

BSM Higgs physics in ATLAS and CMS at HL-LHC

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on behalf of the CMS+ATLAS collaborations

HL-LHC workshop, CERN, 18-20 June 2018

Explore BSM Higgs territory

Dark matter

Naturalness

Theoretical models

- MSSM, 2HDM, Additional EW singlet
- Composite Higgs Model
- ...

Theoretical models inspire
new experimental searches

Experimental results
constraint theoretical models

Experimental searches for

- Extra Higgs bosons, gauge bosons
- Heavy resonance, light scalars
- LFV, displaced decay, invisible decay
- ...



**h(125) property
measurement**

BSM Higgs at ATLAS and CMS

Heavy neutral Higgs

$A/H \rightarrow \tau\tau$

$A/H \rightarrow t\bar{t}$

$H \rightarrow ZZ$

$A \rightarrow ZH / Zh$

$H \rightarrow WW$

...

Charged Higgs

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

$H^\pm \rightarrow tb$

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

$H^\pm \rightarrow WZ$

...

LFV, FCNC

$h \rightarrow e\tau, \mu\tau$

$t \rightarrow uh, ch$

Rare decay

$h \rightarrow \gamma\rho, \gamma\phi$

$Z(ll) + h(\text{inv})$

h to light bosons

$h \rightarrow Z_{\text{dark}} Z_{\text{dark}}$

$h \rightarrow aa \rightarrow 4b$

ATLAS Higgs results:

<https://twiki.cern.ch/twiki/bin/view/AtlasPublic/HiggsPublicResults>

CMS Physics results:

<https://twiki.cern.ch/twiki/bin/view/CMSPublic/>

Complex object matters

Heavy neutral Higgs

$A/H \rightarrow \tau\tau$

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Charged Higgs

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LFV, FCNC

$h \rightarrow e\tau, \mu\tau$

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Sidenote:

- Pileup sensitive objects, e.g. τ , b-jet, E_T^{miss} , displaced decay important and challenging at the HL-LHC

ATLAS Higgs results:

<https://twiki.cern.ch/twiki/bin/view/AtlasPublic/HiggsPublicResults>

CMS Physics results:

<https://twiki.cern.ch/twiki/bin/view/CMSPublic/>

$h \rightarrow \gamma\rho, \gamma\phi$

$Z(ll) + h(\text{inv})$

$h \rightarrow Z_{\text{dark}} Z_{\text{dark}}$

$h \rightarrow aa \rightarrow 4b$

Towards HL-LHC

- Yellow report
- Relevant prospect studies

Status of the yellow report

Editors on board

- Common editing effort will be initiated soon!

9. **BSM Higgs** (CMS: Martin Flechl, ATLAS: Lei Zhang, LHCb: Martino Borsato, Theo: Stefania Gori)
 - a. Searches for additional Higgs bosons in fermionic final states (taus, b's, muons and tops)
 - b. Searches for additional Higgs bosons in diboson final states.
 - c. Searches for intermediate mass Higgs bosons (60 GeV - 120 GeV). (Heinemeyer)
 - d. Searches for low mass Higgs bosons (up to 60 GeV).
 - e. Covering the MSSM and 2HDMs (J.M.No)
 - f. Covering Twin Higgs models (Redigolo)
 - g. Interference effects in heavy Higgs searches. (M. Carena, Z.Liu)
 - h. New techniques for reconstructing highly boosted heavy Higgs bosons (Klimek)
 - i. Exotic decays of the Higgs boson (D. Curtin, Z.Liu, L.T.Wang)

Status of HL-LHC prospect studies

	Topic	CMS	ATLAS	LHCb
Exotic decays	Invisible	✓		
	LFV	✓		
	Displaced 4jets/4 μ	✓		
Additional scalars	A \rightarrow Zh	✓	✓	
	$\tau\tau$	✓	✓	
	$\mu\mu$		✓	✓
	ZZ	(+ZZ \rightarrow llqq)	✓	
	WW		✓	
	$\gamma\gamma$ low mass	✓		

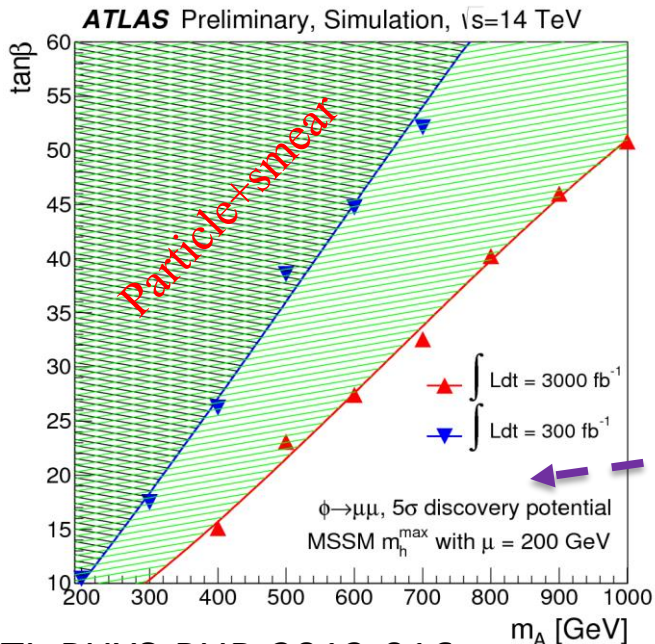
Legend: Past studies, Wishlist for 2018

Additional Higgs bosons: fermionic channel

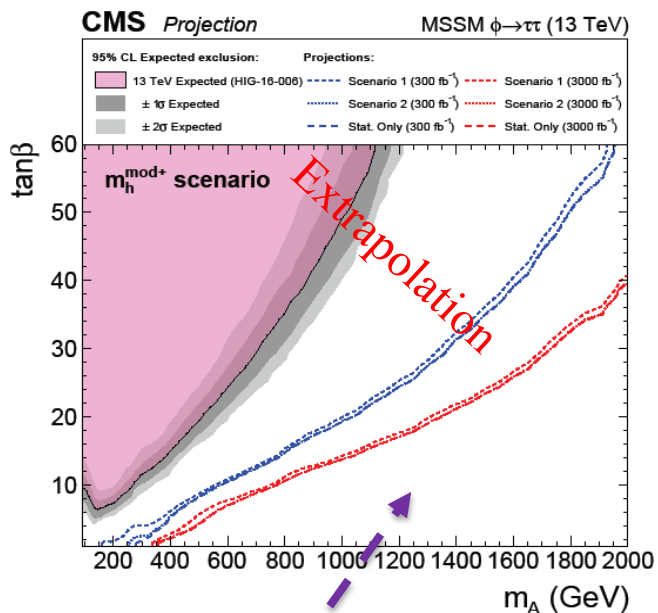
$\phi \rightarrow \tau\tau$ channel

- Most sensitive analysis over a large region of MSSM parameter space

$\phi \rightarrow \mu\mu$ channel



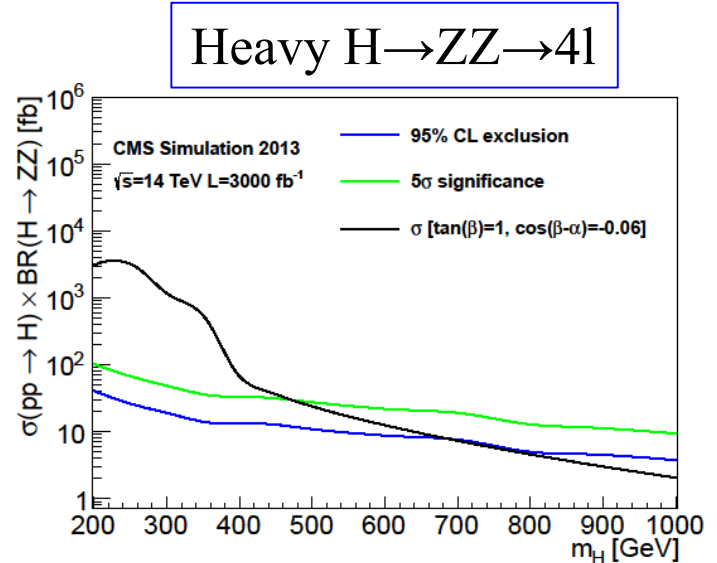
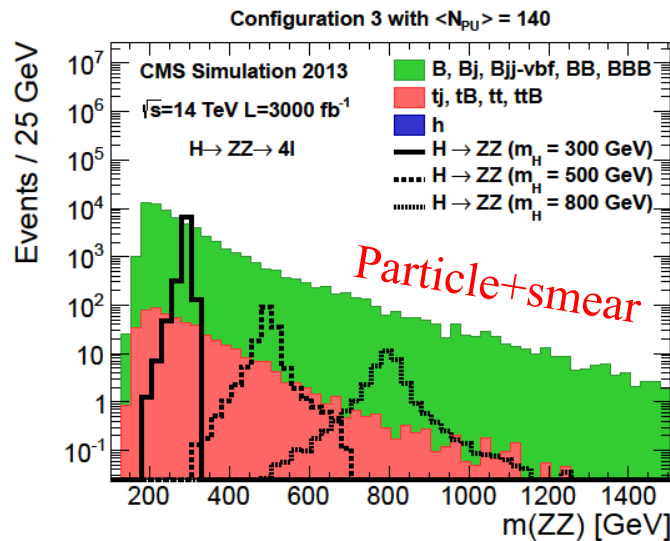
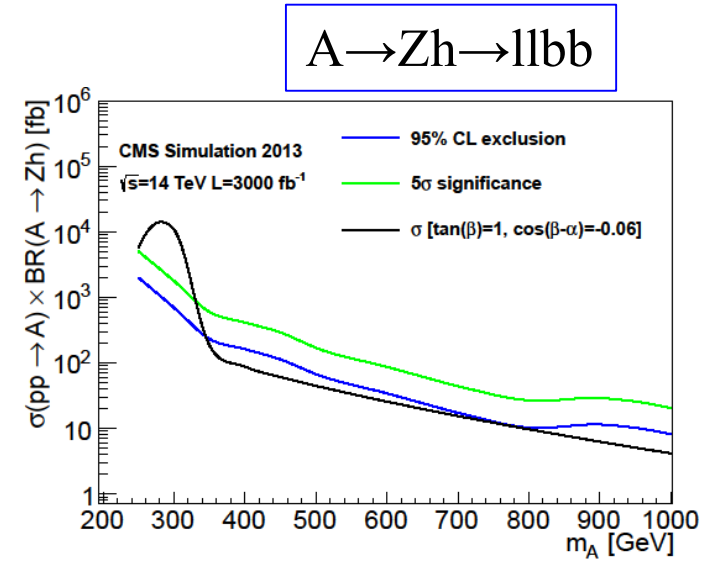
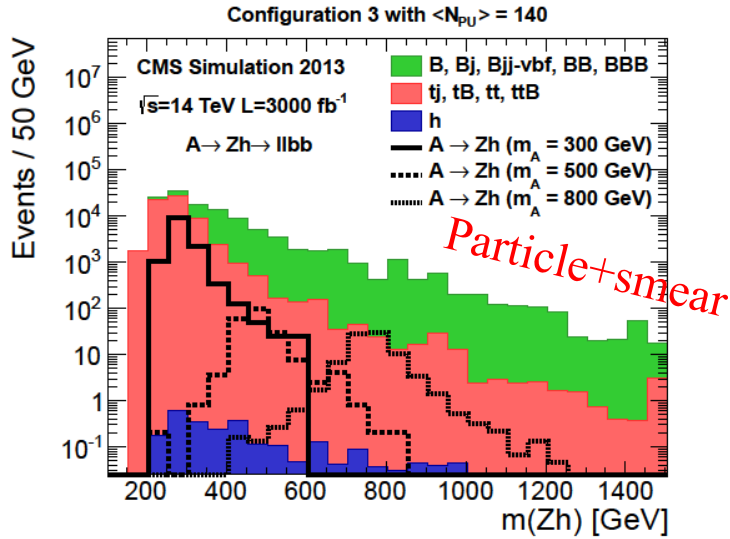
ATL-PHYS-PUB-2013-016



FTR-16-002-pas

$\phi \rightarrow t\bar{t}$ channel useful to explore the high mass low $\tan \beta$ region

Additional Higgs bosons: bosonic channel

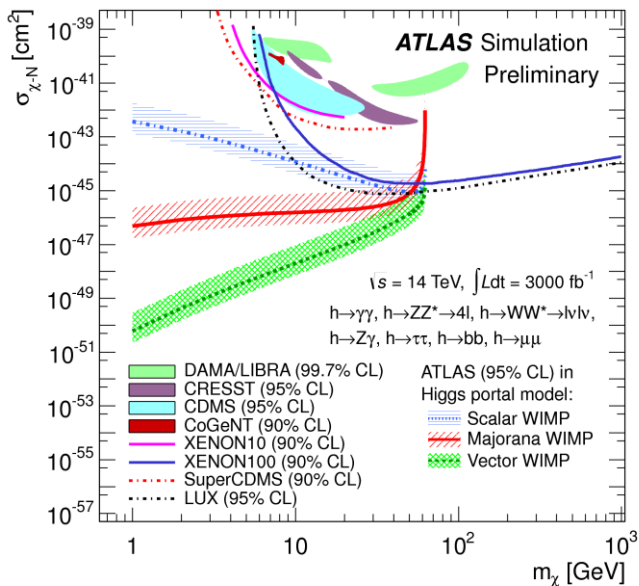
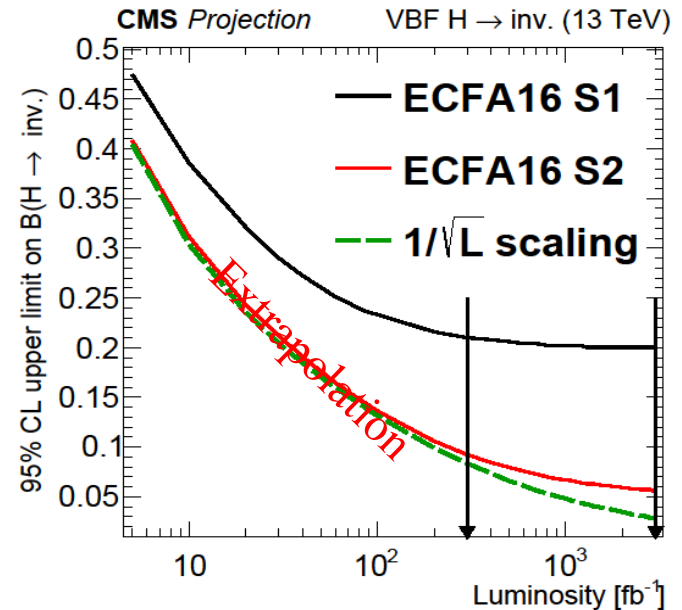


Dark matter search: $h \rightarrow \text{invisible}$

FTR-16-002-pas

■ VBF, $h \rightarrow \text{inv.}$

	ECFA2016 (S1)	ECFA2016 (S2+)	ECFA2016 (S2)
300 fb^{-1}	0.210	0.092	0.084
3000 fb^{-1}	0.200	0.056	0.028



Dark matter

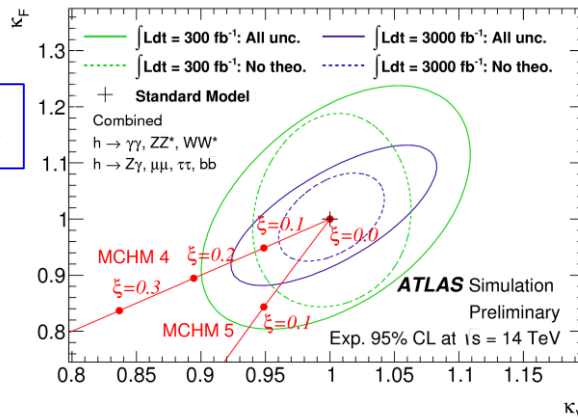
$h(125)$ combination

- $\text{Br}(H \rightarrow \text{Inv.}) < 0.13$ (0.09) w. (w.o.) systematics uncertainty

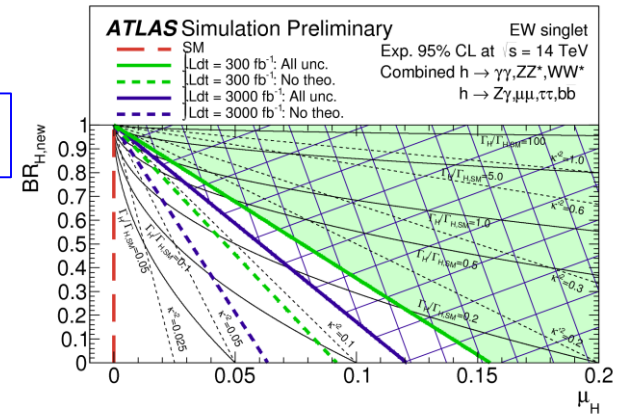
Constrain BSM from h(125) measurement

- Main selling points of HL-LHC
- Be able to constrain various BSM models

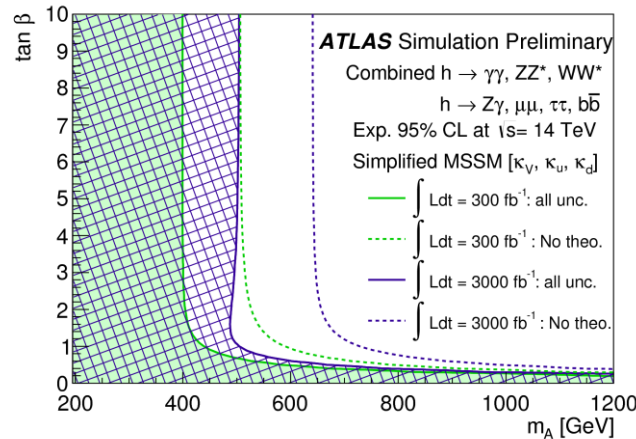
Compositeness



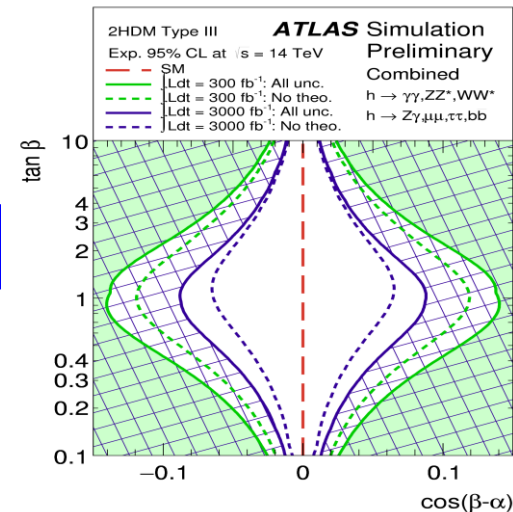
EW singlet



MSSM

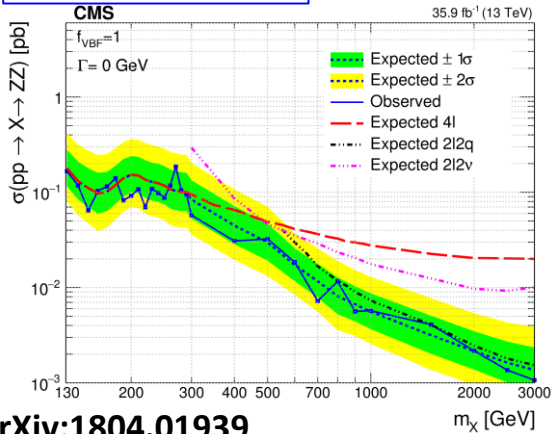


2HDM



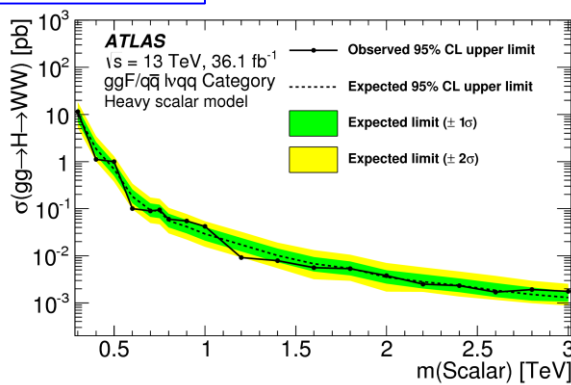
Analyses in our wish list: 1

H → ZZ → llqq



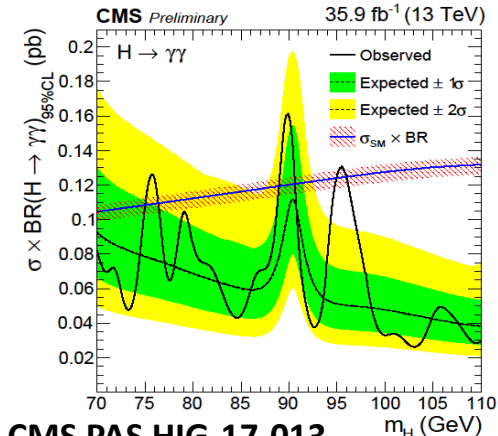
arXiv:1804.01939

H → WW



JHEP 03 (2018) 042

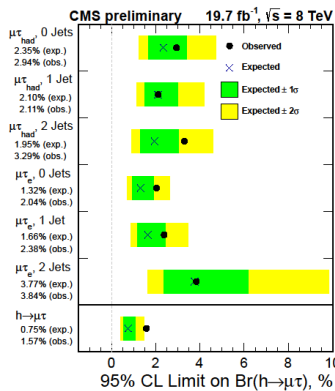
Di-photon low mass



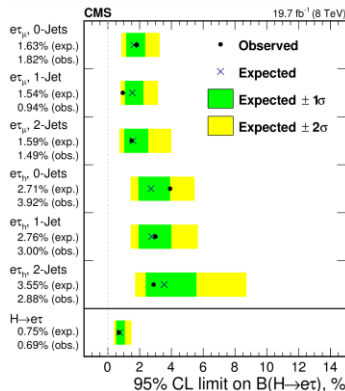
CMS PAS HIG-17-013

Lepton Flavor Violation

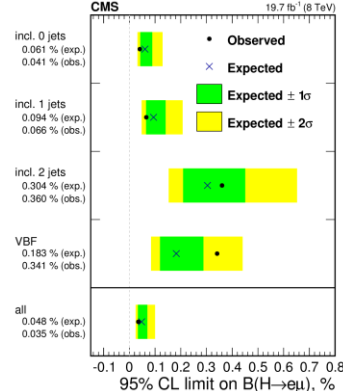
$B(H \rightarrow \mu\tau) < 1.57\%$, $B(H \rightarrow e\tau) < 0.69\%$, $B(H \rightarrow e\mu) < 0.035\%$



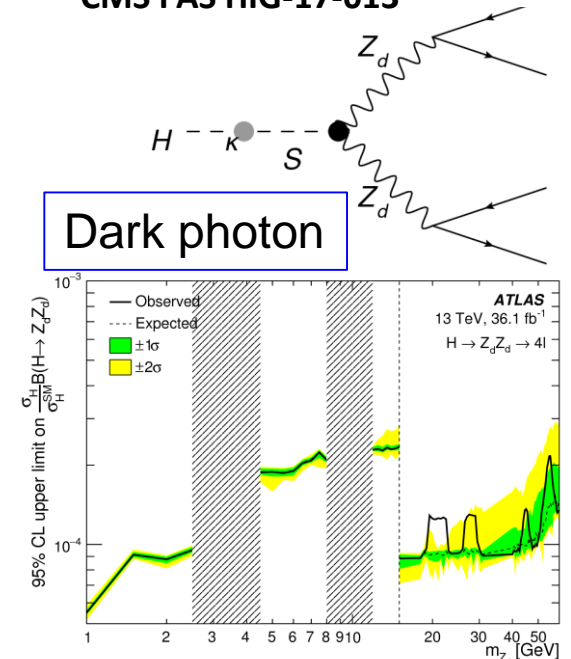
CMS-PAS-HIG-14-005



Phys. Lett. B 763 (2016) 472



Dark photon

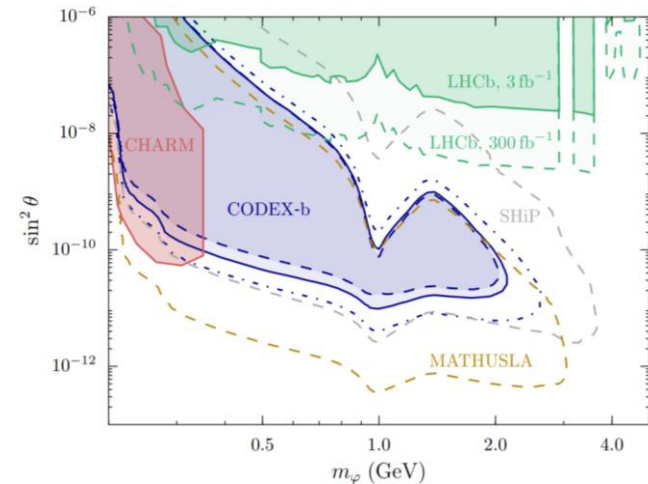
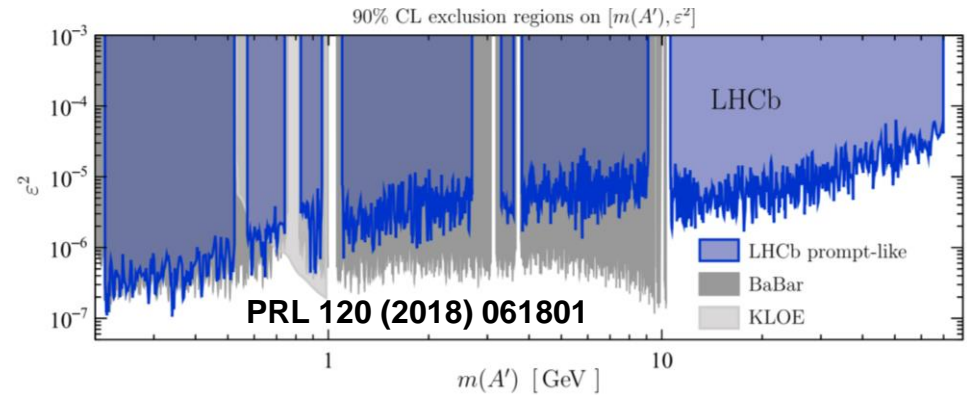
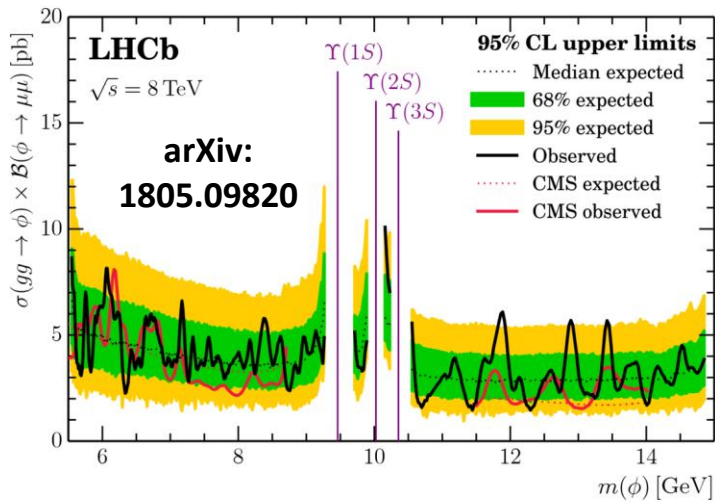


arXiv:1802.03388

Analyses in our wish list: 2

Low mass $\mu\mu$ resonance search at LHCb

- Advantage: low- p_T trigger thresholds and good online μ identification



$\mu\mu$ res. prospect at HL-LHC

- References: PRL 115 161802 (2015), PRD 95, 071101(R) (2017), PRL 120, 061801 (2018), arXiv:1805.09820, JHEP03(2018)178

Summary

- Status of BSM Higgs physics prospect studies at HL-LHC, as well as the yellow report are presented
- Several prospect studies are on-going and will ready soon.
- Do we miss anything important? How to prioritize?

	Topic	CMS	ATLAS	LHCb
Exotic decays	Invisible	✓		
	LFV	✓		
	Displaced 4jets/4μ	✓		
Additional scalars	A->Zh	✓	✓	
	ττ	✓	✓	
	μμ		✓	✓
	ZZ	(+ZZ→llqq)	✓	
	WW		✓	
	γγ low mass	✓		

Legend:
 Past studies,
 Wishlist for 2018

Backup