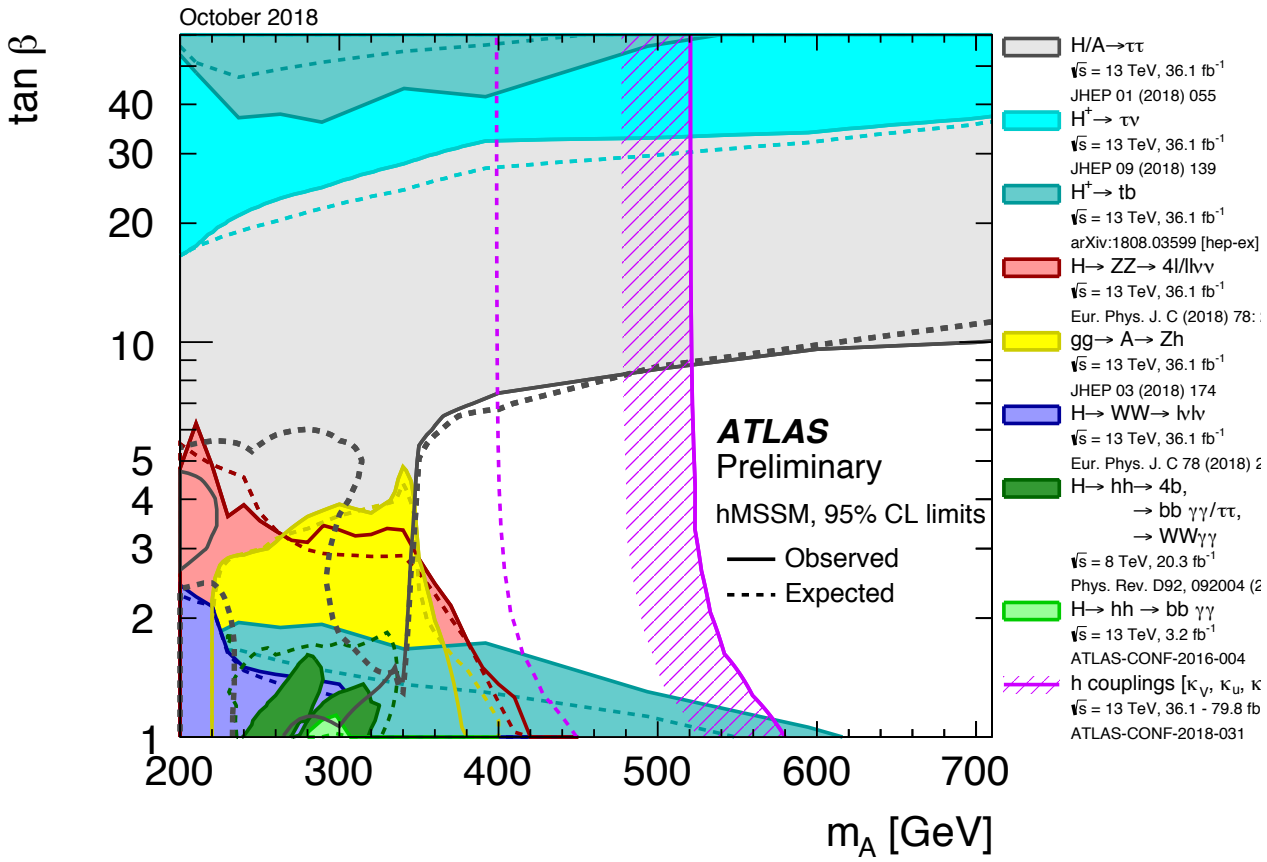


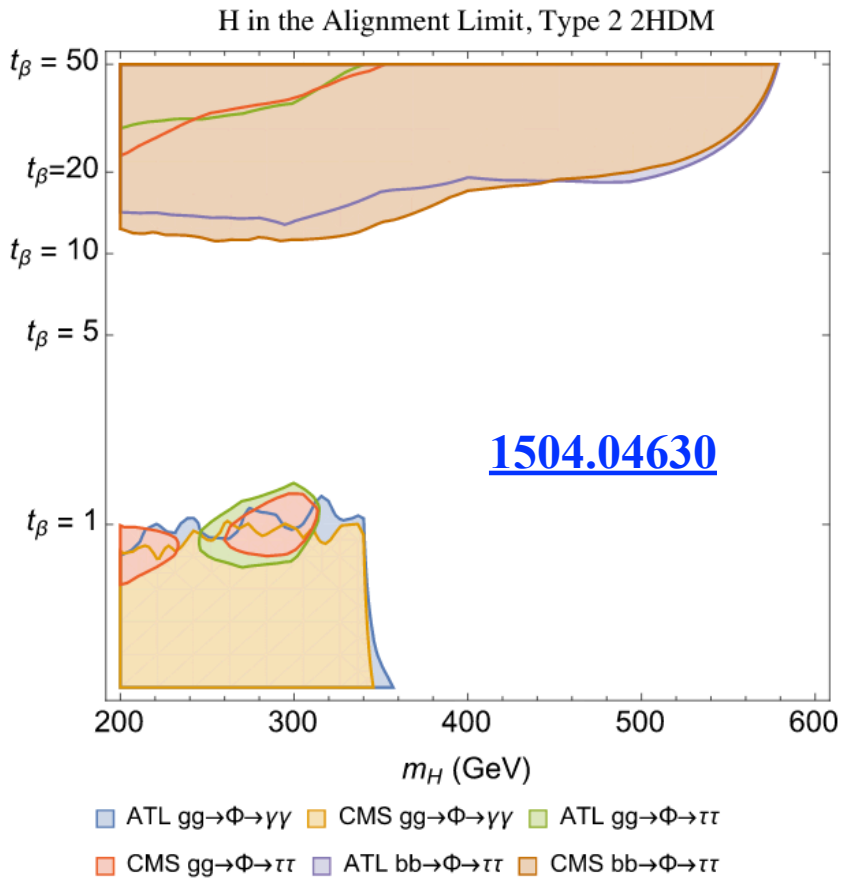


Low and high pT bTagging play a key role to suppress the ttbar background.

HIG-17-026

Additional Higgs like scalars





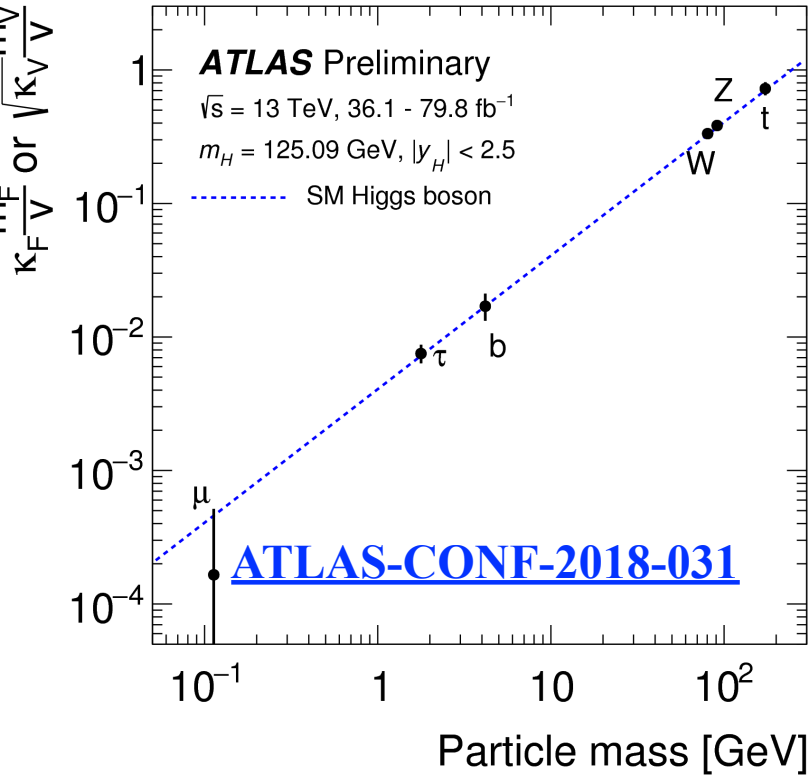
Link

Indirect constraints in BSM model imposed by h_{125}

Low tanβ, high mass generally unexplored
One analysis dominates in one case but not a general statement

Direct search limits on a heavy CP even neutral scalar H as a function of mass in the alignment limit cos(β – α) = 0 in a Type II 2HDM

Higgs → 3rd generation fermions



h_{125} : established *ad-hoc* hierarchical Yukawa couplings ∝mf

BSM scenarios leading search channels:

A/H → tt : CMS Eur. Phys. J. C 77 (2017) 578,
ATLAS: Phys. Rev. Lett. 119, 191803 (2017)

A/H → bb : CMS: arxiv:1805.12191

$H^{\pm}$ → tb : CMS: arxiv:1508.07774,
ATLAS: JHEP 11 (2018) 085

A/Z'/H → $\tau\tau$: CMS: arxiv:1803.06553
ATLAS: JHEP 01 (2018) 055

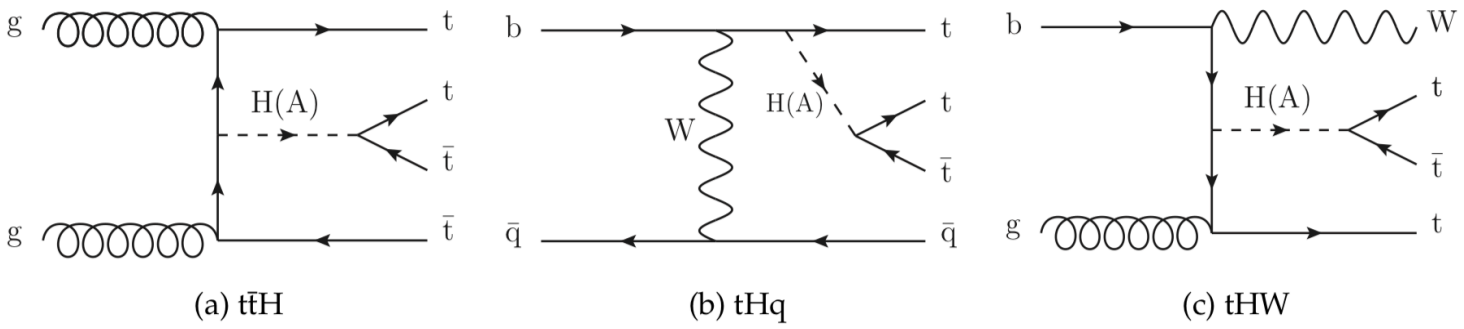
$H^{\pm}$ → $\tau\nu$: CMS: HIG-18-014
ATLAS: JHEP 09 (2018) 139

Not imposed by a fundamental symmetry
→ searches exist in other decay modes

A/H → μμ, $H^{\pm}$ → cs,cb

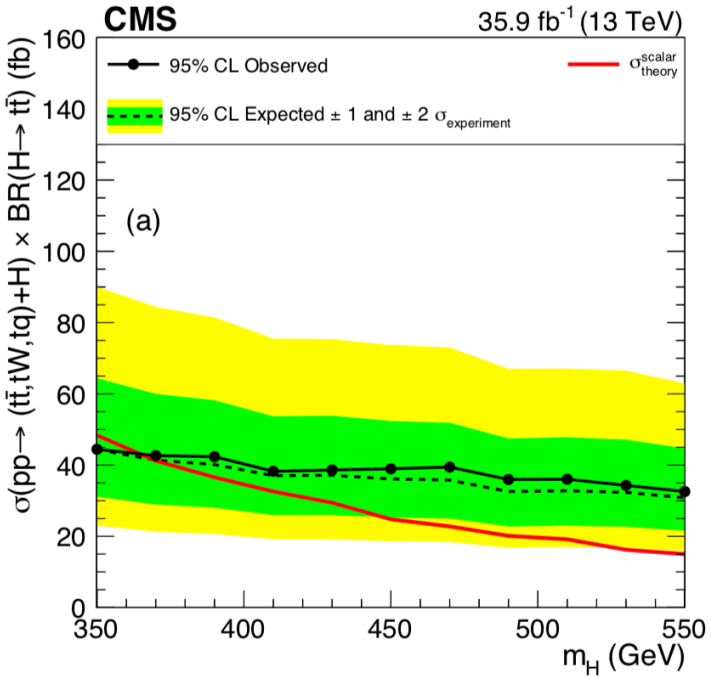
t(t) A/H → tt

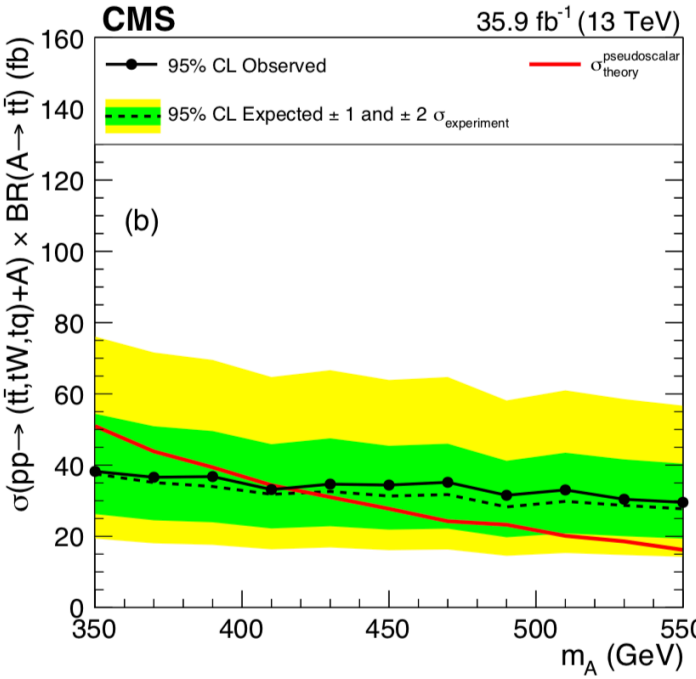
Eur. Phys. J. C 77 (2017) 578



Same Sign leptons

signature helps to kill the overwhelming background.
O(100) search regions binned in N_j, N_b, H_T, MET, m_T, and lepton p_T.



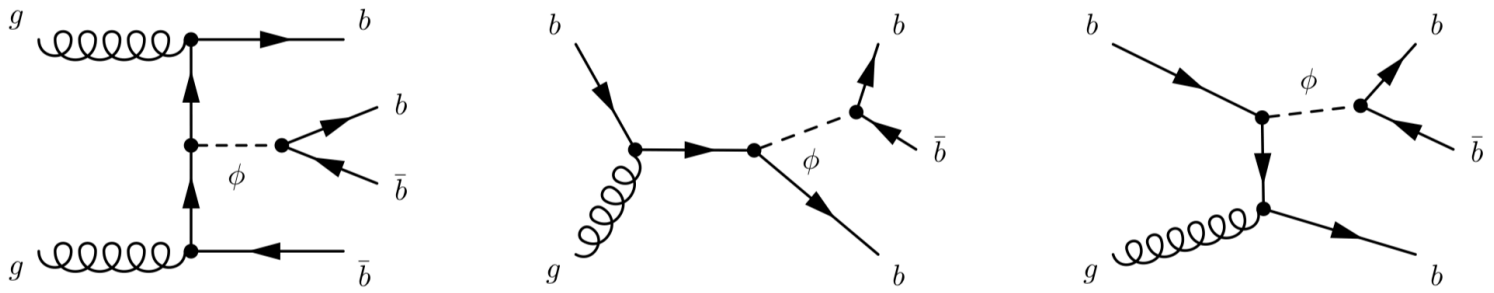


Statistics limited, expect continued progress in future

A/H → bb

[JHEP 08(2018) 113]

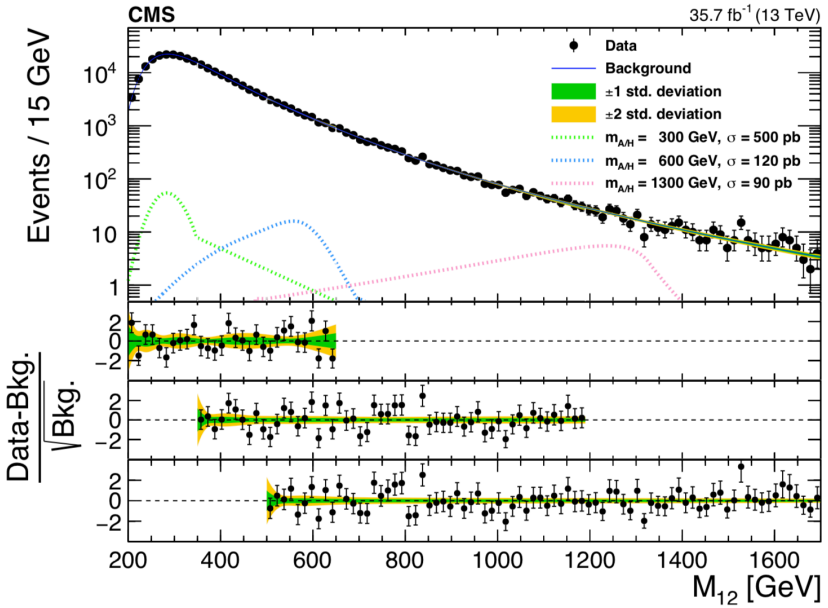
Flipped Model
Unique Coupling
to down-type fermion

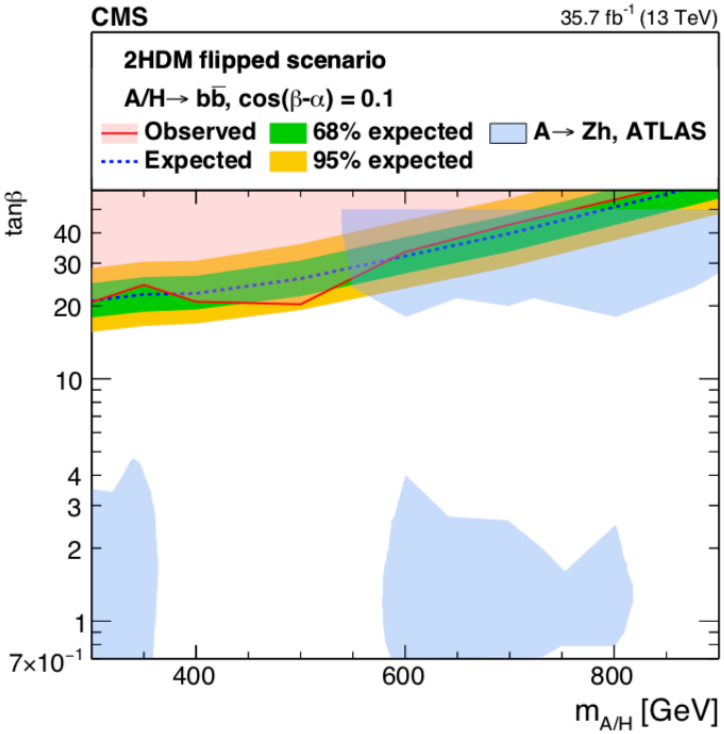


QCD multijet is the main background

Three subranges to reduce bias from the choice of the background model

Signal shape for different signal hypothesis



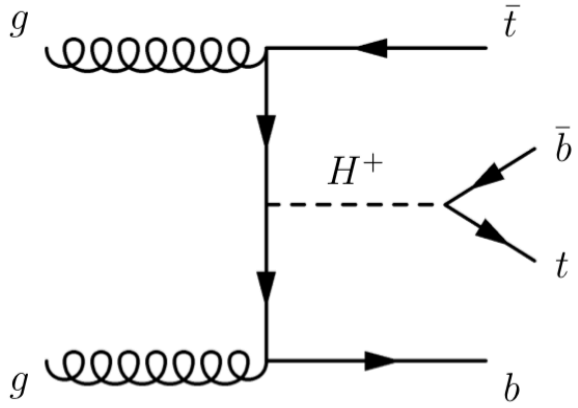


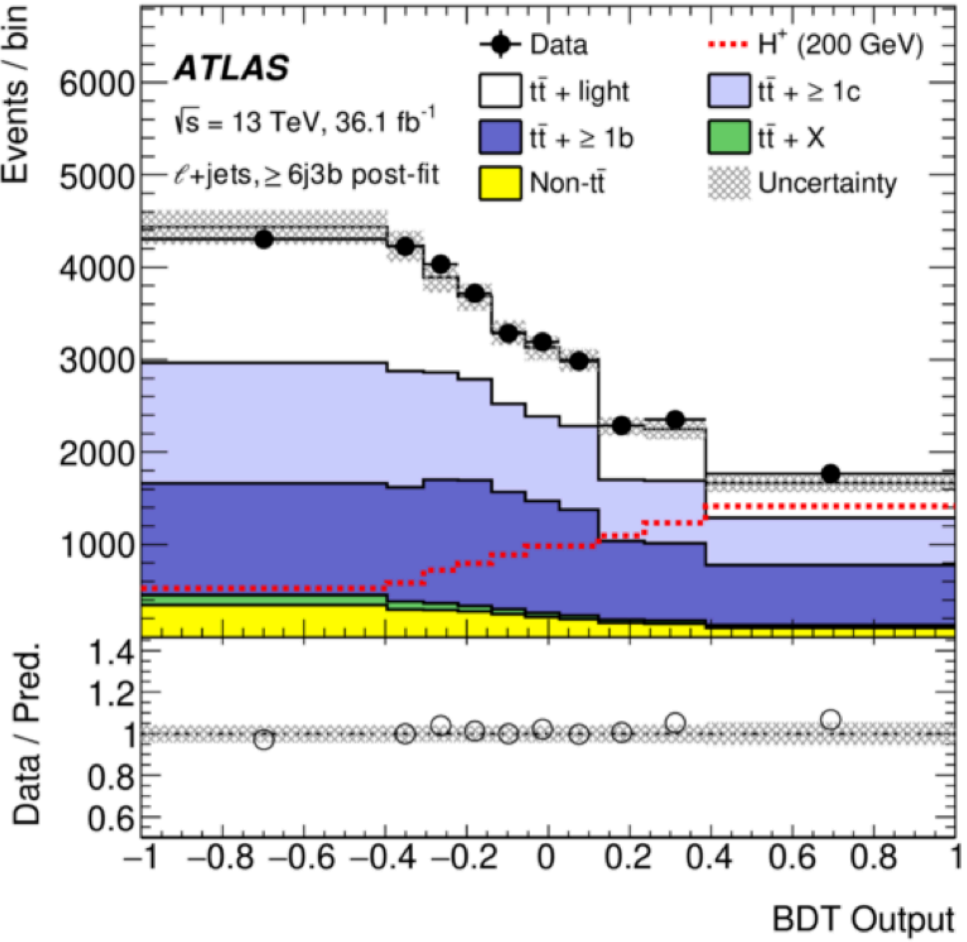
Statistics limited, expect continued progress in future

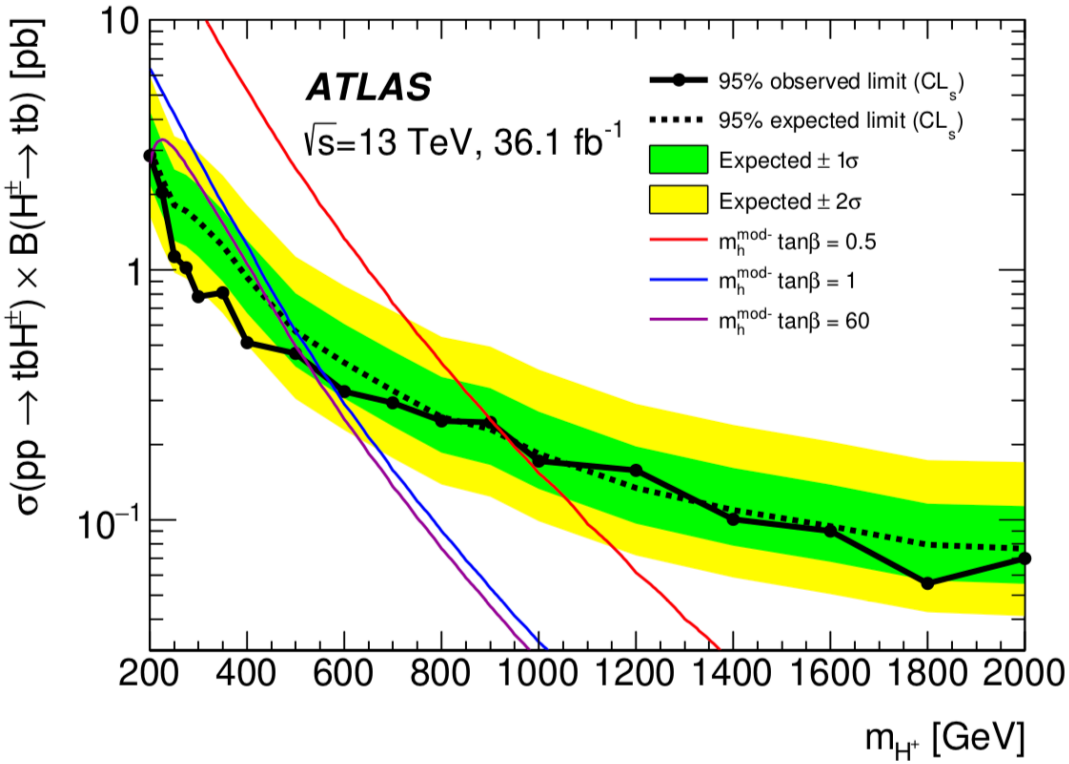
(b)tH$^{\pm}$ → (b)ttb

JHEP 11 (2018) 085

TTbar + HF production the major background.
Analysis categorized in jet and bjet multiplicity.
MVA discriminant used to separate the small signal respect to the background.



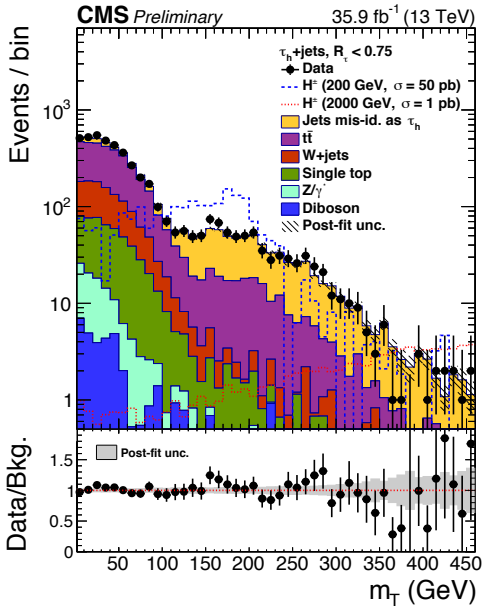


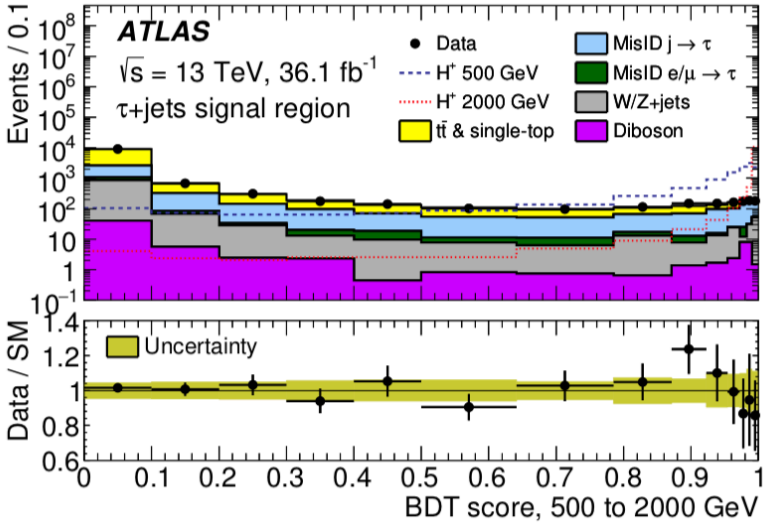


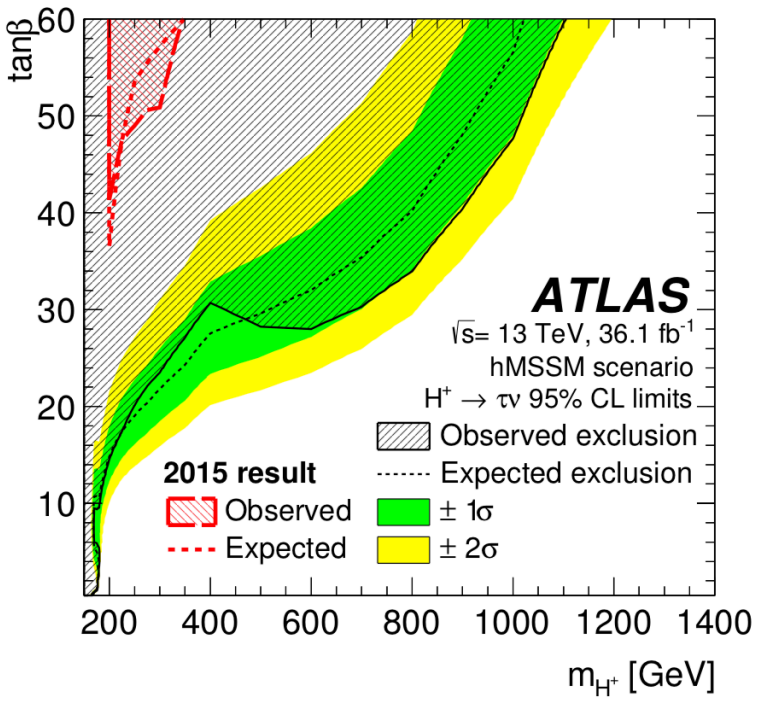
$H^{\pm} \rightarrow \tau\nu$

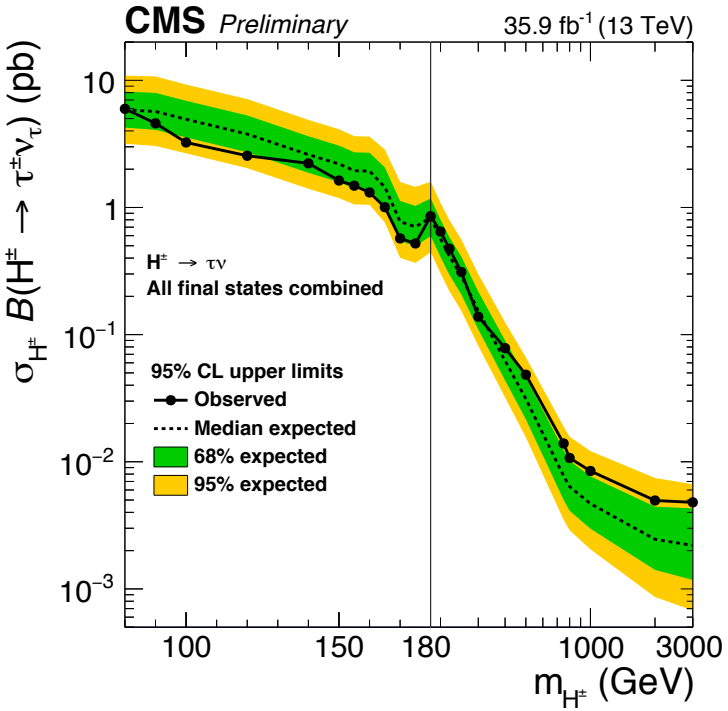
CMS-PAS-HIG-18-014

JHEP 09 (2018) 139









Heavy Higgs → diboson

This talk

	W	Z	γ	H/A/h_{125}
W	WW → 2l2ν CMS-HIG-16-023,2015 ATLAS-HIGG-2016-31 WW → lνqq ATLAS EXOT-2016-28 $H^{\pm\pm}$ → $W^{\pm}W^{\pm}$ CMS-PAS-SMP-17-004			
Z	$H^{\pm}$→$W^{\pm}$Z→3lν CMS-HIG-16-027,2016 $H^{\pm}$→$W^{\pm}$Z→lνqq ATLAS EXOT-2016-28	ZZ→2l2q, 2l2ν, 4l CMS-HIG-17-012,2016 36fb^{-1} ZZ→2l2ν, 4l ATLAS-HIGG-2016-19 Z W/Z→2q2ν B2G-17-004		
γ	Zγ→(2l,2q)+γ CMS-EXO-17-005, 2016 36 W/Z/h_{125}(→qq) +γ ATLAS-HIGG-2016-19		γγ CMS-EXO-16-027,2016 36fb (*) ATLAS PLB 775 (2017) 105	
H/A/h_{125}	W/Z(→lν,2l,2ν)+h_{125}→bb B2G-17-004 Z(→2l)+H/A(→bb) CMS-HIG-16-010(**) W/Z+h_{125} Z+H CMS-HIG-16-010, 2015 EXOT-2016-10, EXOT-2016-34			$h_{125}h_{125}$

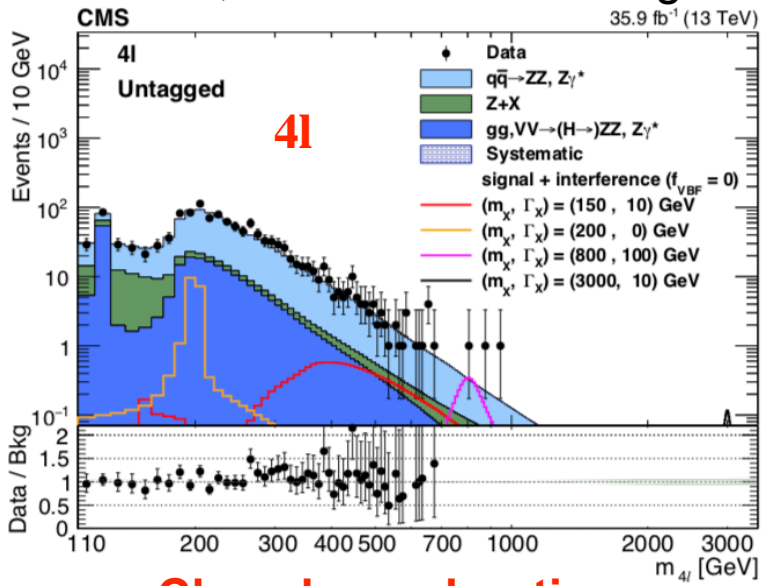
(*) also mass X→γγ 80-125 8TeV HIG-14-037
(**) also Z(→2l) + AH/A(→ττ) 8TeV HIG-14-034

H → ZZ → 2l2q, 2l2ν, 4l

arxiv:1804.01939

ggH, VBF

Lowest BR, Low reducible background



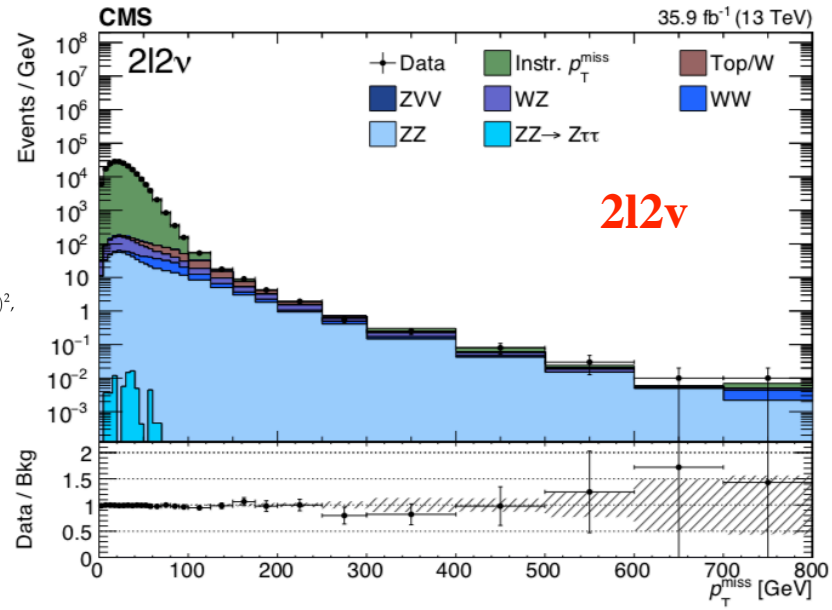
Clean bump hunting

ggH, VBF

Signal extraction:

$$m_{\mathrm{T}}^2 = \left(\sqrt{p_{\mathrm{T}}(\ell\ell)^2 + m(\ell\ell)^2} + \sqrt{p_{\mathrm{T}}^{\mathrm{miss}\,2} + m_{\mathrm{Z}}^2}\right)^2 - (\vec{p}_{\mathrm{T}}(\ell\ell) + \vec{p}_{\mathrm{T}}^{\mathrm{miss}})^2,$$

Limits as function of MH and Γ

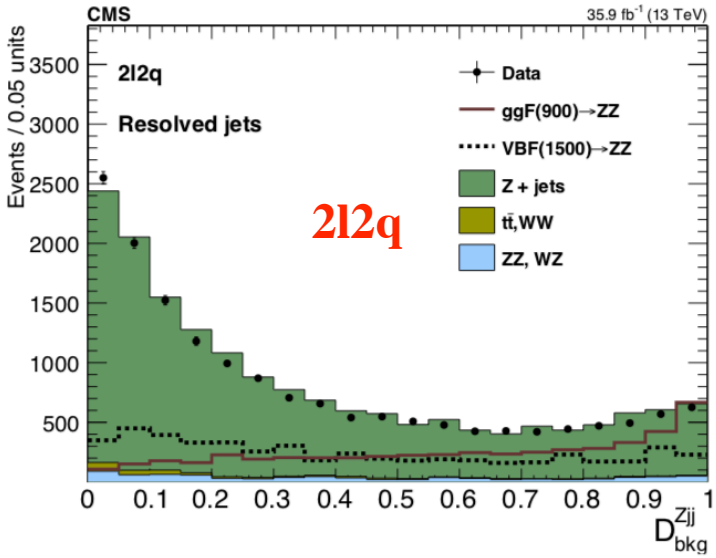


Largest BR

explored both the boosted and resolved Z→qq ggH, VBF

Search over Mzz and

$$\mathcal{D}_{\mathrm{bkg}}^{\mathrm{Zjj}} = \left[1 + \frac{\mathcal{P}_{\mathrm{Zjj}}(\vec{\Omega}^{\mathrm{X}\to 2\ell 2q}|m_{\mathrm{ZZ}})}{\mathcal{P}_{\mathrm{X}\to 2\ell 2\mathrm{q}}(\vec{\Omega}^{\mathrm{X}\to 2\ell 2\mathrm{q}}|m_{\mathrm{ZZ}})}\right]^{-1}$$

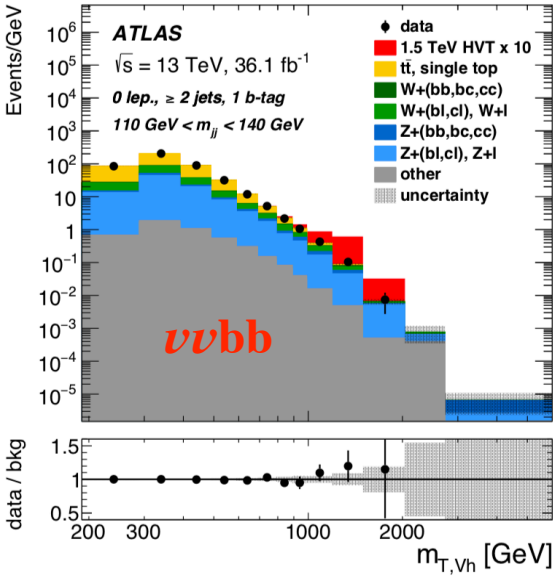


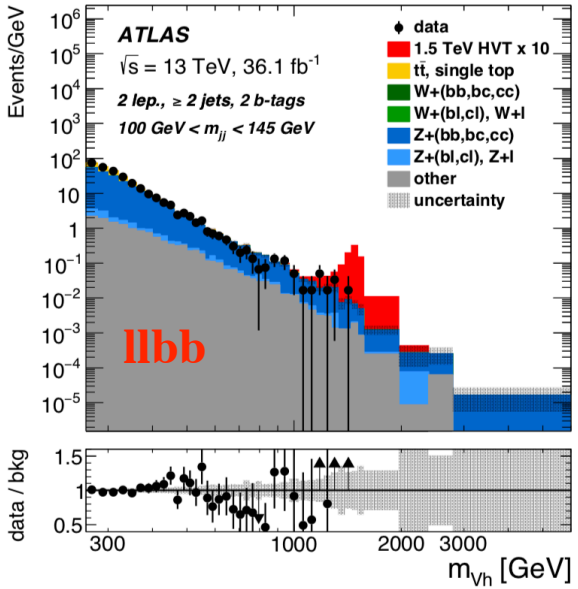
H → W/Z h → llbb, lνbb, $\nu\nu$bb [JHEP 03 (2018) 174]

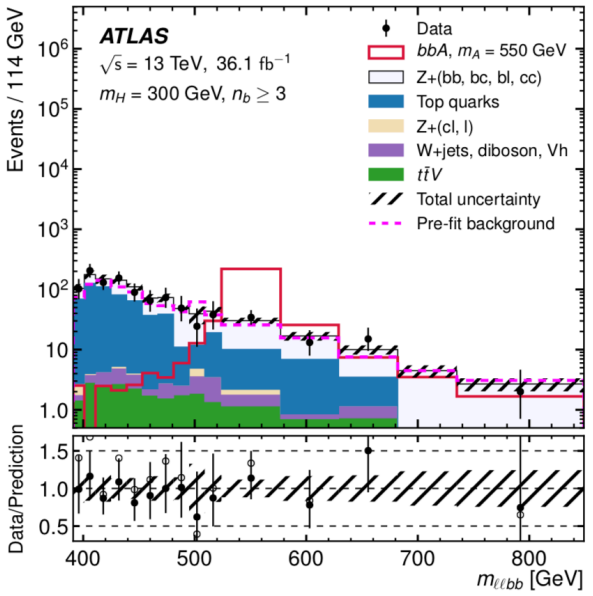
Resonant H → W/Z h_{125} → llbb, lvbb, vvbb

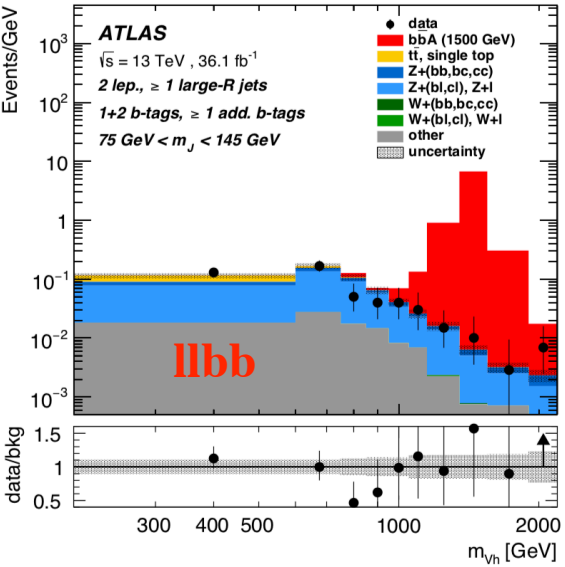
Results on gluon fusion and associate production

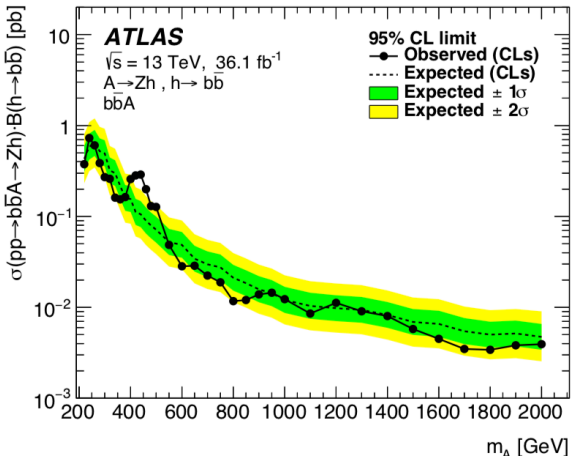
Resonant A → Z H → llbb

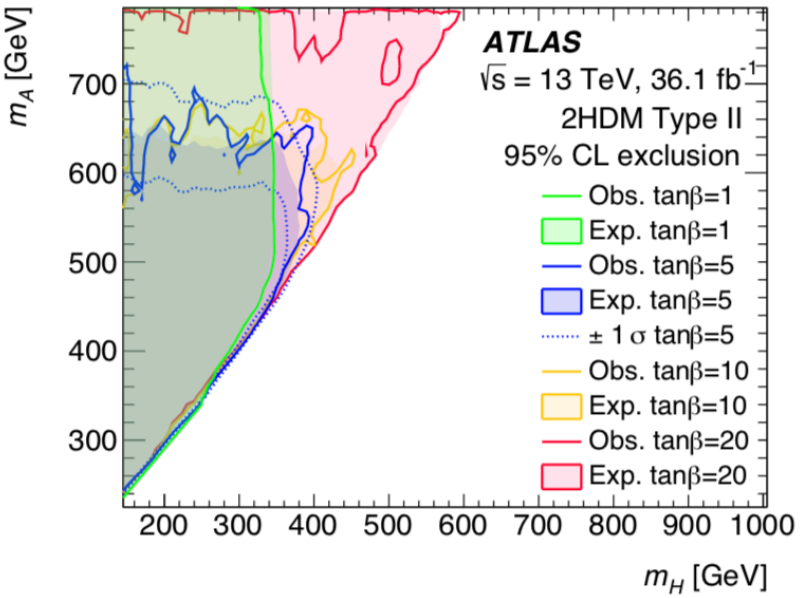










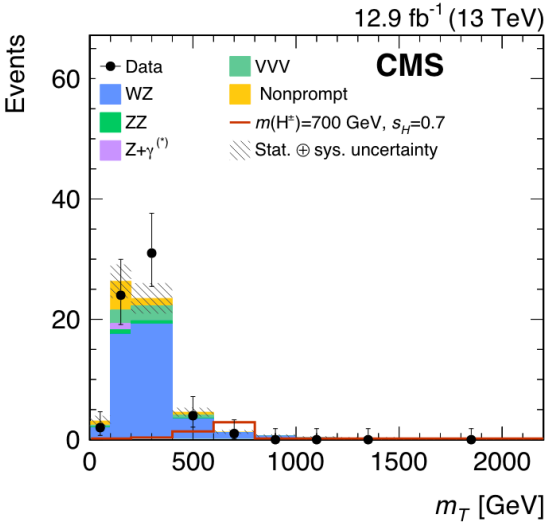


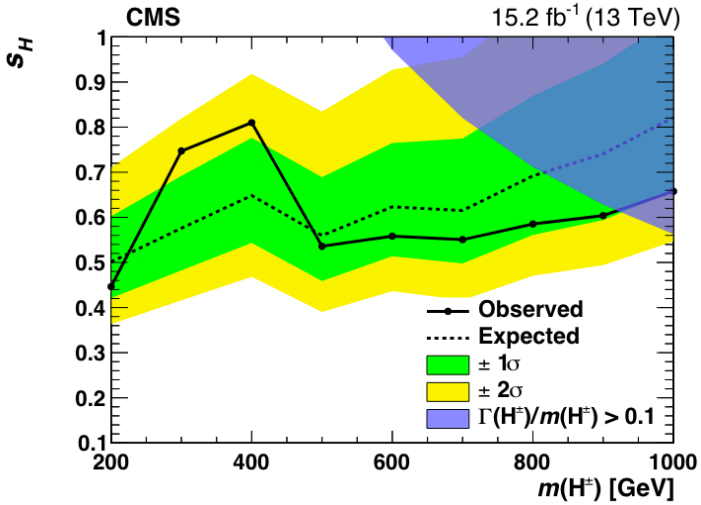
$H^{\pm} \rightarrow W^{\pm}Z$

[Phys. Rev. Lett. 119 (2017) 141802]

Three Leptons search with two OS on Z

$$m_{\mathrm{T}}(\mathrm{WZ}) = \sqrt{(E_{\mathrm{T}}(\mathrm{W}) + E_{\mathrm{T}}(\mathrm{Z}))^2 - (\vec{p}_{\mathrm{T}}(\mathrm{W}) + \vec{p}_{\mathrm{T}}(\mathrm{Z}))^2},$$

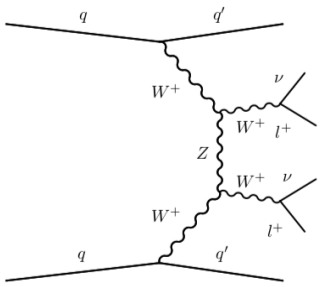


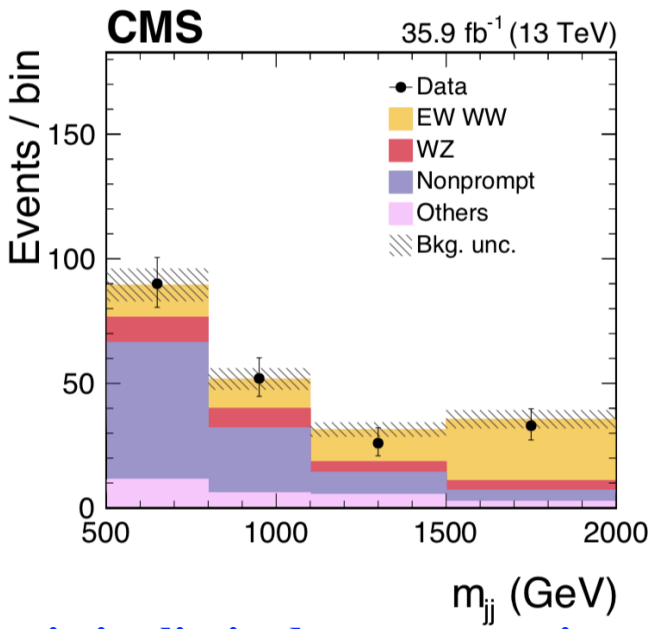


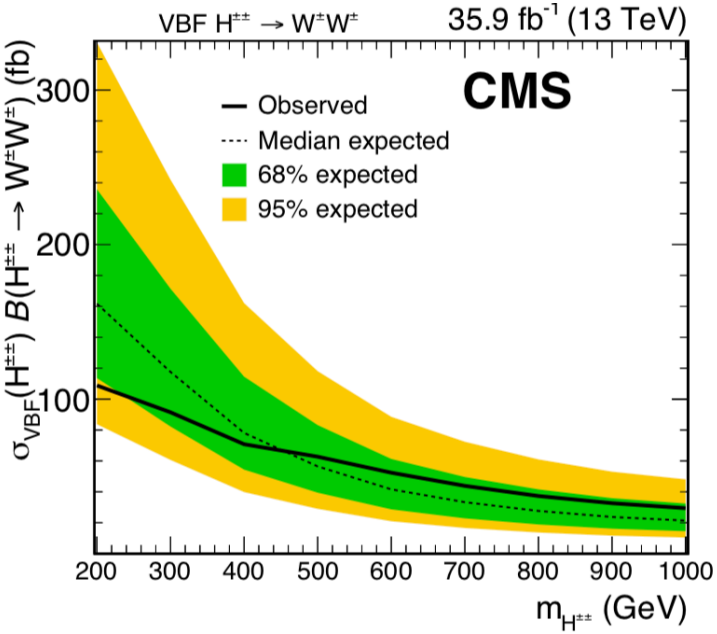
$H^{\pm\pm} \rightarrow W^{\pm}W^{\pm}$

[Phys.Rev.Lett. 120 (2018)]

Same sign leptons





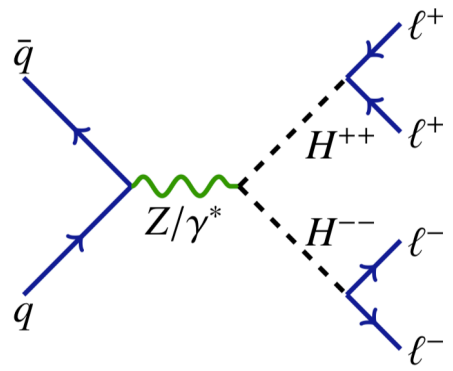


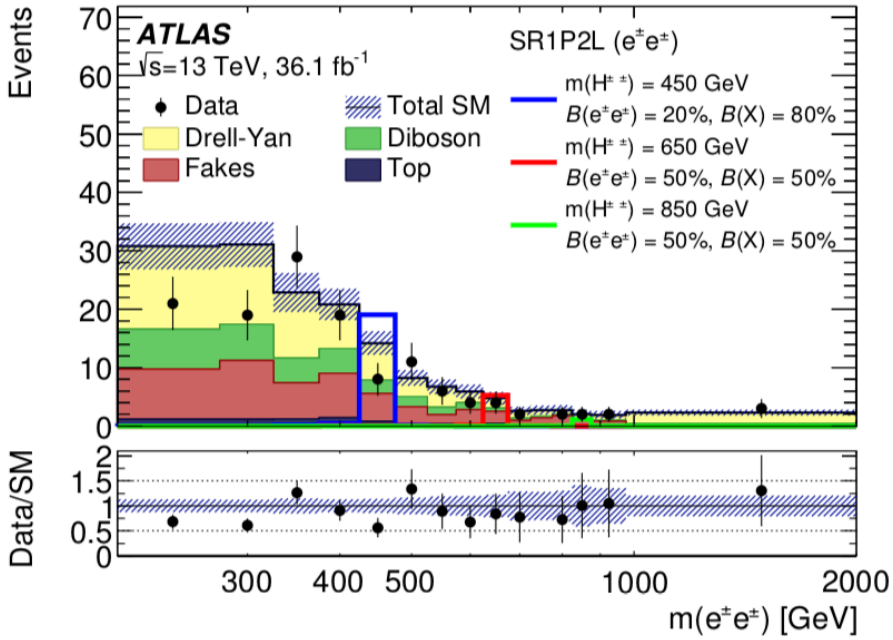
Both statistics limited, expect continued progress in Future

$H^{\pm\pm} \rightarrow l^{\pm}l^{\pm}$

[Eur.Phys.J. C78 (2018) 199]

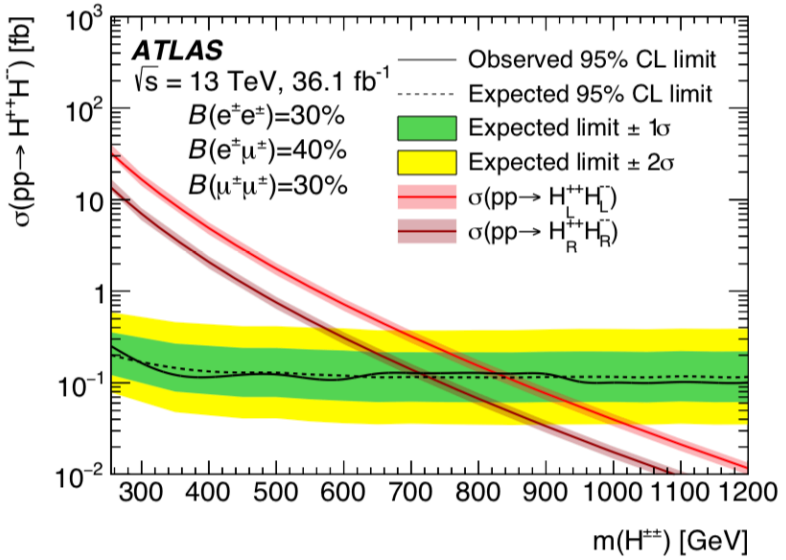
Only electron and muon channels





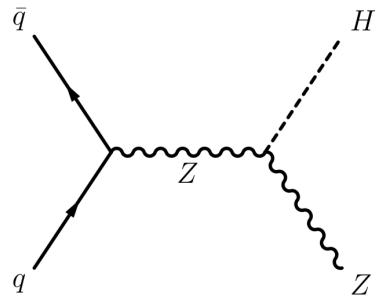
Similar results from CMS using 12.9 fb^{-1}

[CMS-PAS-HIG-16-036]

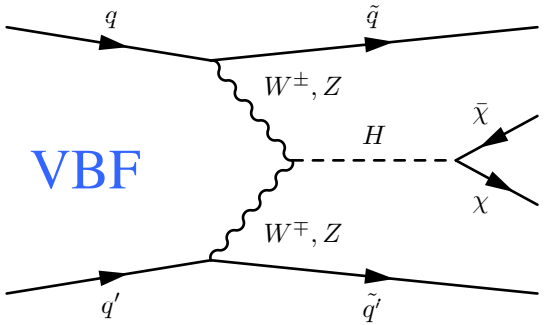


Both statistics limited, expect continued progress in Future

Invisible decay of Higgs



W/Z + H



VBF

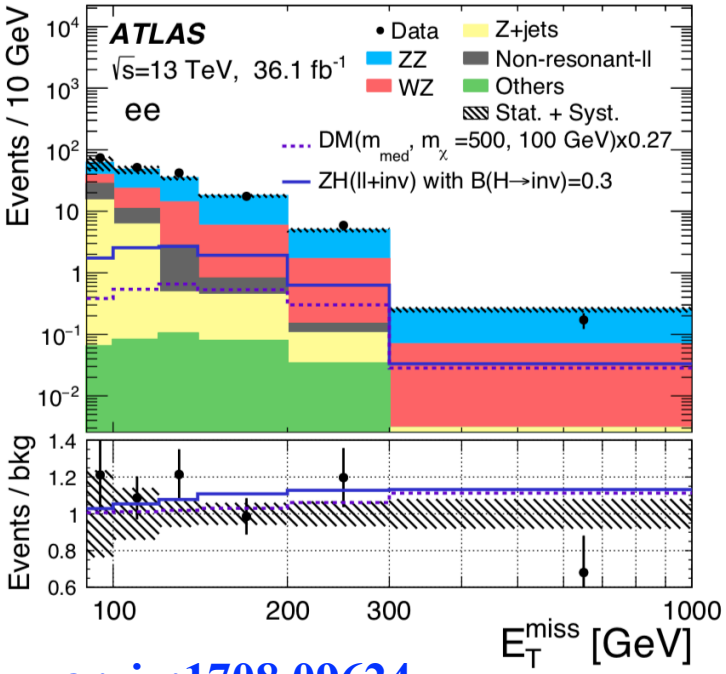
Z-> OS/SF leptons close to Mz

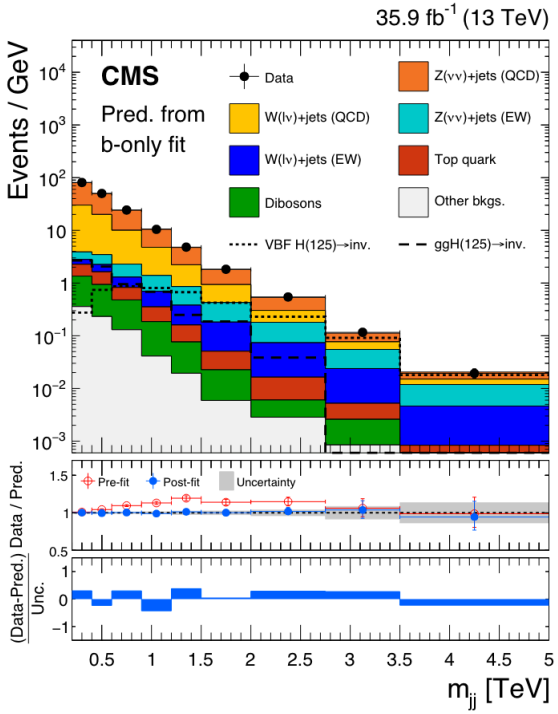
Smallest BR , Higher S/B

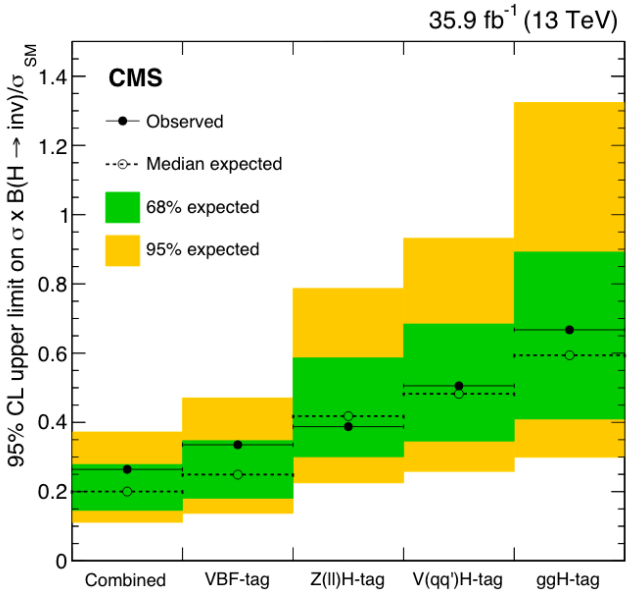
V-> qq resolved or boosted

Dijet system with Large rapidity gap

Δη(j1,j2) Large dijet mass M(j1,j2)







arxiv:1708.09624

CMS-PAS-HIG-17-023

Summary

A rich program of searches for Higgs bosons in the context of models beyond the SM being pursued since Run-1

Direct search of new physics exploits:

- Production of extra higgs decaying in Standard Model particles
- Exotic decays of the h_{125}

BSM Higgs bosons are still hiding

More decay channels being explored, more statistics to come

- *So far analyzed mainly (36 fb-1) , expected new results with 5 times large Run2 dataset*