

Higgs Results from CMS

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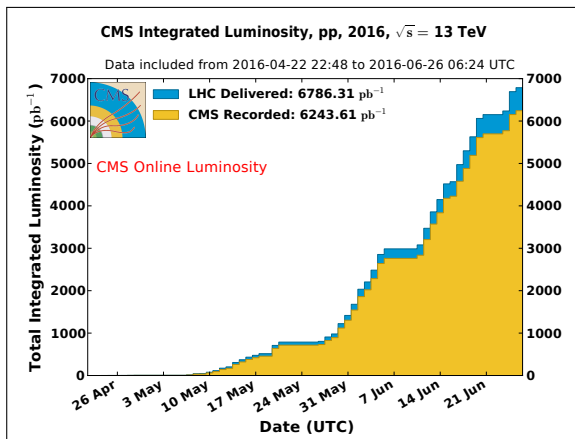
Massachusetts Institute of Technology

June 2016 DESY Seminar

- ▶ This is not a full comprehensive talk, but rather a collection of highlights
- ▶ Focus on 13 TeV results
 - ▶ 8 TeV results will also be also, in particular if no 13 TeV result exists yet
- ▶ Possible future studies will also been described on the way
- ▶ Apologize if I left behind your favorite topic, do not hesitate ask if you have questions!

On the upper right side of the slides I include references to the most recent CMS public material

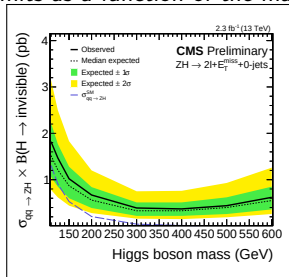
Taking Data at $\sqrt{s} = 13$ TeV



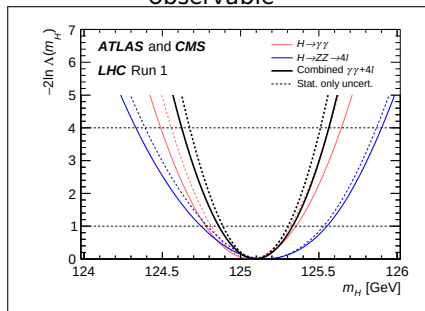
- ▶ $\mathcal{L} = 2 - 3 \text{ fb}^{-1}$ at $\sqrt{s} = 13$ TeV in 2015, much faster pace in 2016
- ▶ Today's results using 2015 data only, new results expected for ICHEP and beyond

Some Terminology

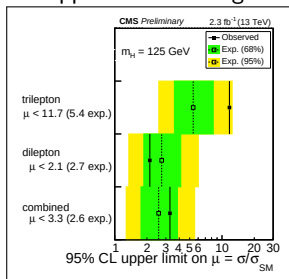
95% Confidence Level (CL) upper limits as a function of the mass



Likelihood profile of a given observable

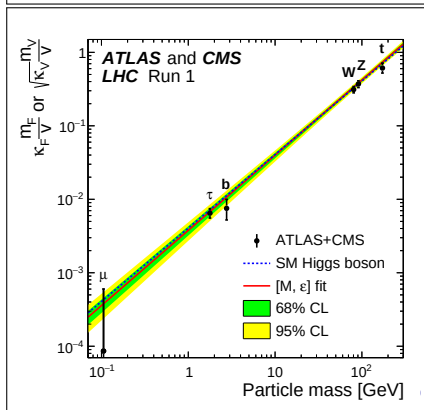
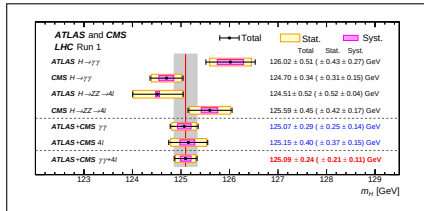


95% CL upper limits for a given mass



Summary of Run-I Higgs Results

- ▶ Combined measurement using LHC run-I dataset:
 - ▶ $m_H = 125.09 \pm 0.21 \text{ (stat.)} \pm 0.11 \text{ (syst.) GeV}$
 - ▶ overall precision 0.19%
- ▶ Couplings consistent with Standard Model (SM) Higgs boson
- ▶ No additional Higgs bosons found so far

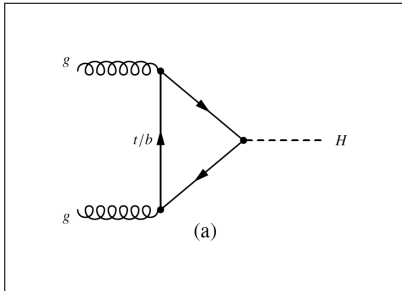


Introduction

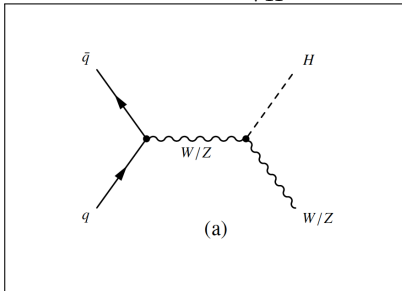
- ▶ Several ways to find Physics Beyond the Standard Model (BSM) within the Higgs sector:
 - ▶ measuring couplings and differential distributions of known SM Higgs boson decays:
 - ▶ main modes: $ZZ, WW, \gamma\gamma, \tau\tau, b\bar{b}$
 - ▶ (less) rare modes: $\mu\mu, Z\gamma, \gamma^*\gamma, ee$
 - ▶ very difficult modes (at LHC): $s\bar{s}, c\bar{c}, gg$
 - ▶ couplings: $gg \rightarrow H, qqH, VH, t\bar{t}H, tqH, b\bar{b}H$
 - ▶ searching for additional Higgs bosons:
 - ▶ direct searches for low mass (pseudo-)scalars (NMSSM...)
 - ▶ direct searches for heavy Higgs bosons (2HDM, $H^{\pm\pm} \dots$)
 - ▶ searching for particle decays involving Higgs bosons, e.g.:
 - ▶ $t \rightarrow cH$
 - ▶ $\tilde{\chi}_1^0 \rightarrow H\tilde{G}, \tilde{t}_2 \rightarrow \tilde{t}_1H \rightarrow t\tilde{\chi}_1^0H, \tilde{\chi}_1^\pm \tilde{\chi}_2^0 \rightarrow W^\pm \tilde{\chi}_1^0H\tilde{\chi}_1^0$
 - ▶ searching for rare neutral Higgs boson decays:
 - ▶ either forbidden or a branching fraction well below the experimental reach within the SM
- ▶ Focus on analyses with experimental (public) CMS results, mention to future studies

Main Production Modes

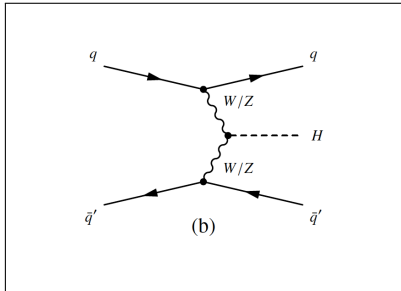
Gluon-fusion (ggH)



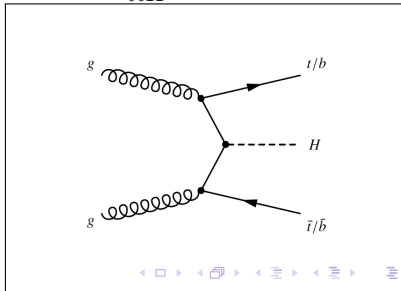
VH



Vector Boson Fusion (VBF)



$t\bar{t}H$



- ▶ Electroweak Singlets
 - ▶ 2nd CP-even boson
- ▶ Two-Higgs Doublet Models (2HDM)
 - ▶ 5 Higgs bosons ($H, h, A, H^\pm$)
 - ▶ MSSM prominent example; hMSSM common benchmark
- ▶ 2HDM + singlets
 - ▶ NMSSM prominent example
 - ▶ 7 Higgs bosons ($a_1, a_2, h_1, h_2, h_3, H^\pm$)
- ▶ Triplet Models
 - ▶ adding doubly charged Higgs bosons to 2HDM phenomenology
- ▶ ... and more

Signatures

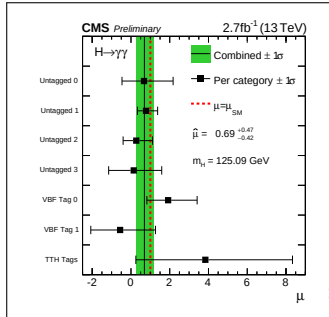
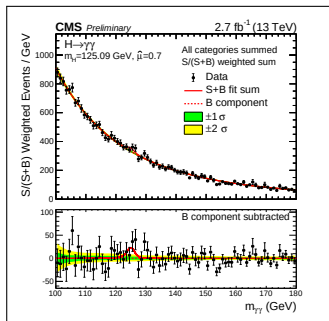
- ▶ “SM” Higgs boson and other neutral Higgs bosons
 - ▶ $H \rightarrow \gamma\gamma/ZZ/WW/\tau\tau/bb/\mu\mu/Z\gamma$
- ▶ Rare (or forbidden) Higgs boson decays
 - ▶ $H \rightarrow \text{inv.}/\text{inv.} + \gamma/\text{prompt electron} - \text{jets}/\text{long lived}...$
- ▶ Charged Higgs bosons
 - ▶ $H^\pm \rightarrow \tau\nu/tb/cs/cb/\chi^0\chi^+/WH/WZ$
- ▶ Doubly charged Higgs bosons
 - ▶ $H^{\pm\pm} \rightarrow WW/4\ell$
- ▶ Higgs bosons to Higgs bosons decays
 - ▶ $H \rightarrow ZA/Zh$
- ▶ Di-Higgs bosons
 - ▶ $H \rightarrow hh \rightarrow bb\gamma\gamma/bb\tau\tau/bbbb/WW\gamma\gamma...$
 - ▶ $H \rightarrow a_1a_1 \rightarrow \mu\mu\mu\mu/\mu\mu\tau\tau/\tau\tau\tau\tau/bb\tau\tau$

In case of a discovery, signatures of new Higgs bosons can also be due to other new particles (e.g. SUSY particles)

Neutral Higgs Bosons

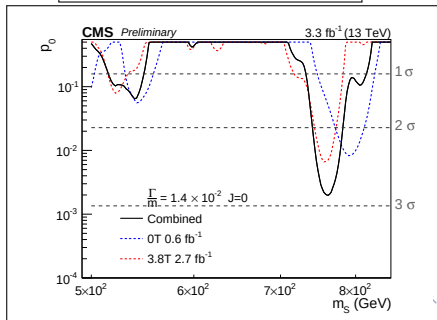
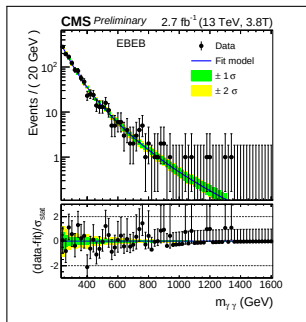
$H \rightarrow \gamma\gamma$ (SM Case) - HIG-15-005

- ▶ Clean signature under a huge background
- ▶ Complicated analysis to squeeze all the data information
 - ▶ Best of the best ECAL calibrations
 - ▶ MVA to select event vertex
 - ▶ MVA to select photons
 - ▶ MVA to select photon pairs
- ▶ Split in many categories to improve signal-to-background ratio (S/B) and separate production modes
- ▶ Differential/fiducial cross section measurements at 13 TeV will come with a larger dataset



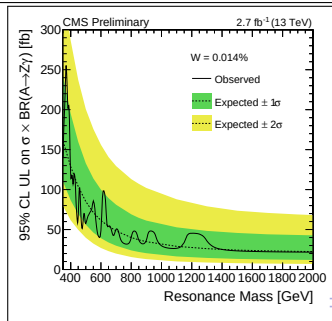
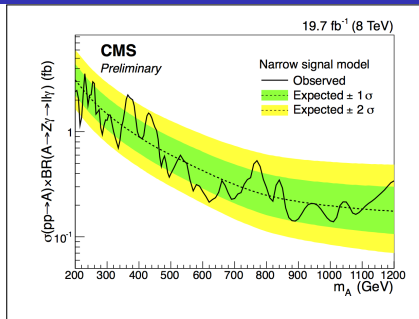
$H \rightarrow \gamma\gamma$ (High Mass) - EXO-16-018

- Highlights of Run-II presented at December CERN seminar
 - ATLAS and CMS updated studies for Moriond
 - Local p-value: 3.4σ for CMS and 3.9σ for ATLAS
 - Global p-value: 1.6σ for CMS and 2.0σ for ATLAS
 - Observed Cross section ~ 10 fb
 - Huge excitement and avalanche of papers (~ 400 and counting)
- 2016 data will show whether or nor this is a sign of new physics
- Searched in other channels



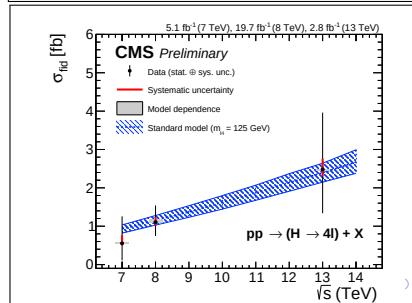
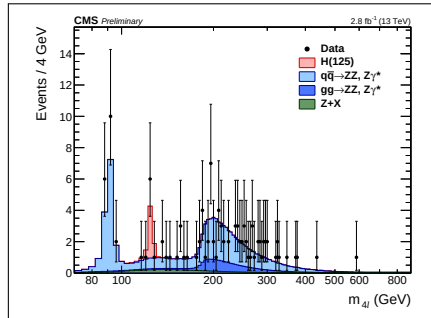
$H \rightarrow Z\gamma$ - HIG-16-014/EXO-16-019

- ▶ Natural extension once something is seen in the $\gamma\gamma$ channel
- ▶ Search for $H \rightarrow Z\gamma$ (at high mass)
 - ▶ $Z \rightarrow ee/\mu\mu$ decays are the cleanest channels
 - ▶ $Z \rightarrow \nu\nu$ (mono-photon) and $Z \rightarrow qq$ decays are also doable
- ▶ No significant excess of events seen so far
- ▶ SM analyses will take more time:
 - ▶ $H \rightarrow Z\gamma$ decays, splitting by production modes
 - ▶ $H \rightarrow \gamma^*\gamma$ decays
 - ▶ $H \rightarrow J/\psi\gamma$ decays



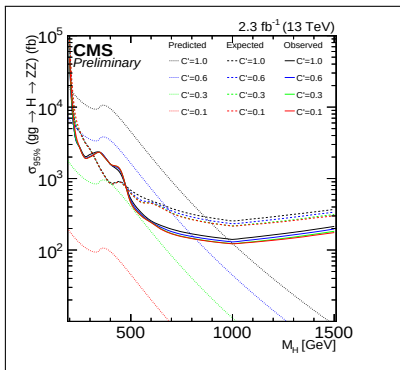
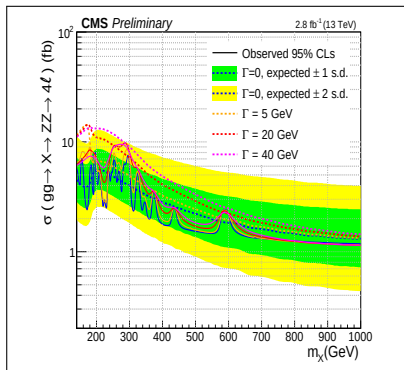
$H \rightarrow ZZ \rightarrow 4\ell$ - HIG-15-004

- ▶ Clean signature under a small background, but tiny signal yield
- ▶ Complicated analysis to add as much sensitivity as possible:
 - ▶ make use of $m_{4\ell}$ vs. kinematic discriminator vs. mode categorization
 - ▶ make use of low p_T leptons, sophisticated lepton selections
- ▶ Differential/fiducial cross section measurements at 13 TeV has started
- ▶ Almost identical analysis used for high mass searches



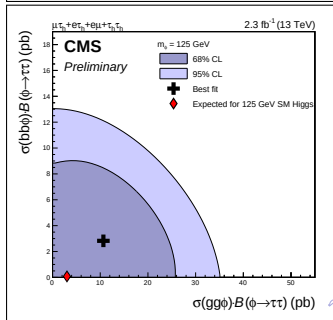
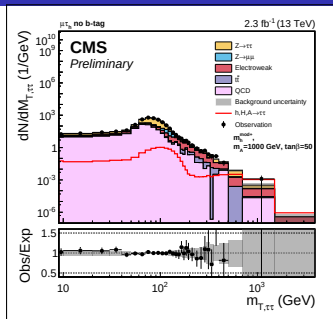
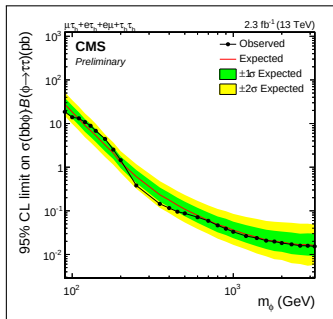
High Mass $H \rightarrow ZZ \rightarrow 2\ell 2\nu/4\ell$ - HIG-15-004/HIG-16-001

- ▶ $2\ell 2\nu$: search using m_T , results using an Electroweak Singlet model
- ▶ 4ℓ : search using $m_{4\ell}$, generic cross section limits for several widths



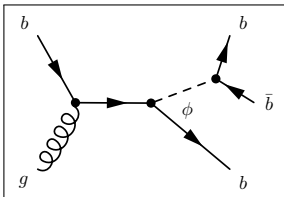
$H \rightarrow \tau\tau$ (Mostly MSSM) - HIG-16-006

- ▶ $H \rightarrow \tau\tau$ coupling enhanced in MSSM at high $\tan\beta$
- ▶ $\mathcal{T}\ell\mathcal{T}_{had}$ and $\mathcal{T}_{had}\mathcal{T}_{had}$ channels studied
- ▶ Using $m_{\tau\tau}$ as a final discriminant
- ▶ Separating ggH and b -associated production
- ▶ SM analysis closely related



H $\rightarrow$ bb (MSSM) - HIG-14-017

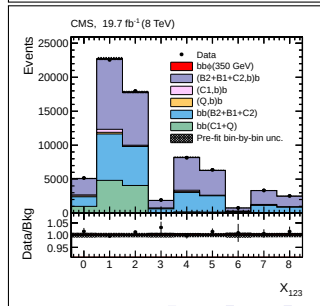
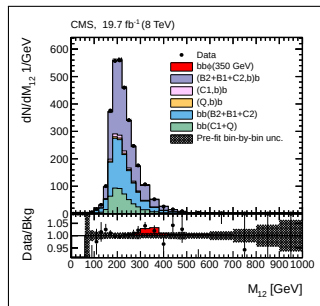
- Search for H $\rightarrow$ bb resonances at high mass
- Final states usually have additional b-quarks
- Dedicated trigger paths to select these events (no high p_T leptons/photons, no high E_T^{miss})



- $X_{123} = (B_1 + B_2) + (B_3)$ to split in categories

$\Sigma M_{SV,i}$ [GeV]	B_i
0-1	0
1-2	1
2-3	2
>3	3

B_3	$B_1 + B_2$		
	0-1	2-3	4-6
0-1	0	1	2
2	3	4	5
3	6	7	8

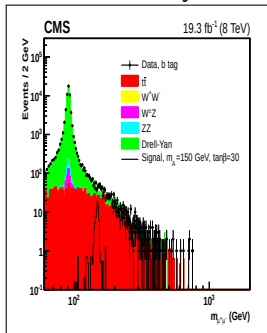


No significant excess seen

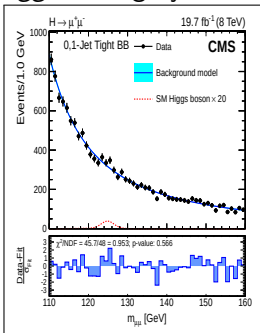
$H \rightarrow \mu^+ \mu^-$ - HIG-13-024/HIG-13-007

- ▶ Two isolated muons in the final state
- ▶ Split in several categories to improve S/B and mass resolution
- ▶ Cross section limits about 5-8 times the SM expectation

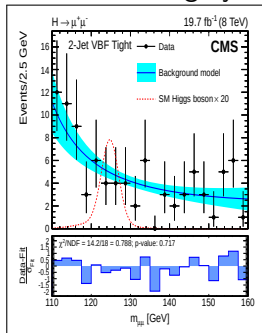
MSSM analysis



ggH category

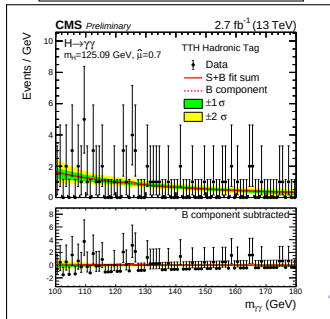
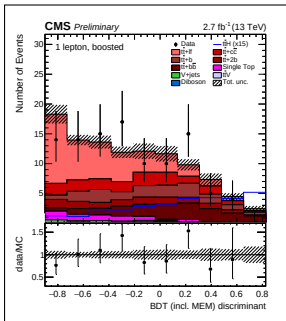
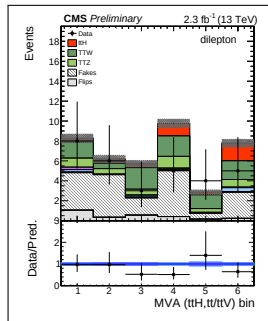


VBF category



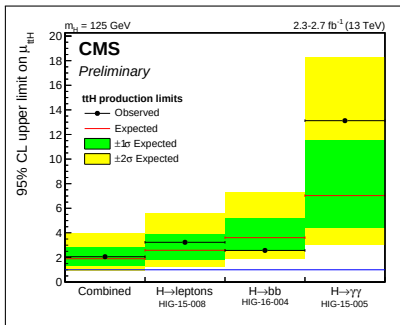
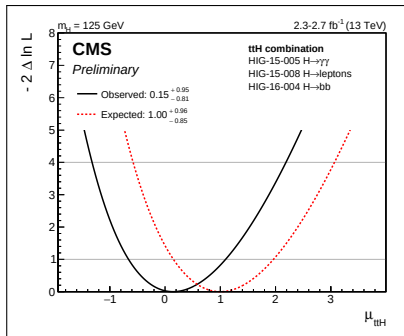
tt̄H (I) - HIG-16-004/HIG-15-008/HIG-15-005

- ▶ $\sigma_{t\bar{t}H}^{13 \text{ TeV}} / \sigma_{t\bar{t}H}^{8 \text{ TeV}} \sim 4$
- ▶ Sensitivity approaching Run 1
- ▶ Sensitive to potential new physics contributions
- ▶ Final states:
 - ▶ $H \rightarrow b\bar{b}$: large BR, low S/B, make use BDT and MEM approaches
 - ▶ $H \rightarrow \text{multilepton}$: small irreducible background, understanding fake leptons a key
 - ▶ $H \rightarrow \gamma\gamma$: small yield, part of main analysis
 - ▶ $H \rightarrow \tau\tau$: relatively large BR, but large backgrounds



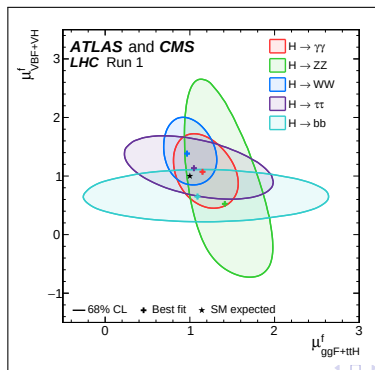
$t\bar{t}H$ (II) - 13 TeV Combination

- ▶ Combined 13 TeV results more consistent with SM expectation than run-I results
- ▶ Need more data to assess conclusions
- ▶ High priority analyses in CMS, looking forward the ICHEP results



Event Rates $\rightarrow$ Coupling Deviations

- ▶ $\sigma(xx \rightarrow H) \times BR(H \rightarrow yy) \propto \Gamma_{xx}\Gamma_{yy}/\Gamma_{tot}$
- ▶ Parameters: $\Gamma_{WW}, \Gamma_{ZZ}, \Gamma_{tt}, \Gamma_{\tau\tau}, \Gamma_{bb}, \Gamma_{\gamma\gamma}, \Gamma_{gg}, \Gamma_{BSM}$ (assumed $\equiv 0$ in most of studies), Γ_{tot}
- ▶ Coupling modifiers: $\kappa_i^2 = \frac{\sigma_i}{\sigma_i^{SM}}$ (production processes) or $\kappa_i^2 = \frac{\Gamma_i}{\Gamma_i^{SM}}$ (decays processes)
- ▶ (κ_V, κ_f) : $\kappa_V = \kappa_W = \kappa_Z, \kappa_f = \kappa_b = \kappa_{top} = \kappa_\tau, \kappa_\gamma = f(\kappa_V, \kappa_f)$
- ▶ All tests performed at a given mass, i.e. the measured m_H value



Rare Higgs Boson Decays

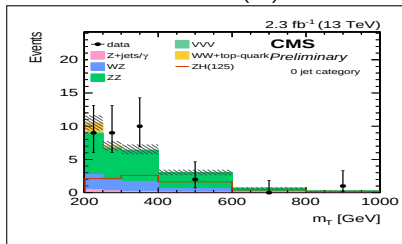
Invisible Higgs Decays (I)

- ▶ The most extensive set of rare decays searches by far
- ▶ It exists in the SM, but extremely rare: $BR(H \rightarrow ZZ \rightarrow 4\nu) \sim 0.1\%$
- ▶ Observation of a large rate would be a sign of BSM:
 - ▶ LSPs in SUSY (neutralinos, gravitinos)
 - ▶ Gravitational (large extra-dimensions)
 - ▶ Dark Matter (DM) $\rightarrow$ limits competitive with other DM searches
- ▶ Large missing transverse energy (E_T^{miss}) is the general pattern of all these searches
- ▶ Several production modes can be studied:
 - ▶ qqH (VBF): two forward/backward jets with high $\Delta\eta_{jj}$ & m_{jj}
 - ▶ $Z(\ell\ell/bb)H$: two leptons/two b-jets compatible with a Z boson
 - ▶ $Z/W(q\bar{q}')H$: two jets compatible with a Z/W boson
 - ▶ $t\bar{t}H$: two top-quarks
 - ▶ $gg \rightarrow H + \text{jet}$: one high p_T jet
- ▶ DM searches can directly be re-used for these studies

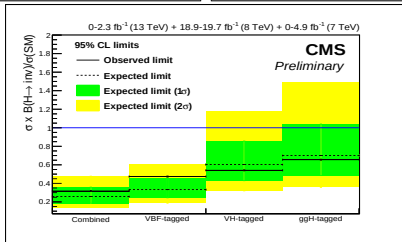
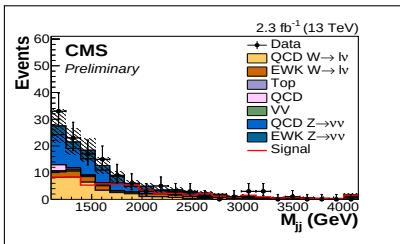
Invisible Higgs Decays (II)

- ▶ A large set of analyses coming up
- ▶ More complex techniques exploited by having a single fit combining signal and background regions
- ▶ For $m_H = 125$ GeV will profit from a larger dataset

$Z(\ell\ell)H$

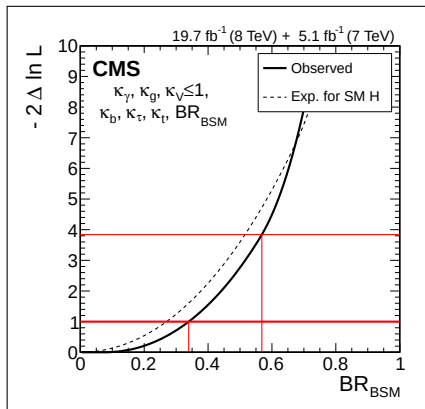


VBF



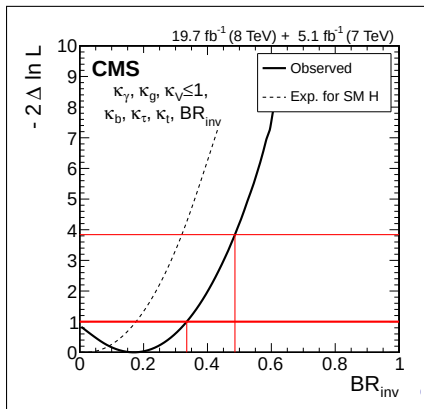
Indirect Limits on Invisible Higgs Decays

- $BR_{BSM} = \Gamma_{BSM}/\Gamma_{tot}$
 - All κ_i modifiers are profiled
 - $\kappa_V \leq 1$



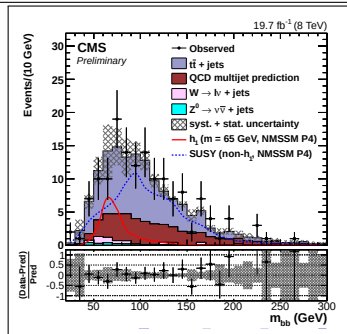
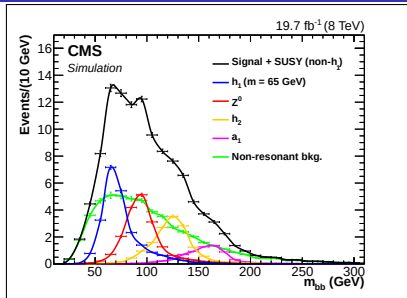
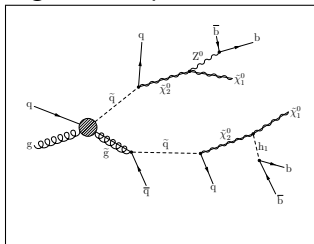
► $BR_{inv} = \Gamma_{inv}/\Gamma_{tot}$

- Combining with data from the $H \rightarrow inv$ searches, thus assuming that $BR_{BSM} = BR_{inv}$, i.e. $BR_{undet} = 0$
- All κ_i modifiers are profiled
- $\kappa_V \leq 1$



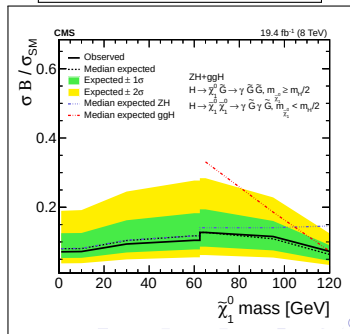
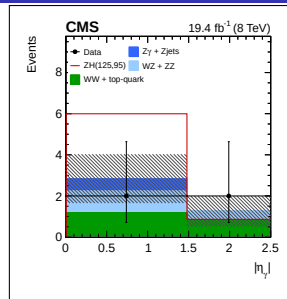
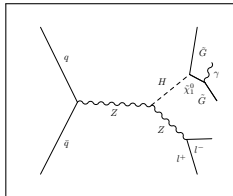
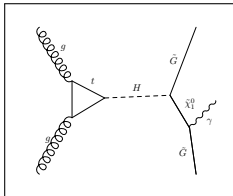
SUSY Cascades Decays - HIG-14-030

- ▶ Search for $H \rightarrow bb$ decays in NMSSM models
- ▶ Events are selected by requiring high p_T b-tagged jets and large E_T^{miss}
- ▶ m_{bb} is the final mass discriminant variable
- ▶ Good agreement between data and background expectation is seen



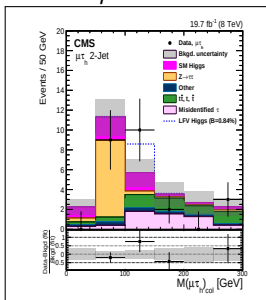
H $\rightarrow \gamma E_T^{\text{miss}}$ - HIG-14-025

- ▶ Search for $H \rightarrow \gamma E_T^{\text{miss}}$ decays in ggH and ZH modes
 - ▶ $\mathcal{B} \equiv \mathcal{B}(H \rightarrow \tilde{\chi}_1 \tilde{\chi}_1) \mathcal{B}(\tilde{\chi}_1 \rightarrow \tilde{G} + \gamma)^2$
for $m_{\tilde{\chi}_1} < m_H/2$
 - ▶ $\mathcal{B} \equiv \mathcal{B}(H \rightarrow \tilde{\chi}_1 \tilde{G}) \mathcal{B}(\tilde{\chi}_1 \rightarrow \tilde{G} + \gamma)$
for $m_{\tilde{\chi}_1} \geq m_H/2$
- ▶ Very tough to perform the ggH analysis at 13 TeV due to trigger conditions
- ▶ $Z(\ell\ell)H$ mode completely statistically limited, will benefit for a larger dataset

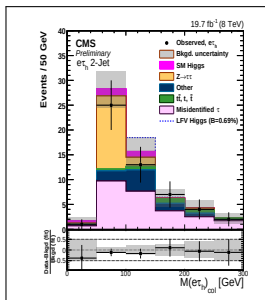


- ▶ Search for a mass peak at $m_H \sim 125$ GeV in $\mu\tau/e\tau/e\mu$ pairs
- ▶ Split in 0/1/2-jet and in τ decays categories
- ▶ Direct limits on $BR(H \rightarrow \mu\tau/e\tau/e\mu)$ can be established
- ▶ Interesting upper fluctuation in the $\mu\tau$ final state at 8 TeV

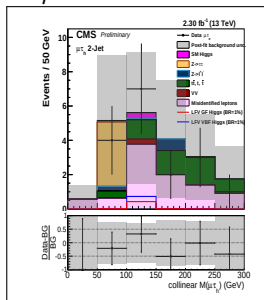
$\mu\tau$ 8 TeV



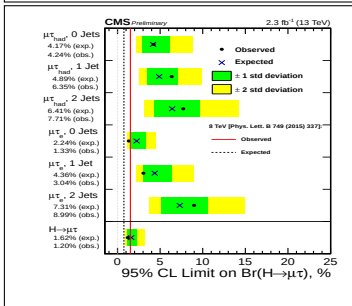
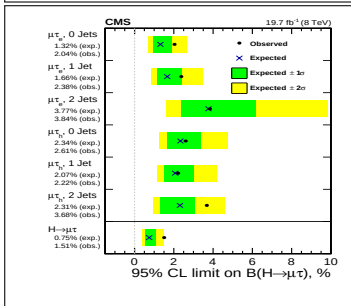
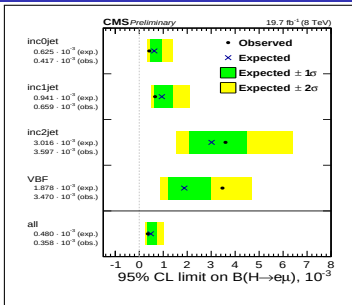
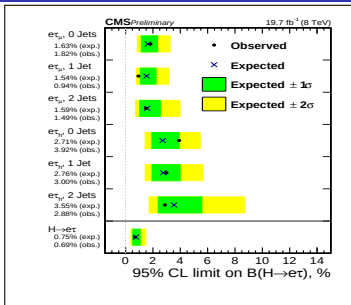
$e\tau$ 8 TeV



$\mu\tau$ 13 TeV



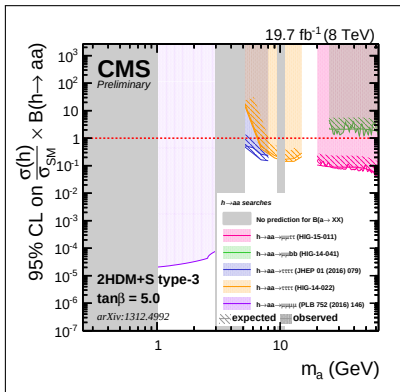
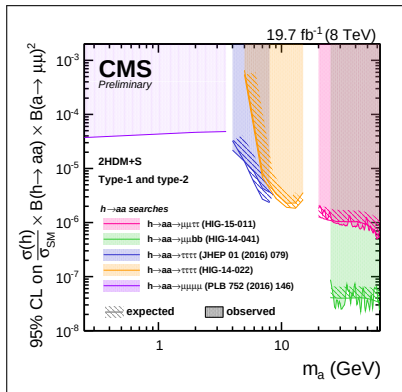
LFV $H \rightarrow \mu\tau/e\tau/e\mu$ (II) - HIG-14-005/HIG-14-040/HIG-16-005



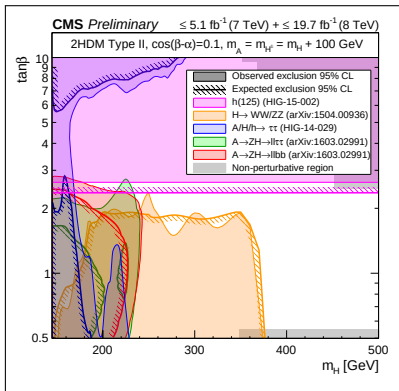
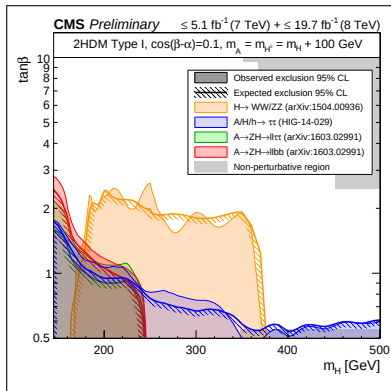
Need more 13 TeV data to take conclusions

Summary of $H \rightarrow a_1 a_1$ Run-I Searches

- Summary of several $H \rightarrow a_1 a_1$ Run-I searches for several scenarios
- $\sigma_{13 \text{ TeV}} / \sigma_{8 \text{ TeV}} \sim 2.3$
- These analyses more suitable for larger datasets at this point



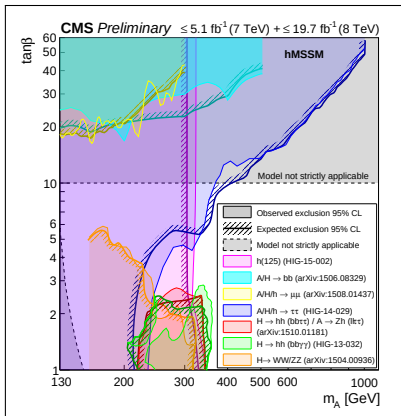
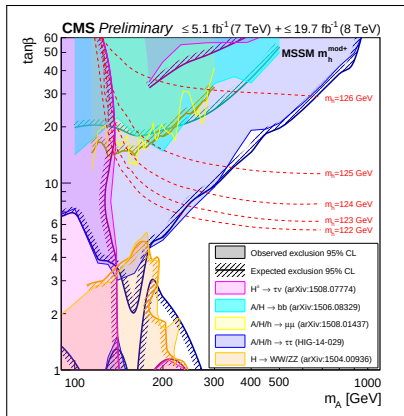
Summary of BSM Run-I Searches (I)



Parameter	Value (type I or type II)
m_h	125.09 GeV
m_A	$m_H + 100 \text{ GeV}$
$m_{H^\pm}$	$m_H + 100 \text{ GeV}$
$\cos(\beta - \alpha)$	0.1
$m_{1/2}^2$	$\max(1 - \tan\beta^{-2}, 0) \cdot \frac{1}{2} \sin(2\beta)(m_A^2 + \lambda_5 v^2)$
m_H and $\tan\beta$	scanned.

	2HDM	hMSSM
	type I	type II/MSSM
κ_V	$\sin(\beta - \alpha)$	$\sin(\beta - \alpha)$
κ_u	$\cos(\alpha) / \sin(\beta)$	$\cos(\alpha) / \sin(\beta)$
κ_d	$\cos(\alpha) / \sin(\beta)$	$-\sin(\alpha) / \cos(\beta)$

Summary of BSM Run-I Searches (II)



Parameter	Value (type I or type II)
m_h	125.09 GeV
m_A	$m_H + 100 \text{ GeV}$
$m_{H^\pm}$	$m_H + 100 \text{ GeV}$
$\cos(\beta - \alpha)$	0.1
$m_{1/2}^2$	$\max(1 - \tan\beta^{-2}, 0) \cdot \frac{1}{2} \sin(2\beta)(m_A^2 + \lambda_5 v^2)$ m_H and $\tan\beta$ scanned.

	2HDM	hMSSM
	type I	type II/MSSM
κ_V	$\sin(\beta - \alpha)$	$\sin(\beta - \alpha)$
κ_u	$\cos(\alpha) / \sin(\beta)$	$\cos(\alpha) / \sin(\beta)$
κ_d	$\cos(\alpha) / \sin(\beta)$	$-\sin(\alpha) / \cos(\beta)$

Other Possible Rare Decays

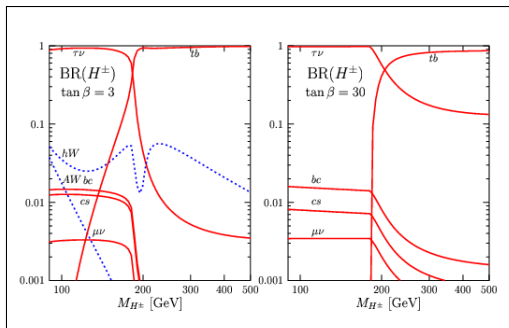
A summary can be found in e.g. [arXiv1312.4992](#)

- ▶ $H \rightarrow XX \rightarrow 4b$
- ▶ $H \rightarrow aa \rightarrow 2b2\tau/2b2\mu/4\tau/2\tau2\mu$
 - ▶ multilepton analyses may be used to put limits on them
- ▶ $H \rightarrow XX \rightarrow 4j$
- ▶ $H \rightarrow XX \rightarrow 2j2\gamma$
- ▶ $H \rightarrow XX \rightarrow 4\gamma$
- ▶ $H \rightarrow aZ$
- ▶ $H \rightarrow Z_D Z / Z_D Z_D$, with Z_D a new gauge boson
- ▶ $H \rightarrow \chi_1 \chi_2 \rightarrow \gamma/2\gamma + E_T^{\text{miss}}$
- ▶ $H \rightarrow \ell/\ell\ell/b\bar{b}/\tau\tau + E_T^{\text{miss}}$
 - ▶ SUSY analyses may be used to put limits on them
- ▶ $H \rightarrow \text{one/two prompt leptons} - \text{jets} + X$

Charged Higgs Bosons

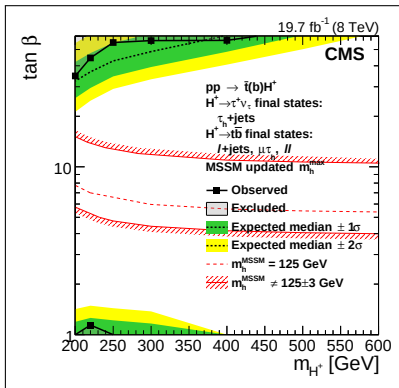
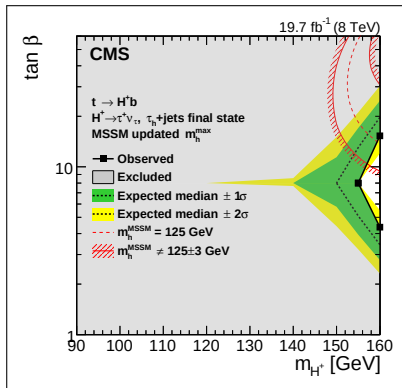
Search for Charged Higgs Bosons (I) - HIG-14-023/HIG-13-035

- ▶ Predicted in several new Physics scenarios
- ▶ For $m_{H^\pm} < m_{top}$, search for $top \rightarrow H^\pm b$ decays
- ▶ For $m_{H^\pm} > m_{top}$, mostly search for $tH^\pm(b)$ decays
- ▶ $H \rightarrow \tau\nu$ dominates a large phase space, but several other decay modes possible
- ▶ A large room for gain at 13 TeV, this is a long term project



Search for Charged Higgs Bosons (II) - HIG-14-023/HIG-13-035

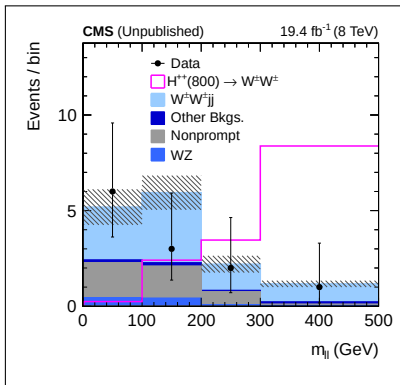
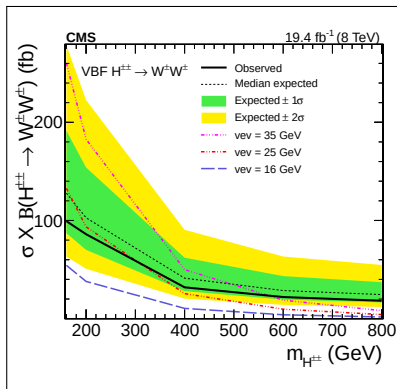
- ▶ 13 TeV analyses ramping up, expected by this Summer
- ▶ Low mass region largely excluded
- ▶ A way to go at high mass



Doubly Charged Higgs Bosons

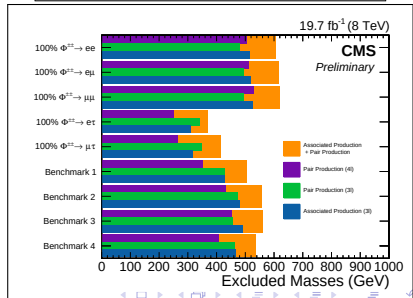
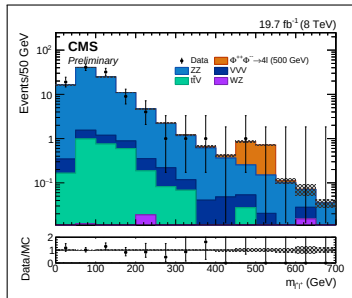
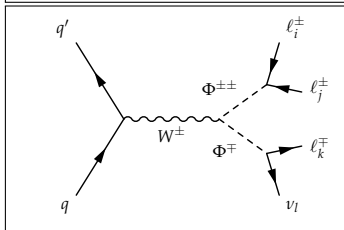
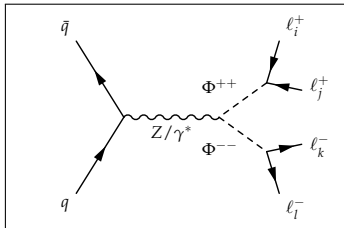
VBF $H^{\pm\pm} \rightarrow W^{\pm}W^{\pm}$ - SMP-13-015

- ▶ $H^{\pm\pm} \rightarrow W^{\pm}W^{\pm} \rightarrow \ell^{\pm}\ell^{\pm}2\nu$ (vector boson scattering topology)
- ▶ Predictions from Georgi-Machack Higgs Triplet Models
- ▶ Spin-off of vector boson scattering measurement
- ▶ Large benefit from a larger dataset and increase on $\sqrt{s}$



$H^{\pm\pm} \rightarrow 4\ell$ - HIG-14-039

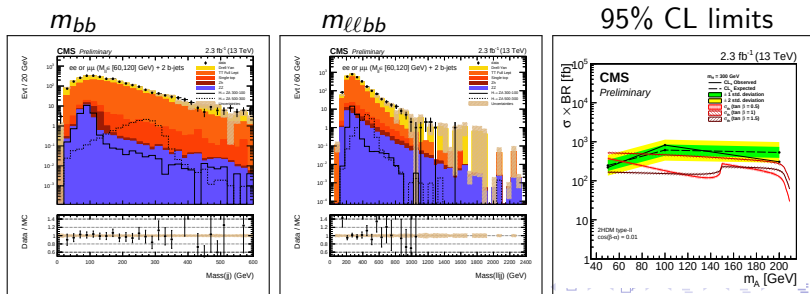
- Search for associated- or pair-production in 3 or 4 lepton final state



Higgs to Higgs Decays

Search for $A/H \rightarrow ZH/A \rightarrow \ell\ell bb$ Decays - HIG-15-001/HIG-16-010

- ▶ Search for $A/H \rightarrow ZH/A \rightarrow \ell\ell bb$ decays, $H/A \rightarrow \tau\tau$ also considered in run-I analysis
- ▶ Signal region defined in $m_{bb} - m_{\ell\ell bb}$ plane for each $m_H - m_A$ hypotheses
- ▶ Simple cut-and-count approach, backgrounds from sideband
- ▶ Large room for improvements, e.g. by fitting signal and sidebands regions simultaneously or by having a more sophisticated template fit
- ▶ Limits on $\sigma \times BR$ for m_H hypotheses as function of m_A



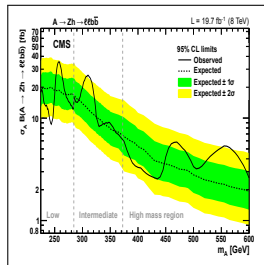
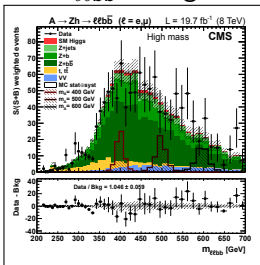
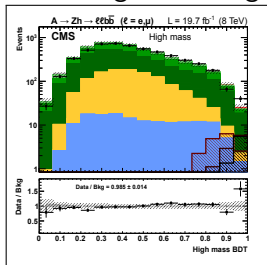
Search for $A \rightarrow Zh(125)$ Decays - HIG-14-011

- ▶ Search for $A \rightarrow Zh(125) \rightarrow \ell\ell b\bar{b}$ decays
- ▶ A particular region of a more general A-H phase space
- ▶ Analysis split in three regions: low/intermediate/high masses
- ▶ Two-dimensional BDT vs. $m_{\ell\ell b\bar{b}}$ to discriminate signal and backgrounds

BDT high mass region

$m_{\ell\ell b\bar{b}}$ at high BDT

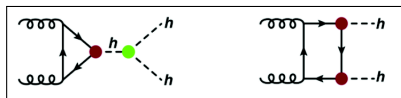
95% CL limits



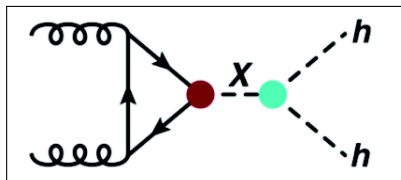
Double Higgs Boson Production

Di-Higgs Production

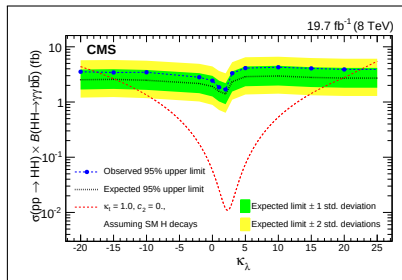
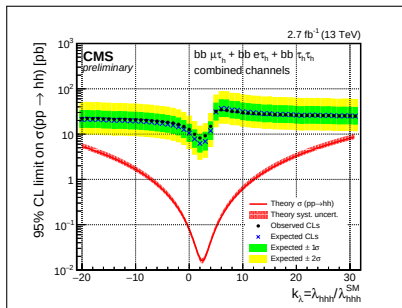
- ▶ Exciting prospects of the HL-LHC
 - ▶ process like di-Higgs production has not been observed yet
 - ▶ gluon fusion cross section is only ~ 40 fb
 - ▶ vector boson fusion cross section is ~ 2 fb
 - ▶ challenging measurements
 - ▶ enhancement due to new physics scenarios
- ▶ Destructive interference in gluon fusion



- ▶ Resonant production
 - ▶ enhance production cross section

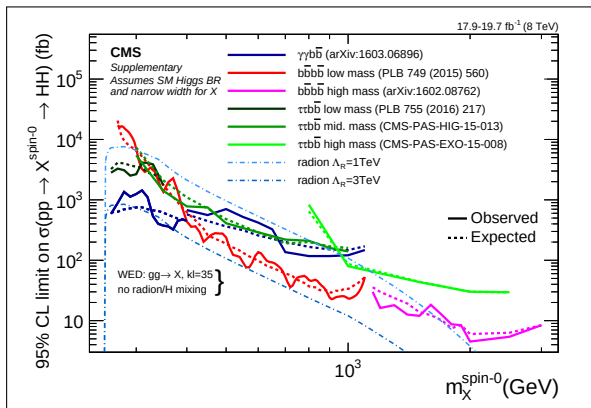


- Analyses getting mature, but a long way to get SM reach
- One of the high priority LHC analyses in the long term
- Room for improvements and new channels to be added



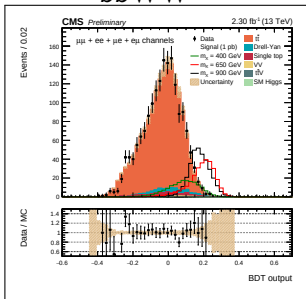
Search for Resonant $X \rightarrow HH$ Decays - HIG-16-002/HIG-16-011/HIG-16-013/...

- ▶ Larger number of analyses than in the non-resonant case so far
- ▶ Boosted techniques are needed for m_X masses greater than ~ 1 TeV
- ▶ New final studies can help, combining resolved and boosted analyses will improve the performance at intermediate m_X masses

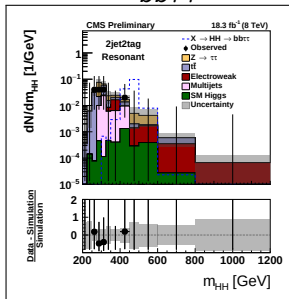


$X \rightarrow HH$ Analyses at 13 TeV - HIG-16-002/HIG-16-011/HIG-16-013

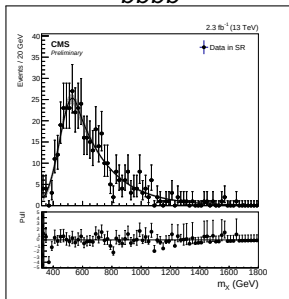
$bbWW$



$bb\tau\tau$



$bbbb$



- ▶ The H(125) boson well-established in several decay modes
- ▶ The 125 GeV Higgs boson consistent with the SM prediction within the 20-30% relative uncertainties
- ▶ Neither sign of BSM Higgs bosons nor sign of BSM Higgs boson decays yet
- ▶ A lot of room for improvements at $\sqrt{s} = 13$ TeV
- ▶ You can find all Higgs results on:
<http://cms-results.web.cern.ch/cms-results/public-results/publications/HIG/index.html>

Back-Up Slides

Higgs Sector in MSSM

- ▶ Higgs sector in SUSY contains two scalar doublets:
 - ▶ five physical Higgs bosons:
 - ▶ 3 neutral: CP-even $\Phi = h$ & H ; CP-odd A
 - ▶ 2 charged: $H^\pm$
 - ▶ SM-like Higgs boson: h
- ▶ Neutral Higgs “ Φ ” decay modes:
 - ▶ $BR(\Phi \rightarrow b\bar{b}) \sim 90\%$
 - ▶ $BR(\Phi \rightarrow \tau\tau) \sim 10\%$
 - ▶ $BR(\Phi \rightarrow \mu\mu) \sim 0.1\%$
- ▶ Two main production modes:
 - ▶ $gg \rightarrow H$
 - ▶ $b\bar{b}H$
- ▶ B-tagged topologies make analyses rather different w.r.t. SM searches
- ▶ Observation of $H(125)$ does not exclude a heavy MSSM Higgs boson in a wide range of $\tan\beta$, still fits both SM and MSSM
- ▶ Signal extraction based on looking for a mass resonance
- ▶ Showing $\Phi \rightarrow \mu\mu$ case here, other analyses in Susan Gascon-Shotkin's talk