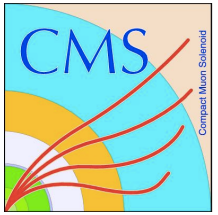


Searches for Exotic Higgs Boson Decays with the ATLAS and the CMS Experiment

Theodota Lagouri

Yale University (ATLAS)

for the ATLAS and CMS collaborations

Introduction - Motivation

- Observed H(125) an excellent opportunity to look for new physics at LHC
  - Branching fraction (BF) of Higgs to beyond-the Standard Model (BSM) particles constrained by fits of coupling constants to SM particles
  - BF(h → BSM) up to O(50%) depending on Higgs production cross section
  - Small total width of Higgs (≈4 MeV) means even a small BSM coupling can translate into detectable signature
  - Current precision of measurements of couplings to SM particles leaves ample room for BSM physics
- Explicit search for (BSM) Exotic Higgs boson decays presents an alternative opportunity for discovery of BSM physics
    - provide the best window on dark matter

Outline

Exotic Higgs boson decays with ATLAS and CMS

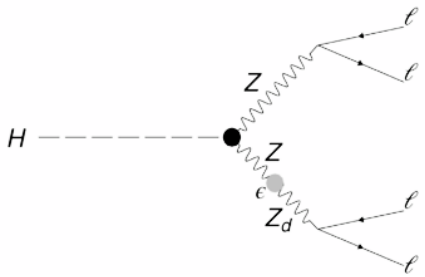
- Decays to dark vector bosons – Z_{dark} (Z_d)
  - **$H \to Z_{(d)}Z_d \to 4l$ (ATLAS)** New
- Lepton Flavor Violating (LFV) decays
  - **$H \to \mu\tau_e$, $\mu\tau_h$ (CMS)**
  - **$H \to \mu\tau_{had}$ (ATLAS)** **Brand New**
- Flavor Changing Neutral Current (FCNC) decays
  - **$t \to qH$ ($H \to \gamma\gamma$) (ATLAS)**
  - **$t \to qH$ ($H \to \gamma\gamma$) (CMS)**
  - **$t \to ch$ (multi-lepton+di-photon) (CMS)**
- Decays to a light pseudoscalar neutral Higgs boson (α) as in NMSSM
  - **$H \to \alpha\alpha \to 2\mu 2\tau$ (ATLAS)*** New
  - **$H \to \alpha\alpha \to 4\gamma$ (ATLAS)** **Brand New**
  - **$H \to \alpha\alpha \to 4\mu$ (CMS)**** New
- Exotic Higgs decays to Photon+MET
  - **(VBF) $H \to \{1 \text{ or } 2\gamma\} + E_T^{miss}$ (ATLAS)*****
  - **$H \to \{1 \text{ or } 2\gamma\} + E_T^{miss}$ (CMS)** New
- Run-2 prospects
- Conclusions

See also at this conference:
** Poster: B. Kaplan (ATLAS)*
*** Talk: A. Mohammadi (CMS)*
**** Poster: C. Bernius (ATLAS)*

$H \rightarrow Z_{(d)}Z_d \rightarrow 4l$ (ATLAS) New

ATLAS (8 TeV)
arXiv:1505.07645
Submitted to PRD

Higgs as a portal to the hidden/dark sector

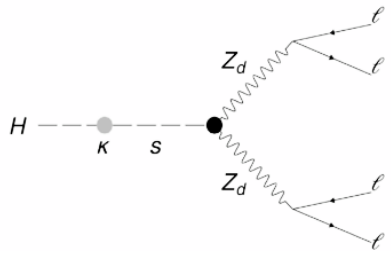


Light exotic gauge boson Z_d: $m_{Zd}<m_Z$

Based on SM Higgs to 4l analysis

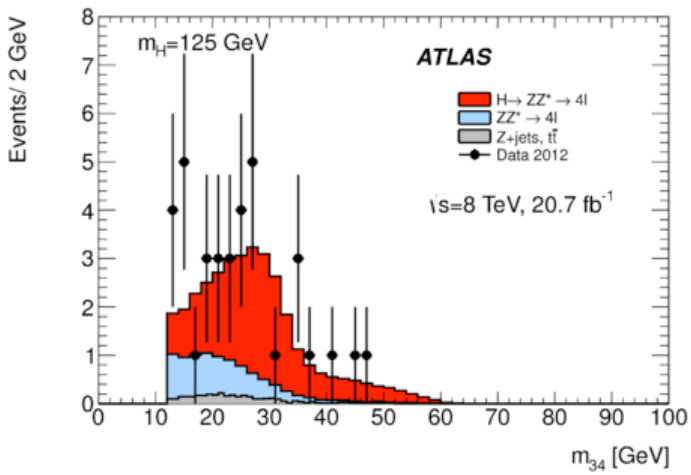
Model independent analysis

115 GeV $<m_{4l}<$130 GeV



Look for excess in m_{34}

m_{12} closest to m_Z

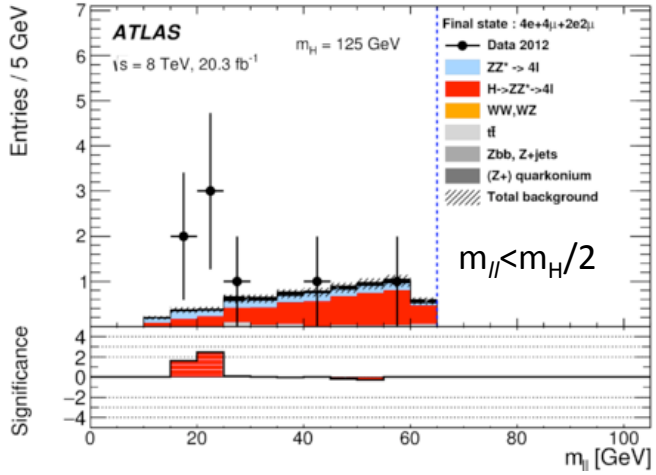


$$n(H \rightarrow 4\ell) = n(4\ell) - n(ZZ^*) - n(tt) - n(Z + \text{jets}).$$

BGs: H→ZZ*→4l determined from data, ZZ* (MC), $t\bar{t}$, Z+jets (DD)

Look for excess in m_{ll}

$|m_{12}-m_{34}|$=min



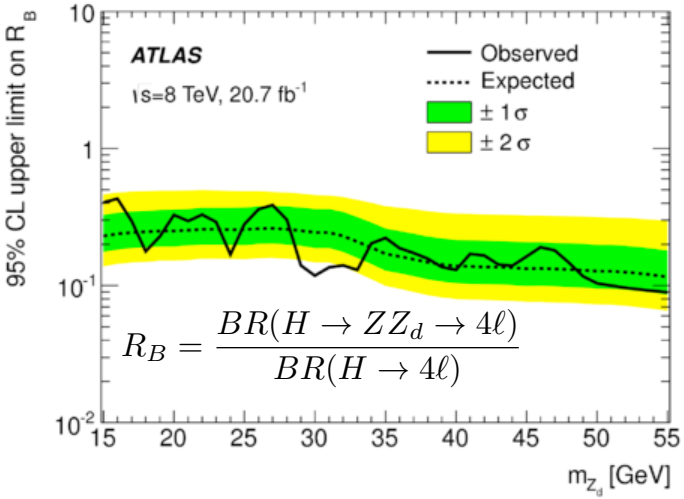
BGs: (MC) H→ZZ*→4l, ZZ*→4l

$m_{Zd}-m_{ll}<\delta m$= 5/3/4.5 GeV - 4e/4μ/2e2μ

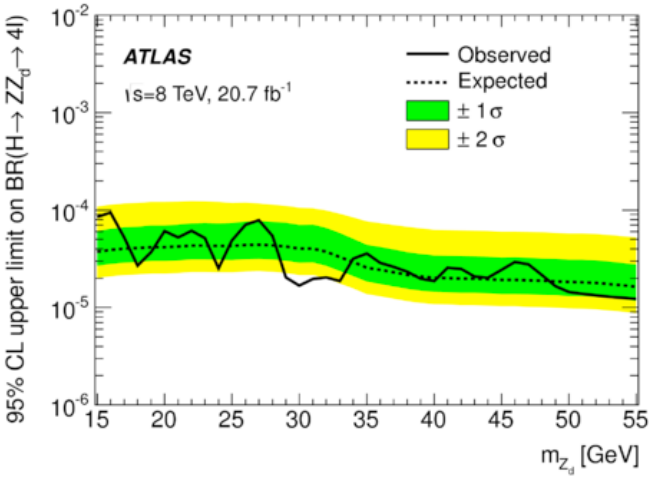
$H \to Z_{(d)} Z_d \to 4l$ (ATLAS)

Observed data well described by SM expectation=>Upper limits set

$H \to Z Z_d \to 4l$

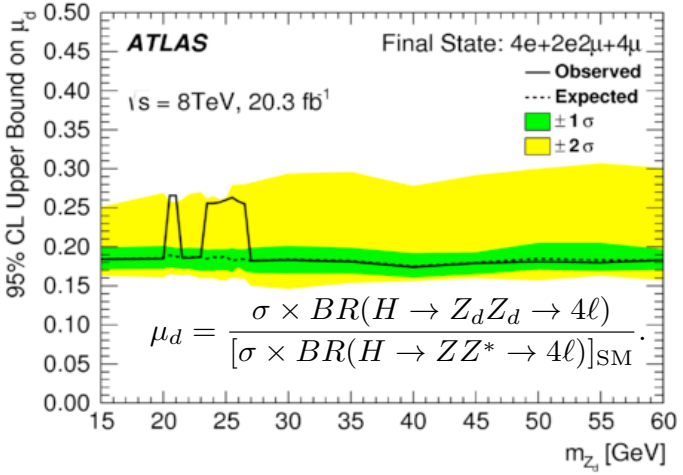


95% CL limits: $R_B < 0.4$ (0.2)

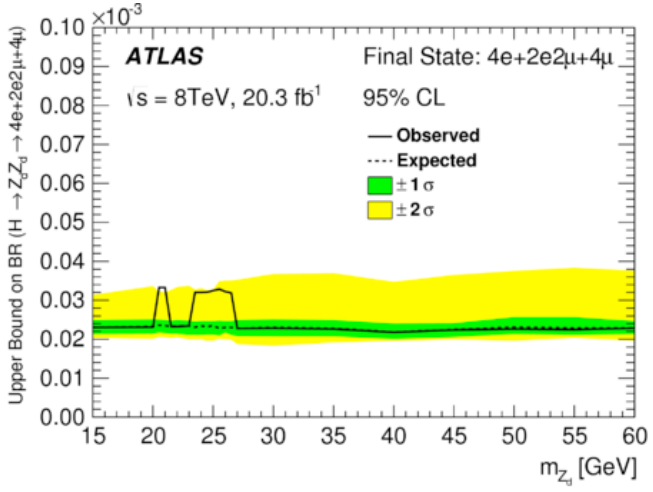


95% CL limits: $BR(H \to ZZ_d \to 4l) < (1\text{-}9) \times 10^{-5}$

$H \to Z_d Z_d \to 4l$



2 (4e, 4μ) observed events with significance 1.7 σ

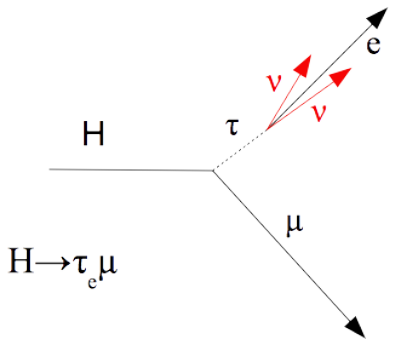


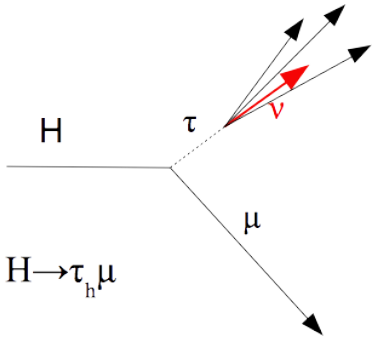
95% CL limits $BR(H \to Z_d Z_d \to 4l)$: $(2\text{-}3) \times 10^{-5}$

CMS (8 TeV):
arXiv:1502.07400
Submitted to Phys. Lett. B
CMS-PAS-HIG-14-005

Lepton Flavor Violating (LFV) decays $H\to\mu\tau_e$, $H\to\mu\tau_h$ (CMS)

- Direct LFV search in $H\to\mu\tau_e$, $H\to\mu\tau_h$ (M_H = 125 GeV)
- LFV decays can occur in models with more than one Higgs doublet, in supersymmetric models, composite Higgs boson models, models with flavor symmetries, Randall–Sundrum models etc.
- Each channel is separated into 0, 1, and 2 jet categories: gg, VBF H-productions





Similar signatures with SM $H\to\tau_\mu\tau_e$, $H\to\tau_\mu\tau_h$
- Muon prompt - higher momentum than in SM
- Fewer neutrinos give different missing energy and topology
  - collinear with the τ decay products

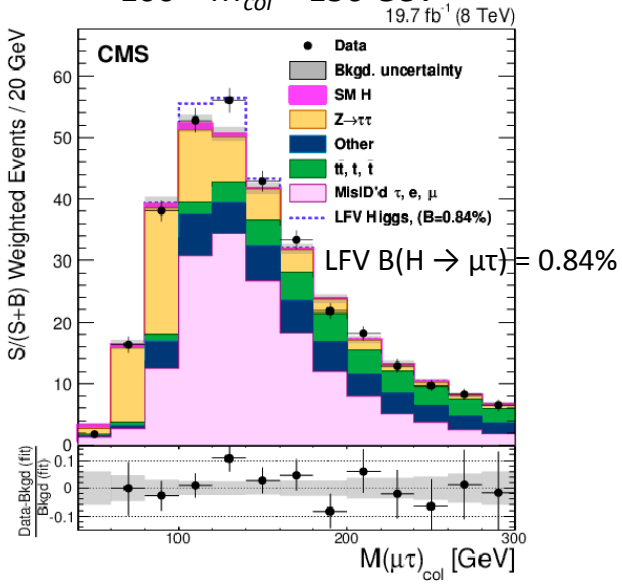
$H\to\mu\tau_e$
- Dominant background: $Z\to\tau_\mu\tau_e$
- Other backgrounds: jets faking leptons in W+jets, QCD multi-jets and $t\bar{t}$ +jets

$H\to\mu\tau_h$
- Dominant background: jets faking τ in W+jets, QCD multi-jet and $t\bar{t}$ +jets
- Other backgrounds: $Z\to\tau\tau$, *Z* + jets and $t\bar{t}$ +jets

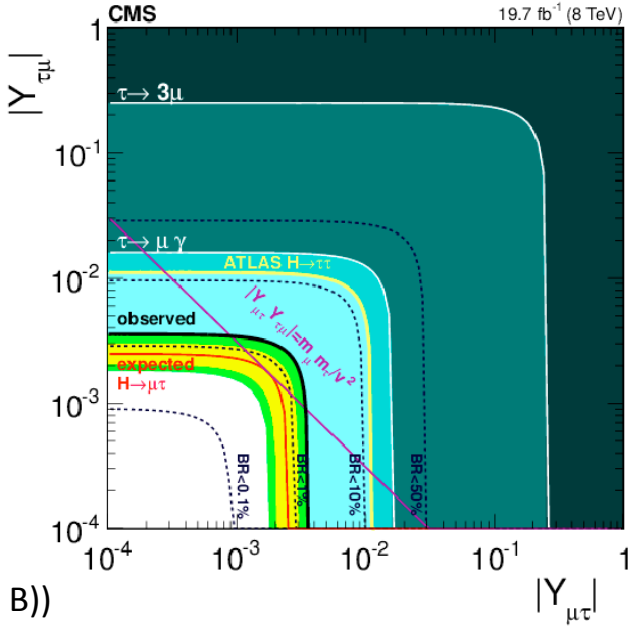
Lepton Flavor Violating (LFV) decays $H\to\mu\tau_e$, $H\to\mu\tau_h$ (CMS)

Post-Fit M_{col}

$100 < M_{col} < 150$ GeV



LFV B(H → μτ) = 0.84%



All categories combined, each category weighted by significance (S/(S + B))

- A slight excess of signal events - still consistent within background uncertainties
  - significance of 2.4 standard deviations
- Best fit branching fraction
  - B(H → μτ) = (0.84 +0.39 -0.37)%
- Constraint on the branching fraction
  - B(H → μτ) < 1.51 (0.75)% at 95% CL

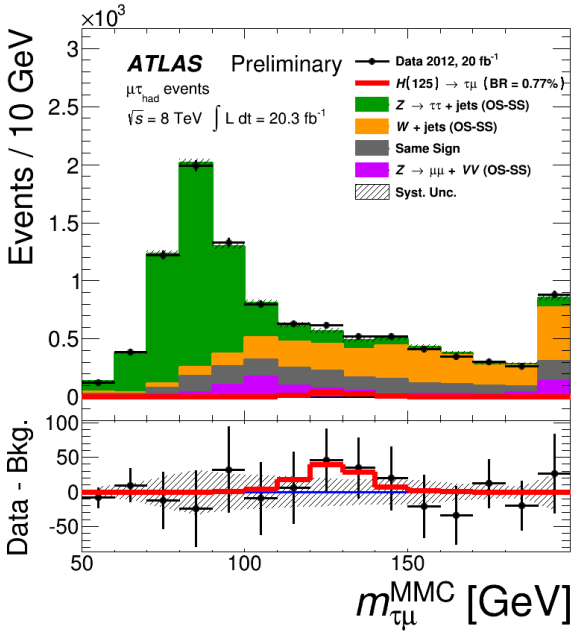
- BR limit <1.51% constrain the μ-τ Yukawa couplings $<3.6\times10^{-3}$
- It improves the indirect current bound by an order of magnitude.

H→eτ, H→eμ will be published soon!

Lepton Flavor Violating (LFV) decays $H\rightarrow\mu\tau_{had}$ (ATLAS) **Brand New**

ATLAS (8 TeV)
HIGG-2014-08
To be submitted to JHEP

Post-fit
110 GeV $M_{\mu\tau}^{MMC} < 150$ GeV



Signal regions (SR1, SR2) defined as:

- SR1: $m_T(\mu, E_T^{miss}) > 40$ GeV, $m_T(\tau_{had}, E_T^{miss}) < 40$ GeV
- SR2: $m_T(\mu, E_T^{miss}) < 30$ GeV, $m_T(\tau_{had}, E_T^{miss}) < 60$ GeV

Backgrounds:

- $\mu+\tau_{had}$: irr. $Z/\gamma^*\rightarrow\tau\tau$ (dominant in SR2), $VV\rightarrow\mu\tau+X$ (V=W,Z), $t\bar{t}$, single-top, SM $H\rightarrow\tau\tau$
- fake τ_{had}: W+jets (dominant in SR1), QCD multi-jet, VV, $t\bar{t}$, t, $Z\rightarrow\mu\mu$+jets

Small excess found in SR2
120 GeV < $M_{\mu\tau}^{MMC}$ < 140 GeV => significance 2.2 σ
SR1+SR2 => combined significance 1.3 σ

Best fit $Br(H\rightarrow\mu\tau_{had}) = (0.77\pm0.62)\%$

No significant excess of data over SM BGs

95% CL $Br(H\rightarrow\mu\tau_{had})$ obs (exp.) < 1.85% (1.24 +0.50 -0.35)%

Flavor Changing Neutral Current (FCNC) decays t→qH (H→γγ) (ATLAS)

ATLAS (7+8 TeV)
JHEP06(2014)008

- FCNC involving light u/c quark highly suppressed in the SM, Br≈10^{-15}
- Might be enhanced by several orders of magnitude in BSM, up to ≈10^{-3}
- LHC is a top factory : can search for rare decays with high sensitivity
- H → γγ appears as the most sensitive mode: large number of events, clean signature

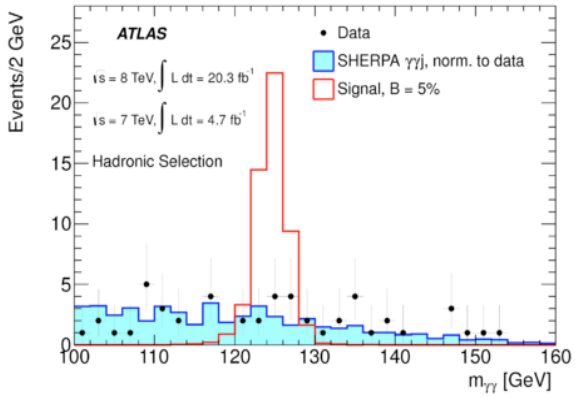
- t→qH, H(125)
- t→bW, W decays:
  - hadronically (7+8 TeV): ≥ 4 jets, ≥ 1 b-tag, top invariant mass cuts (γγj and jjj)
  - leptonically (8 TeV): 1 lepton, ≥ 2 jets, m_T>30 GeV, ≥ 1 b-tag, invariant mass cuts (γγj and lνj)

Analyse the γγ invariant mass distribution (SM H→γγ analysis)

- Hadronic channel: $m_1=m_{\gamma\gamma j}$, $m_2=m_{jjj}$
  - m_1: [156-191] GeV, m_2: [130-210] GeV
- Leptonic channel: $m_1=m_{\gamma\gamma j}$, $m_2=m_{l\nu j}$
  - m_1: [156-191 GeV], m_2: [135-205] GeV

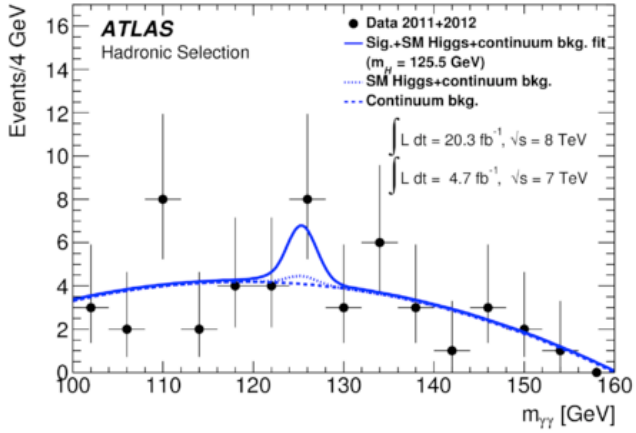
- Start from standard H → γγ selection
  - ≥ 2 tight-isolated leading (sub-leading) γ, E_T>40 GeV (30 GeV)
- Enrich the $t\bar{t}$ topology
- BGs (non-resonant) : di-photon, $t\bar{t}$, W prod.

$m_{\gamma\gamma}$ hadronic selection



$m_{\gamma\gamma}$ discriminating variable in the fit

Flavor Changing Neutral Current (FCNC) decays
t→qH (H→γγ) (ATLAS)



Fixing m_H = 125.5 GeV

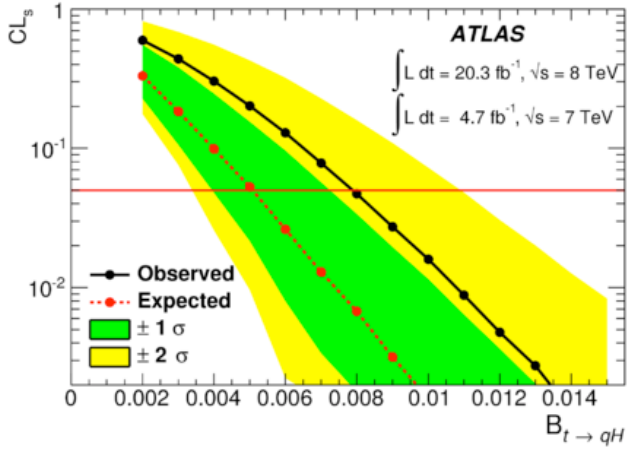
Fitted branching ratio (Br) t→c(u)H:
Br= 0.22 +0.31 -0.26 %

corresponding to a signal yield of

N_s = 3.1 +4.3 -3.7

No significant excess found

For H ~ H_{SM} and B(t → cH) = 1%



95% CL Limit on Br: Br < 0.79 (0.51)%

corresponding to a limit on the λ_{tqH} coupling :

$\sqrt{\lambda_{tcH}^2 + \lambda_{tuH}^2}$ < 1.92 √Br < 0.17 (0.14 expected)

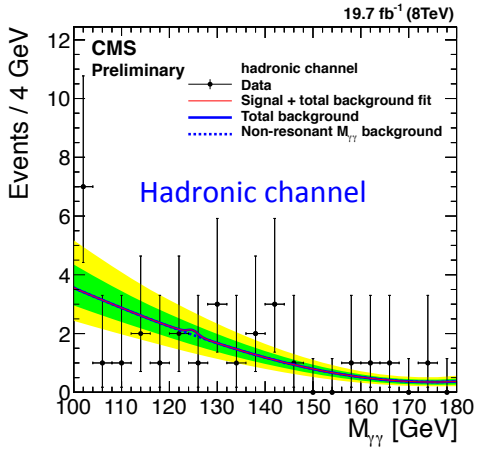
to be compared to top quark Yukawa coupling λ_{ttH} ~ 1

CMS (8TeV)
CMS-PAS-TOP-14-019

Flavor Changing Neutral Current (FCNC) decays t→q(c,u)H (H→γγ) (CMS)

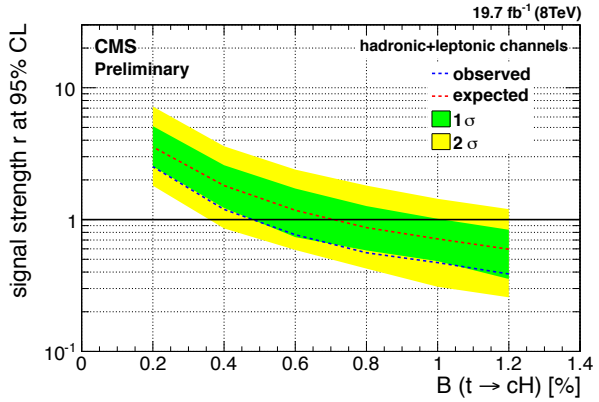
- Analysis: **H→γγ** cut based photon selection criteria
- Hadronic/leptonic channels: ≥4 jets, 1 b-tagged/ ≥ 1 lepton (e or μ), ≥ 2 jets, 1 b-tagged

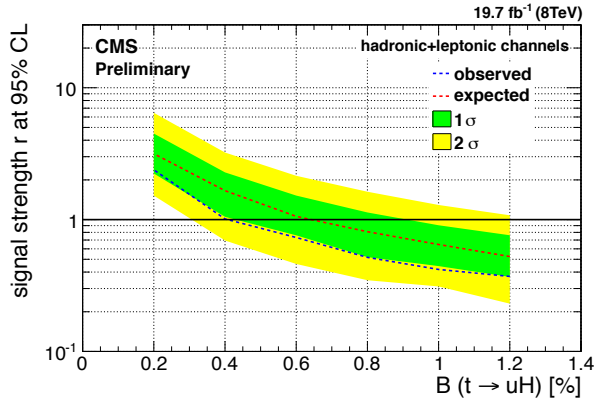
- Resonant diphoton backgrounds: SM-H (γγ)(MC-ttH)
- Non-resonant diphoton backgrounds: fit to data
- 100 GeV ≤ $M_{\gamma\gamma}$ ≤ 180 GeV
- B (t → c,u H) = 1%

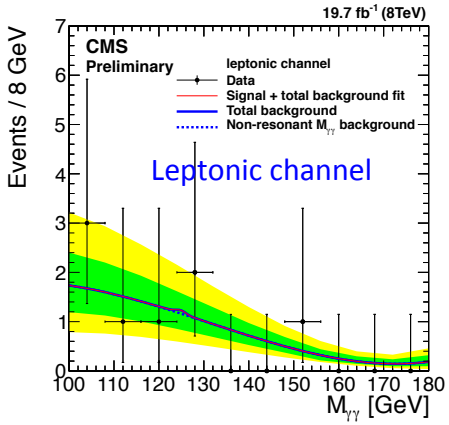


Observed (Expected) 95% CL limit B t→cH: 0.47 (0.71)%
Observed (Expected) 95% CL limit B t→uH: 0.42 (0.65)%

No significant excess observed

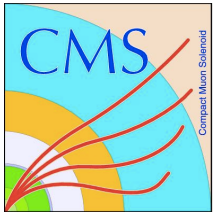






CMS (8TeV)
arXiv:1410.2751v2
CMS-PAS-HIG-13-034

Flavor Changing Neutral Current (FCNC) decays t→ch (multi-lepton+di-photon) (CMS)



Multi-channel counting experiment approach:

- Multi-lepton event: >= 3 isolated and prompt leptons (e, μ, τ_h), >=2 electrons or muons ("light" leptons)
- Lepton+di-photon event: photon pair + ≥1 lepton

Higgs boson decay mode	Upper limits on $\mathcal{B}(t \to ch)$		
	Obs.	Exp.	68% CL range
$\mathcal{B}(h \to WW^*) = 23.1\%$	1.58%	1.57%	(1.02–2.22)%
$\mathcal{B}(h \to \tau\tau) = 6.15\%$	7.01%	4.99%	(3.53–7.74)%
$\mathcal{B}(h \to ZZ^*) = 2.89\%$	5.31%	4.11%	(2.85–6.45)%
Combined multileptons ($WW^*, \tau\tau, ZZ^*$)	1.28%	1.17%	(0.85–1.73)%
$\mathcal{B}(h \to \gamma\gamma) = 0.23\%$	0.69%	0.81%	(0.60–1.17)%
Combined multileptons + diphotons	0.56%	0.65%	(0.46–0.94)%

- Using di-photon and multi-lepton search channels that are sensitive to the decay t→ch, (B(t→ch)=1%)
- Upper combined limit on B(t→ch), observed 0.56%, expected 0.65%
- Significant improvement over the earlier limit of 1.3% from the multi-lepton search alone (Phys. Rev. D 90 (2014) 032006)
- Left- and right- handed top-charm flavor violating Higgs Yukawa couplings limit
  - $\sqrt{|\lambda^H_{tc}|^2 + |\lambda^H_{ct}|^2}$ < 0.14 (0.65)%

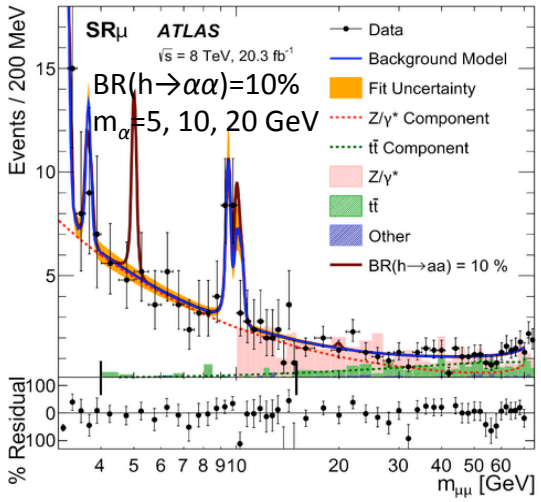
Decays to a light pseudo-scalar neutral Higgs boson (α) (NMSSM)

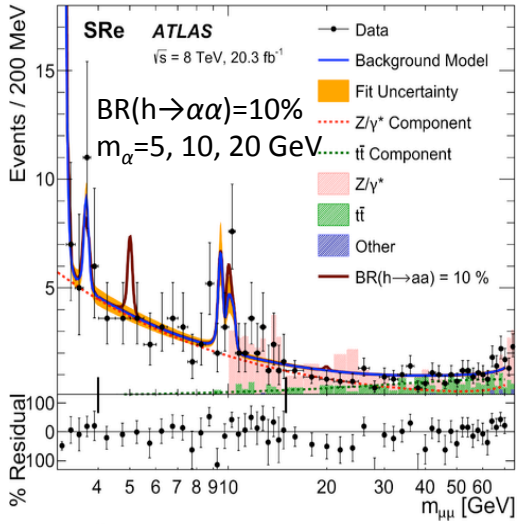
$H \to \alpha\alpha \to 2\mu 2\tau$ (ATLAS)* New

ATLAS (8 TeV)
arXiv:1505.01609
Submitted to PRD

** See also Poster B. Kaplan (ATLAS)*

Dominant BG: Z/γ^* and $t\bar{t}$ (J/Ψ, Υ)



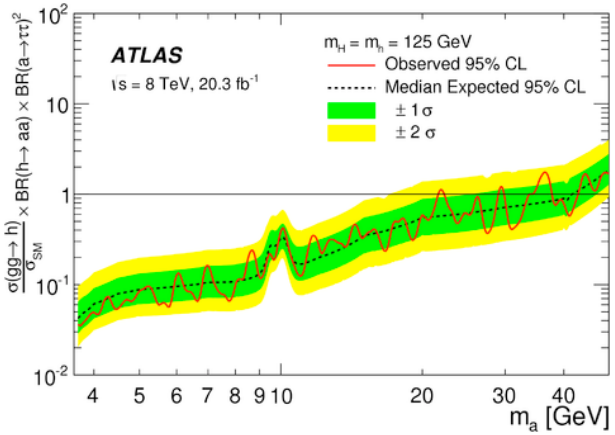


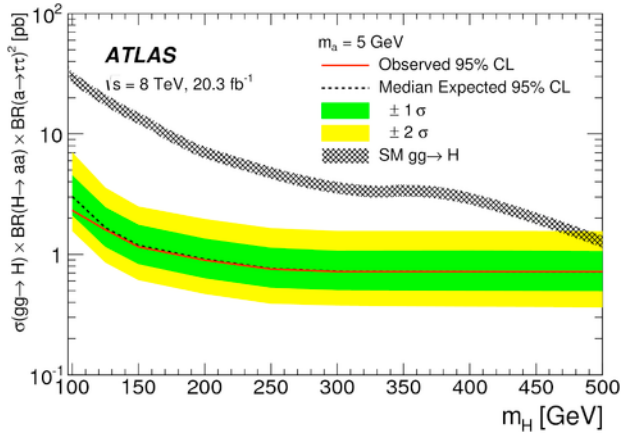
m_H = 125 GeV

$2m_\tau < m_\alpha < 2m_b$:
1 $\alpha \to \tau\tau$, 1 $\alpha \to \mu\mu$

m_α: 3.7-50 GeV

No significant excess of data





Scan of m_H (m_α=5 GeV)
m_H =100-500 GeV

Consistent with expected limits

Most stringent limit 3.5% for m_α=3.75 GeV

95% CL limits on production rate:
$\sigma(gg \to H) \times BR(H \to \alpha\alpha)$: 2.33 pb-0.72 pb

Decays to light pseudoscalar neutral Higgs boson (α)
$H \to \alpha\alpha \to 4\gamma$ (ATLAS) **Brand New**

ATLAS (8 TeV)
EXOT-2013-24
To be submitted to Eur. Phys. J. C

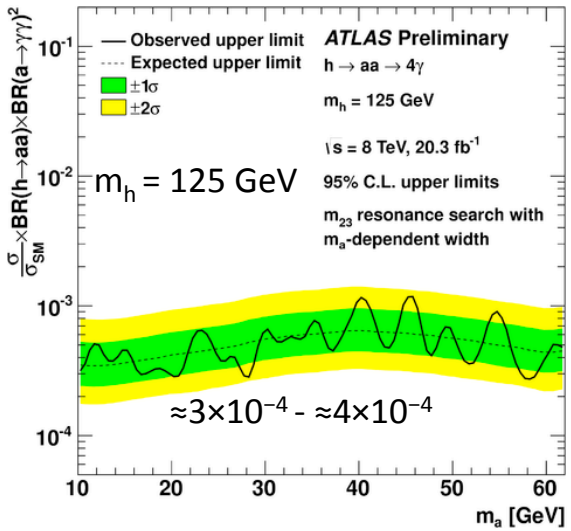
Many extensions of SM Higgs sector include CP-odd particles (α) with couplings to Higgs and branching ratios to photons visible at LHC

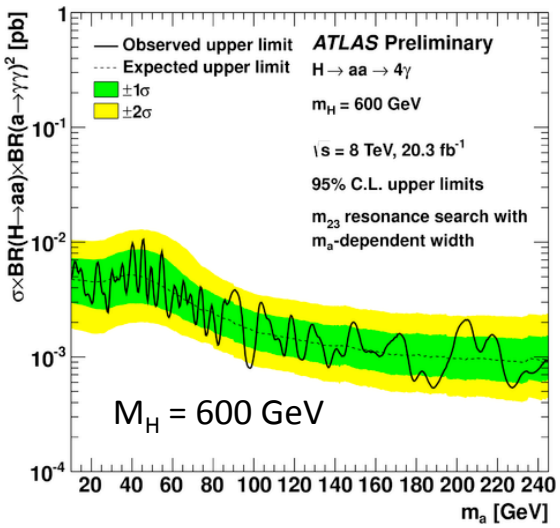
Signature: ≥ 3 isolated photons

- Signal: "tight" $\gamma_{1,2}$: $p_T > 22$ GeV, $\gamma_{3,(4)}$: $p_T > 17$ GeV
- Isolation: E_T(cone40) < 4 GeV
- Backgrounds: irr. (2,3,4) prompt photons, photon(s)+jet(s)
- Combination of data-driven (for jets) and MC

No significant excess of data over SM BGs
Consistent with SM expected limits

Resonance search in m_{23} spectrum





$300 < M_H < 900$ GeV
$10 \text{ GeV} < m_\alpha < m_H/2$

M_H: 600 GeV

$\sigma/\sigma_{SM} \times BR(h \to \alpha\alpha) \times BR(\alpha \to \gamma\gamma)^2 < 10^{-3}$
$m_h = 125$ GeV, $10 \text{ GeV} < m_\alpha < 62$ GeV

$\sigma_H \times BR(h \to \alpha\alpha) \times BR(\alpha \to \gamma\gamma)^2 < 0.02$ pb $10 < m_\alpha < 90$ GeV

< 0.001 pb m_α up to 245 GeV

CMS (8 TeV)
arXiv:1506.00424
Submitted to Phys. Lett. B

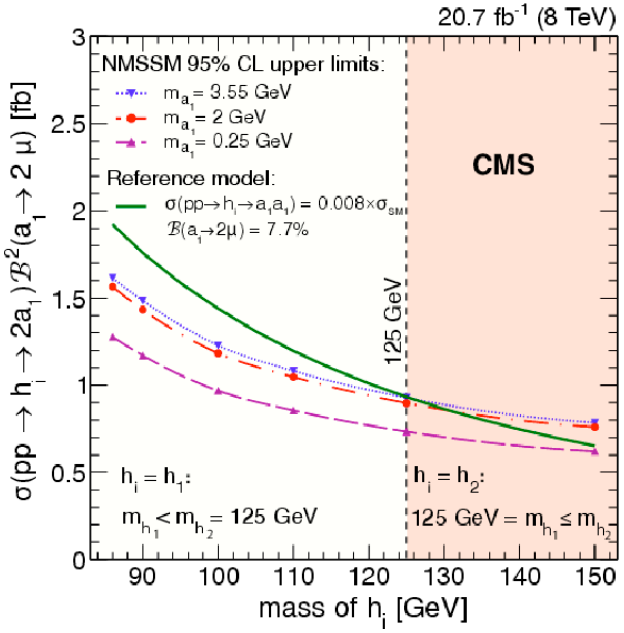
** See also Talk*
A. Mohammadi (CMS)

Decays to a light pseudo-scalar neutral Higgs boson (α) (NMSSM) H→$\alpha\alpha$→4μ (CMS)* New

- NMSSM Higgs sector: 3 CP-even neutral Higgs bosons $h_{1,2,3,}$ 2 CP-odd neutral Higgs bosons $\alpha_{1,2}$ and a pair of charged Higgs bosons $h^{\pm}$
- $h_{1,2}\rightarrow 2\alpha_1$, h_1 or h_2 can be the boson observed at 125 GeV
- $\alpha_1\rightarrow 2\mu$, 2 pairs of isolated muons (di-muons), $m_{1\mu\mu}\approx m_{2\mu\mu}$ within detector resolution

Light boson masses in the range $2m_\mu<m_\alpha<2m_\tau$ (0.25-3.55 GeV)

1 event obs. 2.2±0.7 SM exp.



BGs dominated by $b\bar{b}$ and J/ψ pair production

- 95% CL upper limits for NMSSM on $\sigma(pp\rightarrow h_{1/2}\rightarrow 2\alpha_1)B^2(\alpha_1\rightarrow 2\mu)$ as a function of
  - m_{h1} ($86 < m_{h1} < 125$ GeV) and
  - m_{h2} ($m_{h2} > 125$ GeV)
- Limits compared to predicted rate (solid curve), with simplified scenario
  - $\sigma(pp\rightarrow h_i\rightarrow 2\alpha_1) = 0.008\ \sigma_{SM}$

Exotic Higgs Decays to Photon+MET
(VBF) H→{1 or 2 isol. γ} + E_T^{miss} (ATLAS)*

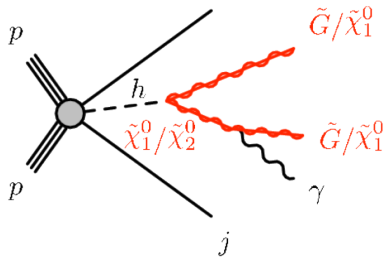
ATLAS (8 TeV)
ATLAS-CONF-2015-001

** See also Poster C. Bernius (ATLAS)*

- Exotic Higgs decay in GMSB and NMSSM
- VBF production facilitates better data-driven γ+jets and multi-jet background estimates than ggH
- VBF Higgs boosted in transverse plane: γ and E_T^{miss} not necessarily back-to-back, use angles to define control regions

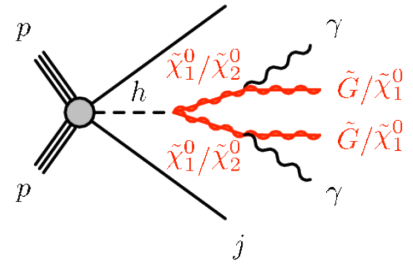
γ+E_T^{miss}+jj

$$m_h/2 < m_{\tilde{\chi}^0_{2,j}} < m_h$$



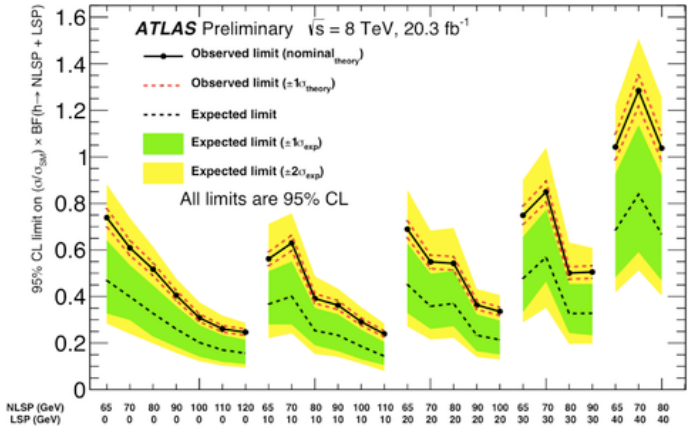
γγ+E_T^{miss}+jj

$$m_{\tilde{\chi}^0_j} < m_h/2 \text{ (or } m_{\tilde{\chi}^0_2} < m_h/2)$$

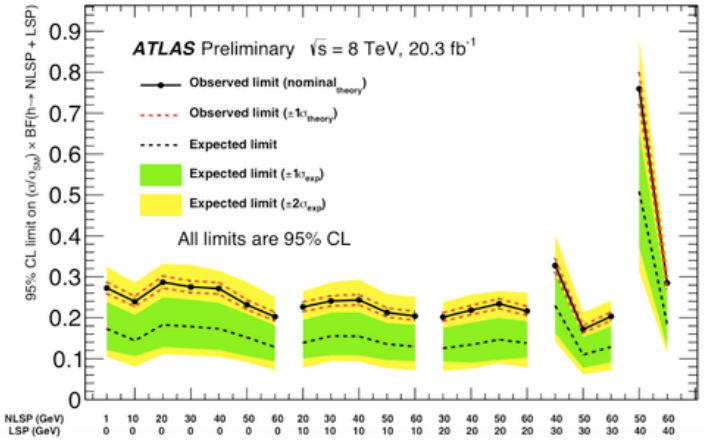


Limits set for different NLSP, LSP mass pairs *Observation consistent with SM*

mono-photon



di-photon



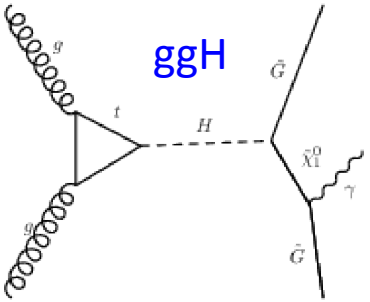
$$(\sigma/\sigma_{SM}) \times \mathrm{BF}(h \rightarrow \mathrm{NLSP} + \mathrm{LSP})$$

First direct limits similar or stronger than indirect Higgs coupling measurements

CMS (8 TeV):
arXiv:1507.00359
Submitted to Phys. Lett. B
CMS-HIG-14-025

Exotic Higgs Decays to Photon+MET

H→{1 or 2 isol. γ} + E_T^{miss} (CMS) New



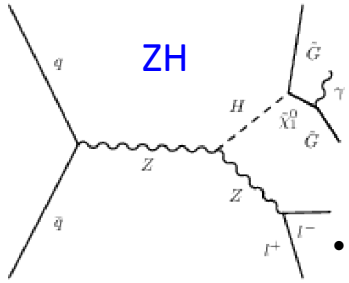
m_H= 125 GeV

$m_H/2 < m_{\tilde{\chi}1}{}^0 < m_H$

$$H \to \tilde{\chi}_1^0 \tilde{G} \to \gamma \tilde{G} \tilde{G}$$

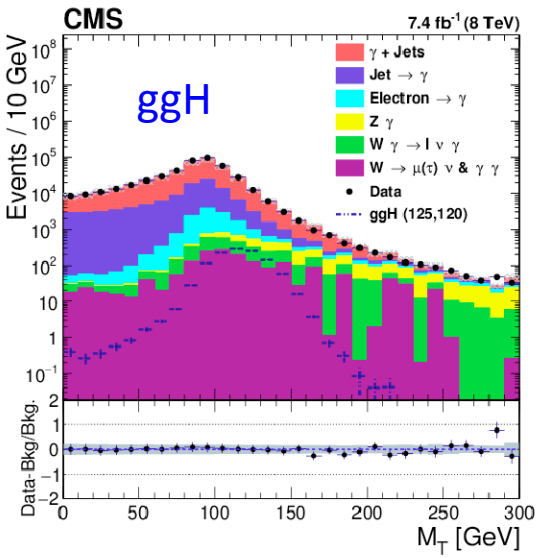
$M_{\tilde{\chi}1}{}^0 < m_H/2$

$$H \to \tilde{\chi}_1^0 \tilde{\chi}_1^0 \to \gamma\gamma \tilde{G} \tilde{G}$$

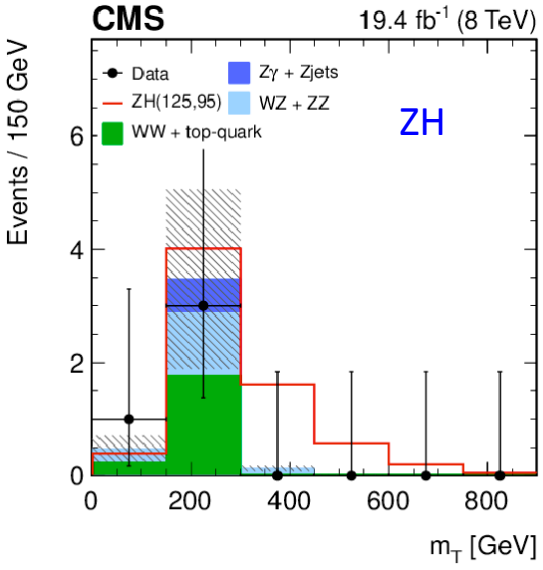


- ZH (8 TeV, 19.4 fb^{-1})
  - 2 lep. p_T>20 GeV
    E_T^{γ}> 20 GeV
  - $|m_{ll}-m_Z|$<15 GeV

- Exotic Higgs decay quasi-model independent search, low-scale SUSY
- ggH BGs: irr. Zγ→νγ, γ+jet and mono-e and mono-jet faking γ
- ZH BGS: di-lep. non-resonant (W^+W^-, t, W+jets, $Z/\gamma^* \to \tau^+\tau^-$) resonant (WZ(lνll), ZZ(2l2ν), Zγ, Z+jets)
  - ggH (8 TeV, 7.4 fb^{-1})
    - E_T^{γ}> 45 GeV
    - E_T^{miss}> 40 GeV

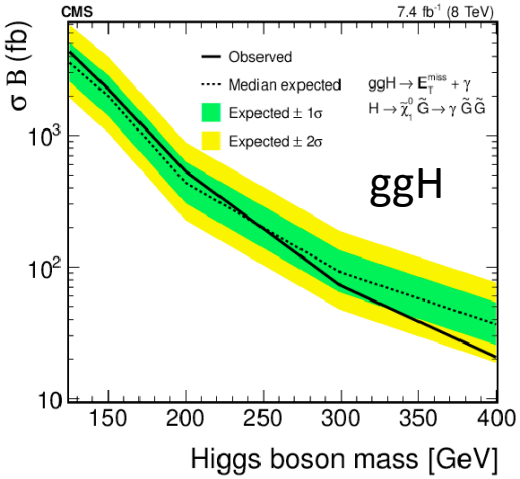


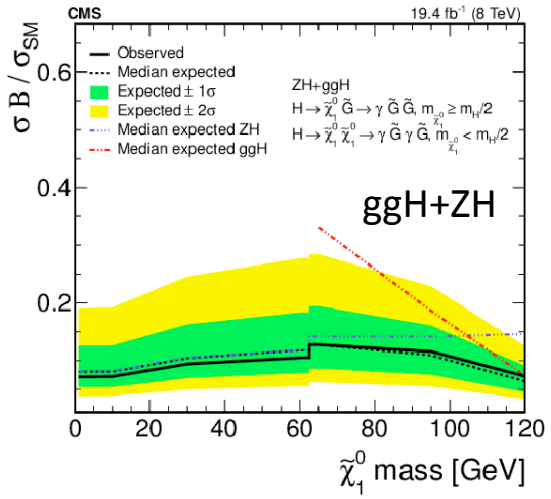
m_H= 125 GeV and $m_{\tilde{\chi}1}{}^0$= 120 GeV



m_H= 125 GeV, $m_{\tilde{\chi}1}{}^0$= 95 GeV, Br=10%

Exotic Higgs Decays to Photon+MET
H→{1 or 2 isol. γ} + E_T^{miss} (CMS)





Data consistent with BG

m_H= 125 GeV

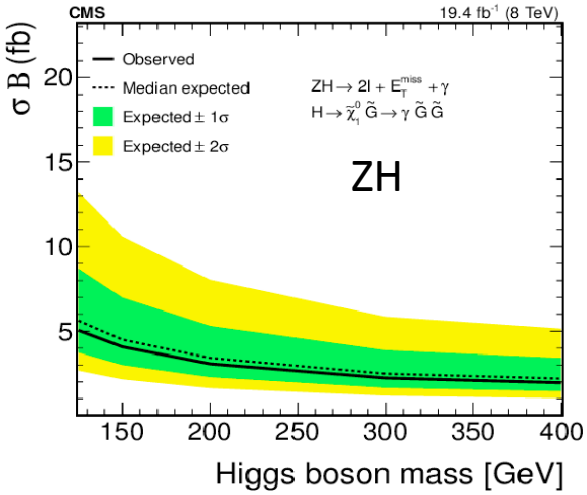
$m\tilde{\chi}_1^0 < m_H/2$ => $B(H\to\tilde{\chi}_1^0\tilde{\chi}_1^0)B(\tilde{\chi}_1^0\to\tilde{G}+\gamma)^2$

$m\tilde{\chi}_1^0 \geq m_H/2$ => $B(H\to\tilde{\chi}_1^0\tilde{G})B(\tilde{\chi}_1^0\to\tilde{G}+\gamma)$

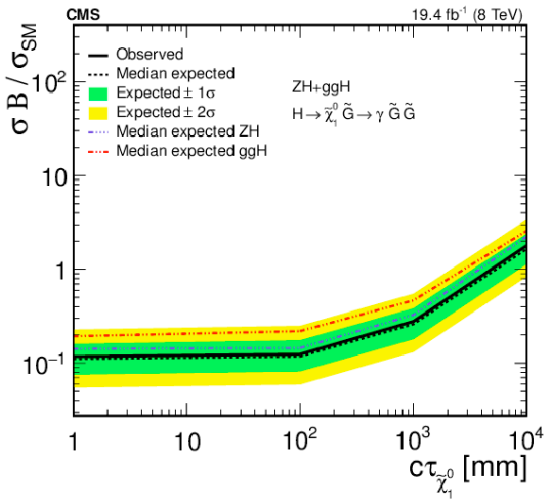
ggH $m_H/2 < m_{\tilde{\chi}1}^0 < m_H$

95% CL Br 10%, $m_{\tilde{\chi}1}^0$= 95 GeV

$m_{\tilde{\chi}1}^0$:1-120 GeV =>95% CL Br: 7-13%



$m_{\tilde{\chi}1}^0 = m_H - 30$ GeV, m_H:125-400 GeV



m_H= 125 GeV, $m_{\tilde{\chi}1}^0$= 95 GeV

$B(H\to\tilde{\chi}_1^0\tilde{G})B(\tilde{\chi}_1^0\to\tilde{G}+\gamma)$

Selection eff.
const. $c\tau(\tilde{\chi}_1^0)$<10 cm
Drops rapidly after

Run-II perspectives

Decays to dark vector bosons - Z_{dark} (Z_d)

- **ATLAS: $H \rightarrow Z_{(d)} Z_d \rightarrow 4l$**
  - Improving the discovery potential of Z_d or setting stricter existing limits.
  - Extension to low mass ($Z_d < 15$ GeV) and Z_d with displaced vertex

Lepton Flavor Violating (LFV) decays:

- **CMS: $H \rightarrow \mu\tau_e$, $H \rightarrow \mu\tau_h$**
  - A new τ lepton identification algorithm with improved background rejection has been deployed for Run-II
  - Investigating possible analysis improvements for μ-τ

Flavor Changing Neutral Current (FCNC) decays: t→qH

- **ATLAS: $t \rightarrow qH$ ($H \rightarrow \gamma\gamma$)**
  - Increased $t\bar{t}$ cross section in Run-II
  - Could set better limit on Br (λ_{tqH})
  - Add a multi-lepton analysis to increase sensitivity

Conclusions

- Searches for Exotic Higgs bosons decays performed in various channels and with different strategies
  - No evidence found so far
  - Observation of SM-like Higgs boson excludes large regions of parameter space
- Still room left for BSM models to be compatible with observed Higgs boson
  - Many Exotic Higgs analyses with Run-I 8 TeV data still on-going
- Run-II with 13 TeV will enhance discovery potential of Exotics Higgs boson decay searches
  - New challenges for the analyses

Additional Slides

Other talks in EPS

- "Searches for invisible Higgs boson decays with ATLAS and CMS" Philippe CALFAYAN (talk, ATLAS)
- "Searches for long-lived, weakly interacting particles in ATLAS and CMS", Andrew Evan Hart (talk, CMS)

- "Searches for invisibly decaying Higgs bosons at ATLAS" K. Shaw (poster, ATLAS)
- "Searches for long-lived particle decays in ATLAS" D. Salvatore (poster, ATLAS)

$H \to Z_{(d)} Z_d \to 4l$ (ATLAS) New

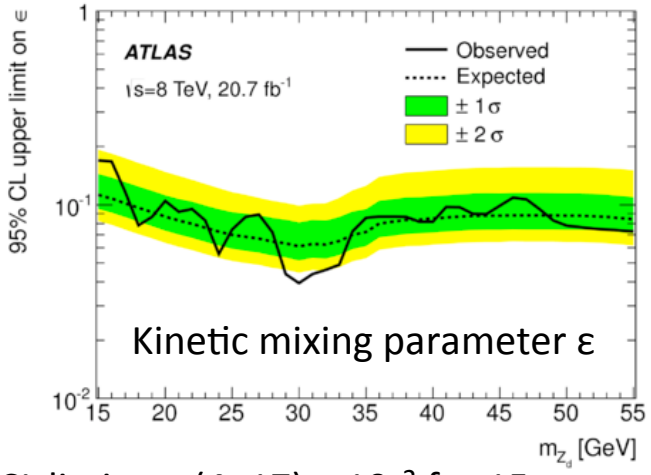
Model interpretation

ATLAS (8 TeV)
arXiv:1505.07645
Submitted to PRD

Simplest benchmark model ($U(1)_d$ gauge symmetry)
SM + dark vector boson + dark Higgs boson

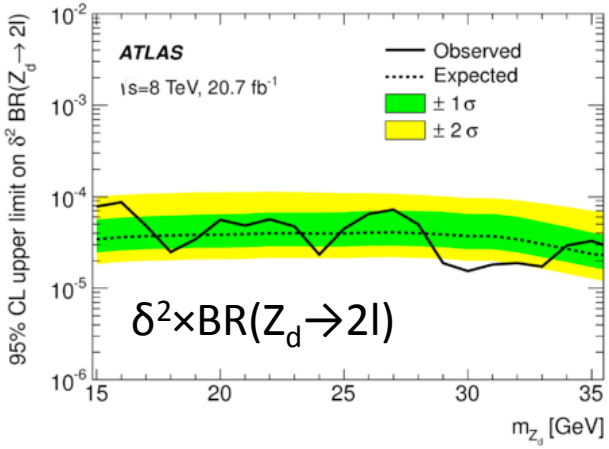
$H \to Z Z_d \to 4l$

Gauge kinetic mixing parameter dominates ($\varepsilon >> \kappa$)



95% CL limits ε: (4–17) × 10^{-2} for 15 < m_{Zd} < 55 GeV

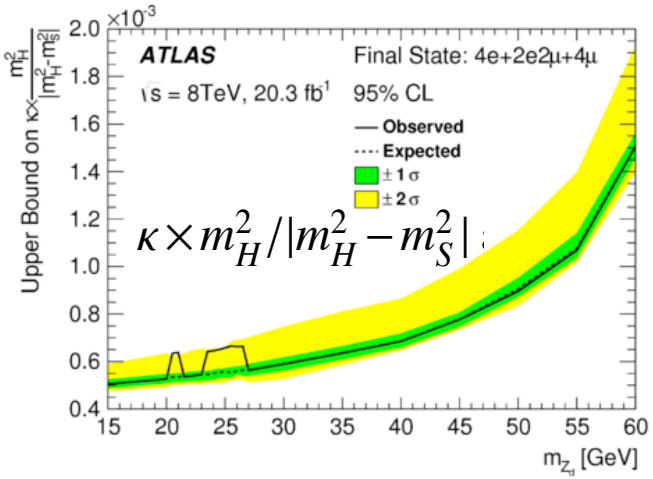
Effective mass mixing parameter Z-Z_d



95% CL limits $\delta^2 \times BR(Z_d \to 2l)$: (1.5-8.7)×$10^{-5}$ for 15<m_{Zd} <35GeV

$H \to Z_d Z_d \to 4l$

Higgs mixing parameter dominates ($\kappa >> \varepsilon$)



Effective Higgs mixing parameter κ'

Dark Higgs boson $m_S > m_H/2$, $m_{Zd} < m_H/2$

κ (Higgs portal coupling) 95% CL limits:
(1-10) × 10^{-4} for 15 < m_{Zd} < 60 GeV

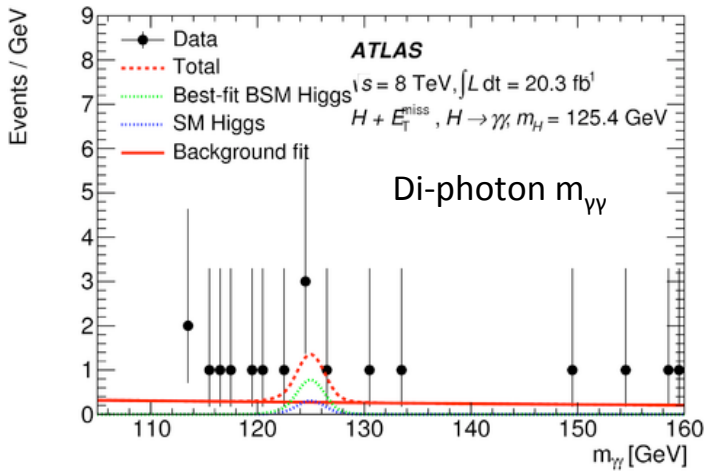
New

$H+E_T^{miss} \rightarrow 2\gamma+E_T^{miss}$ (ATLAS)

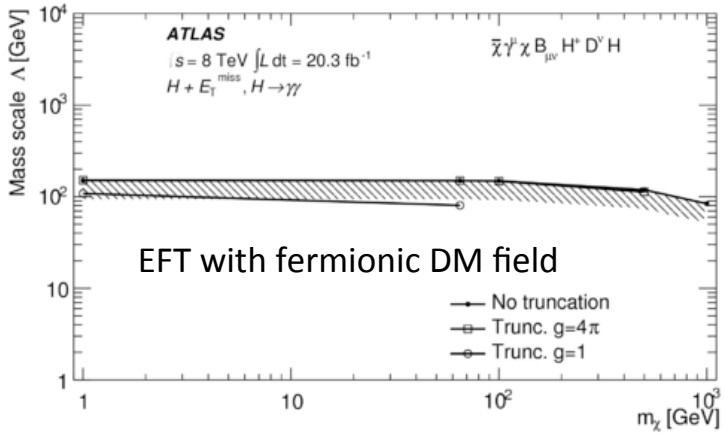
ATLAS (8 TeV)
arXiv:1506.01081
Submitted to PRL

Directly probes the structure of the effective DM-SM coupling

- Sensitive to $m_\chi > m_H/2$
- Consider both EFT and simplified model

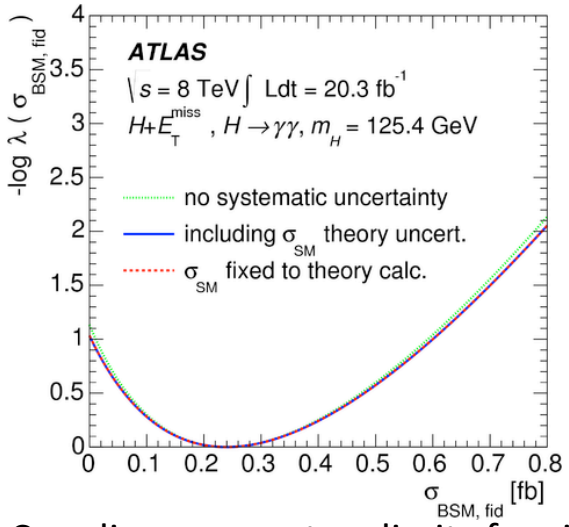


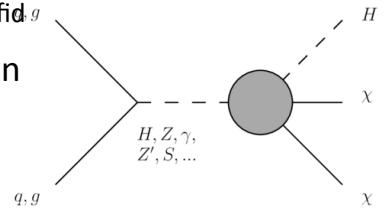
Mass scale Λ limits vs DM mass (m_χ)



Profile likelihood ratio (λ) vs $\sigma_{BSM,fid}$

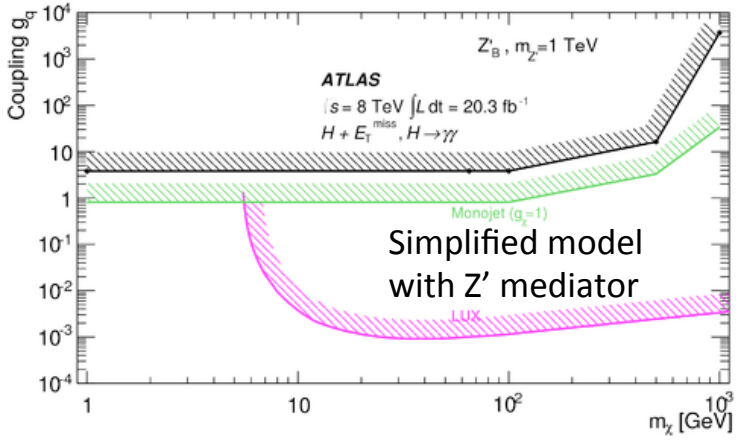
BSM H+DM with the SM contribution





Production of DM particles χ in association with H, mediated by (H,Z,γ) or new mediator: Z' or scalar singlet S

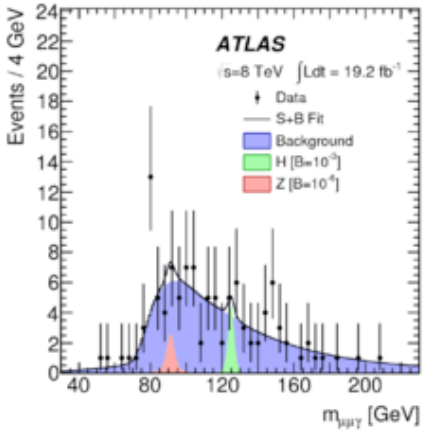
Coupling parameters limits for simplified models with a heavy mediator with mass of 1 TeV

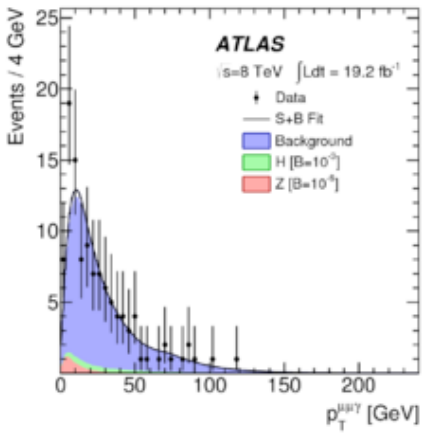


ATLAS (8 TeV)
Phys. Rev. Lett. 114 (2015) 121801

H→J/ψγ & H→Υ(nS)γ (n=1,2,3) (ATLAS)

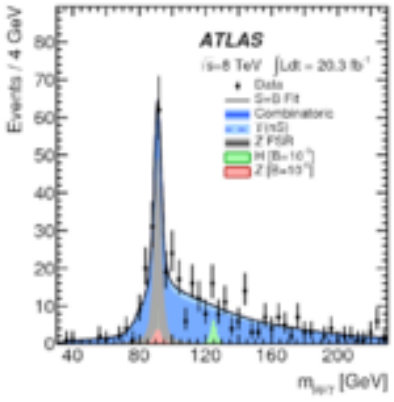
30 GeV < $m_{\mu\mu\gamma}$ < 230 GeV

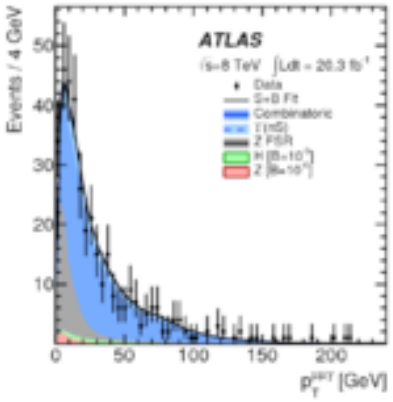


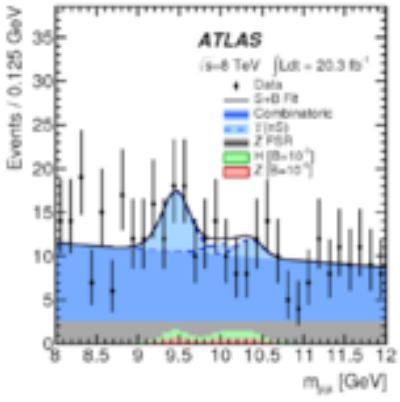


- $Q \to \mu^+\mu^-$: isolation, primary vertex
- $p_T^{\mu\mu} > 36$ GeV
- γ: "tight", isolated, $p_T^{\gamma} > 36$ GeV
- $\Delta\phi(Q,\gamma) > 0.5$

- $J/\Psi \to \mu^+\mu^-$ $M_{\mu\mu}$: $M_{J/\psi} \pm 0.2$ GeV
- Main BG: inclusive QCD







- $\Upsilon(nS) \to \mu^+\mu^-$ 8 GeV < $M_{\mu\mu}$ < 12 GeV
- BGs: inclusive QCD, $Z \to \mu^+\mu^-$(FSR)γ

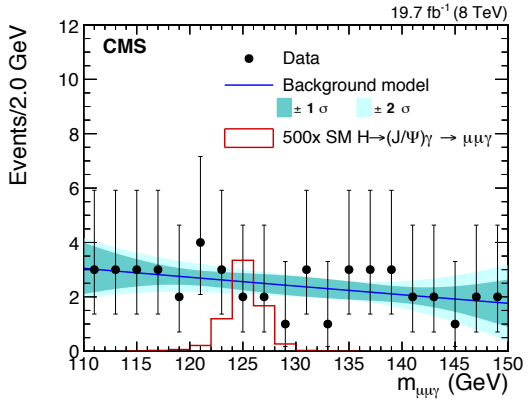
No significant excess of data over BGs

- 95% CL $B(H \to J/\psi\gamma) < 1.5 \times 10^{-3}$
- 95% CL $B(H \to \Upsilon(1S, 2S, 3S)\gamma) < (1.3, 1.9, 1.3) \times 10^{-3}$

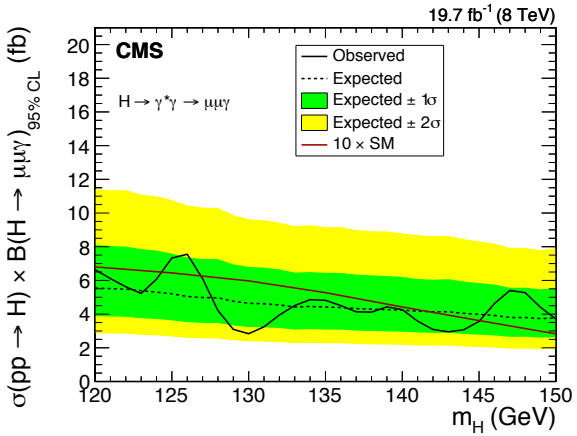
CMS (8TeV)
arXiv:1507.03031v1

Higgs boson decaying into $\gamma^*\gamma \rightarrow ll\gamma$ with low di-lepton mass (CMS)

2.9 GeV < $m_{\mu\mu}$< 3.3 GeV

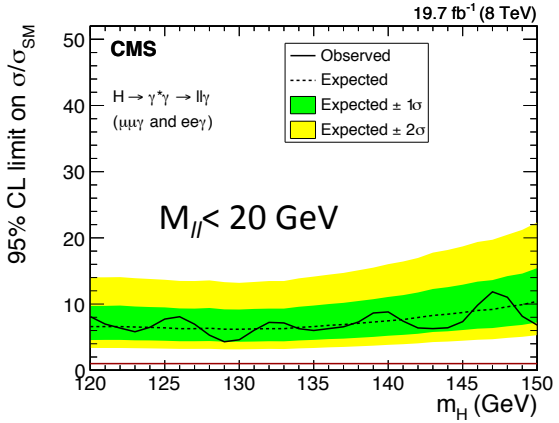


$\sigma(pp \rightarrow H) \times B(H \rightarrow \mu\mu\gamma)$



m_H = 125 GeV, 7.3 (5.2) fb

$\sigma/\sigma_{SM}(pp \rightarrow H) \times B(H \rightarrow \gamma^*\gamma \rightarrow ll\gamma)$



m_H=120-150 GeV

No excess above backgrounds in 120 < $m_{ll\gamma}$ < 150 GeV

Observed (expected): 5-11 (6-10) x SM

m_H=125 GeV: 7.7(6.4) x SM

m_H=125 GeV, 2.9 < m_{ll} < 3.3 GeV

$\sigma(pp \rightarrow H) \times B(H \rightarrow \mu\mu\gamma)$ < 1.80 (1.90) fb

$B(H \rightarrow (J/\psi)\gamma) < 1.5 \times 10^{-3}$

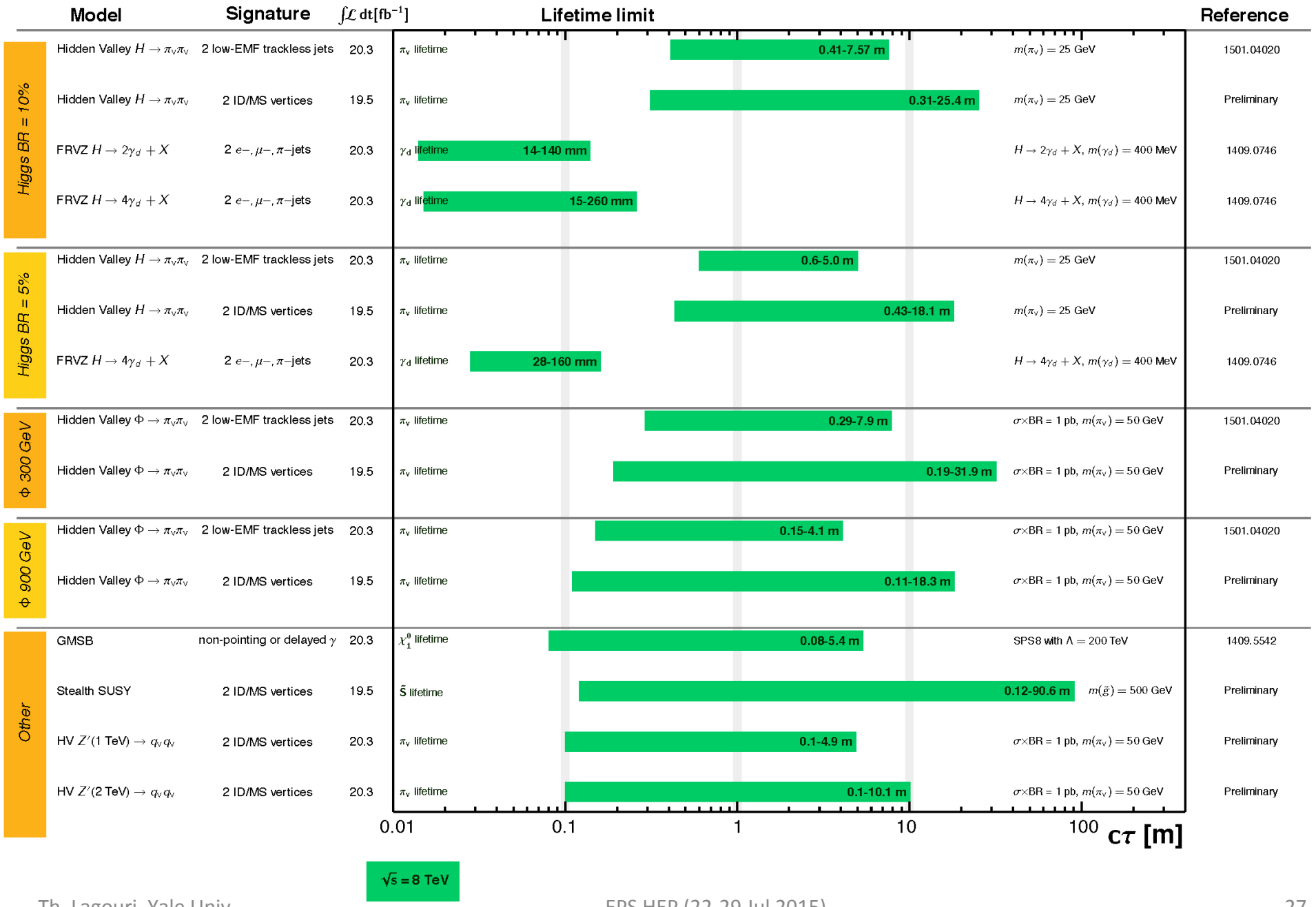
540 x SM (m_H=125 GeV)

ATLAS Exotics Long-lived Particle Searches* - 95% CL Exclusion

Status: March 2015

ATLAS Preliminary

$\int \mathcal{L}\, dt$ = (19.5 - 20.3) fb^{-1} $\sqrt{s}$ = 8 TeV



*Only a selection of the available lifetime limits on new states is shown.