Higgs Results from CMS

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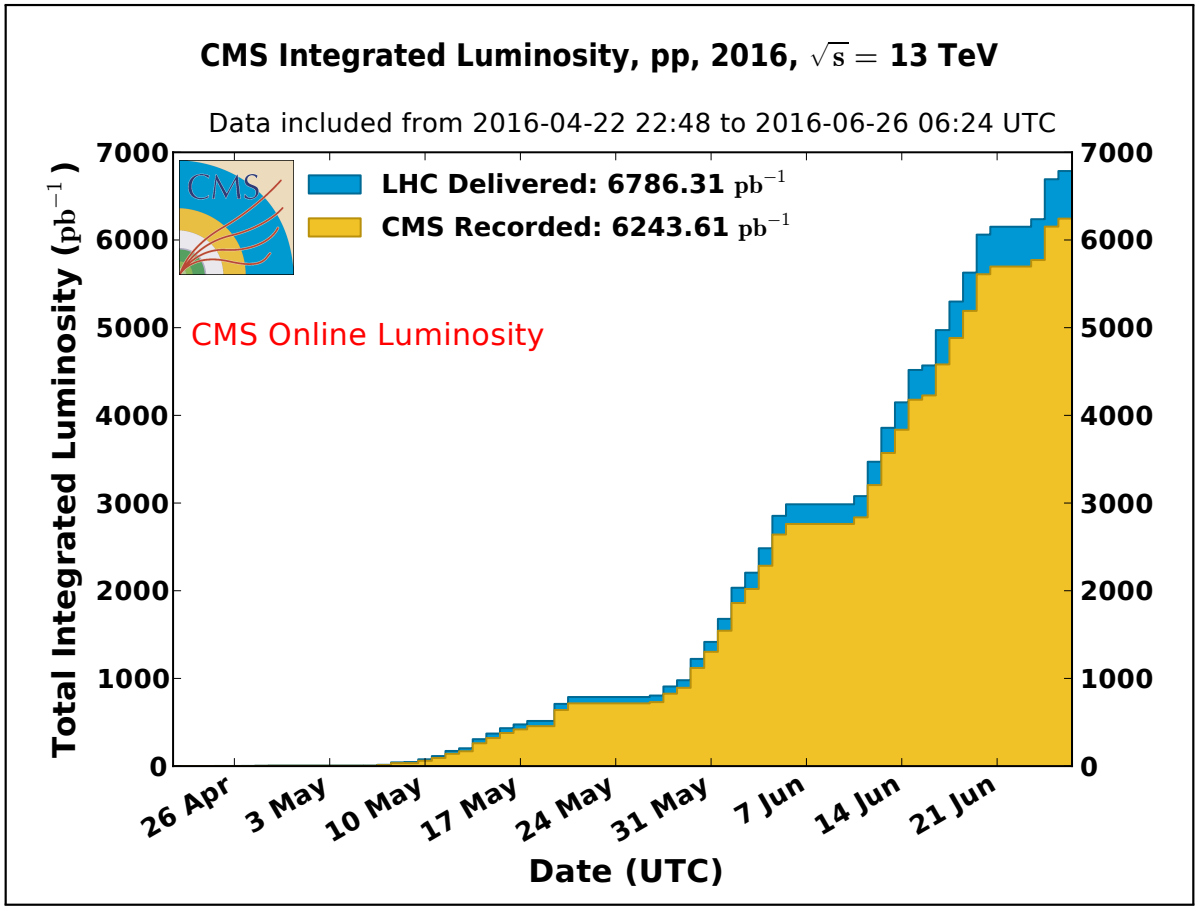
June 2015 DESY Seminar

- 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

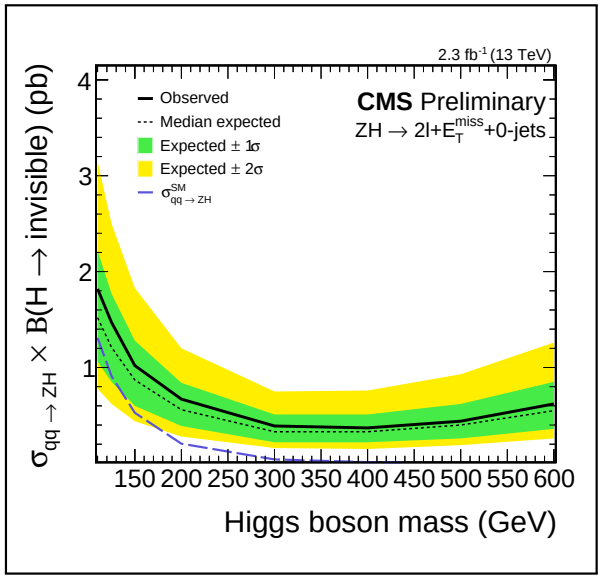
Taking Data at $\sqrt{s} = 13$ TeV



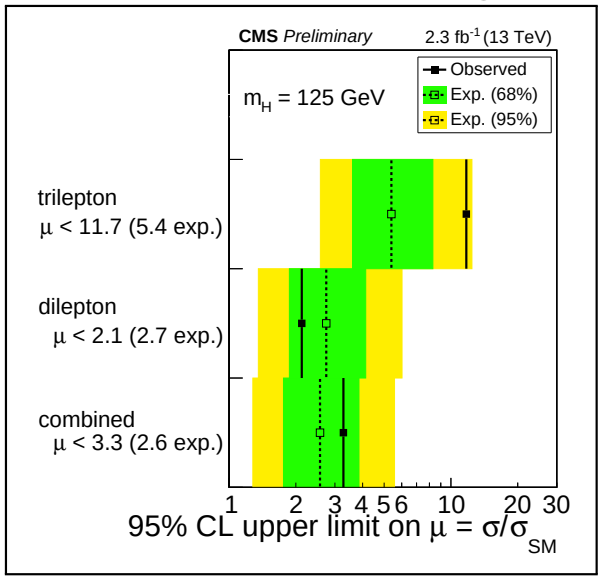
- $\mathcal{L} = 2 - 3\ \mathrm{fb}^{-1}$ at $\sqrt{s} = 13$ TeV in 2015, much faster pace in 2016
- Today's results using 2015 data only, new results expected for ICHEP and beyond

Some Terminology

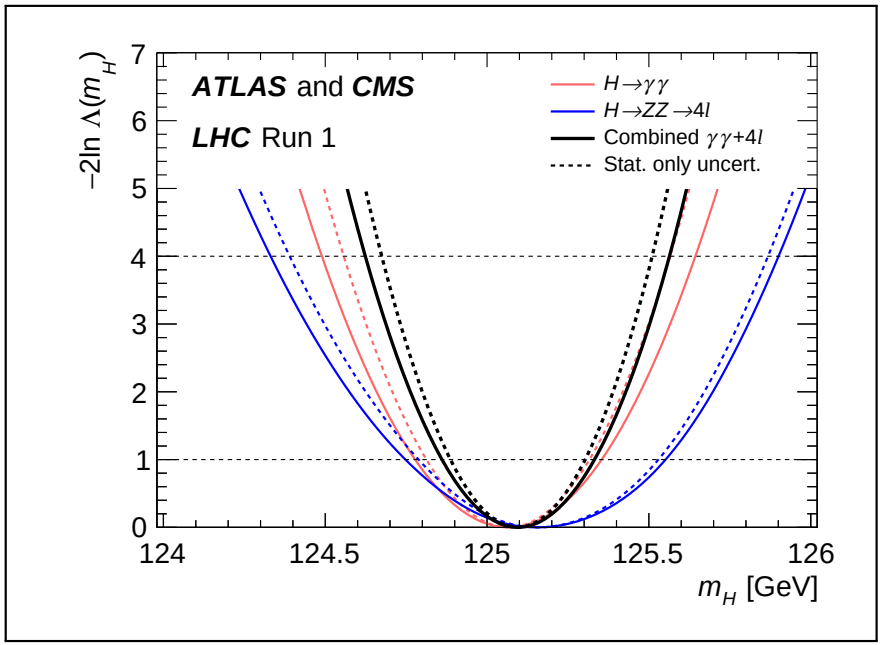
95% Confidence Level (CL) upper limits as a function of the mass



95% CL upper limits for a given mass

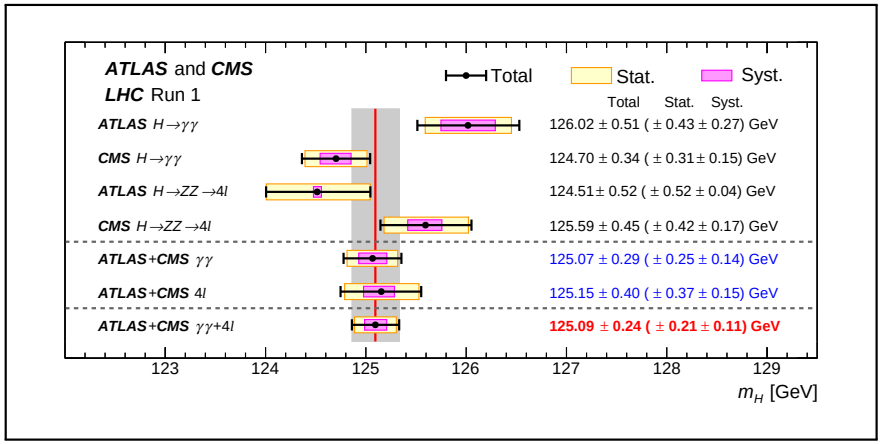


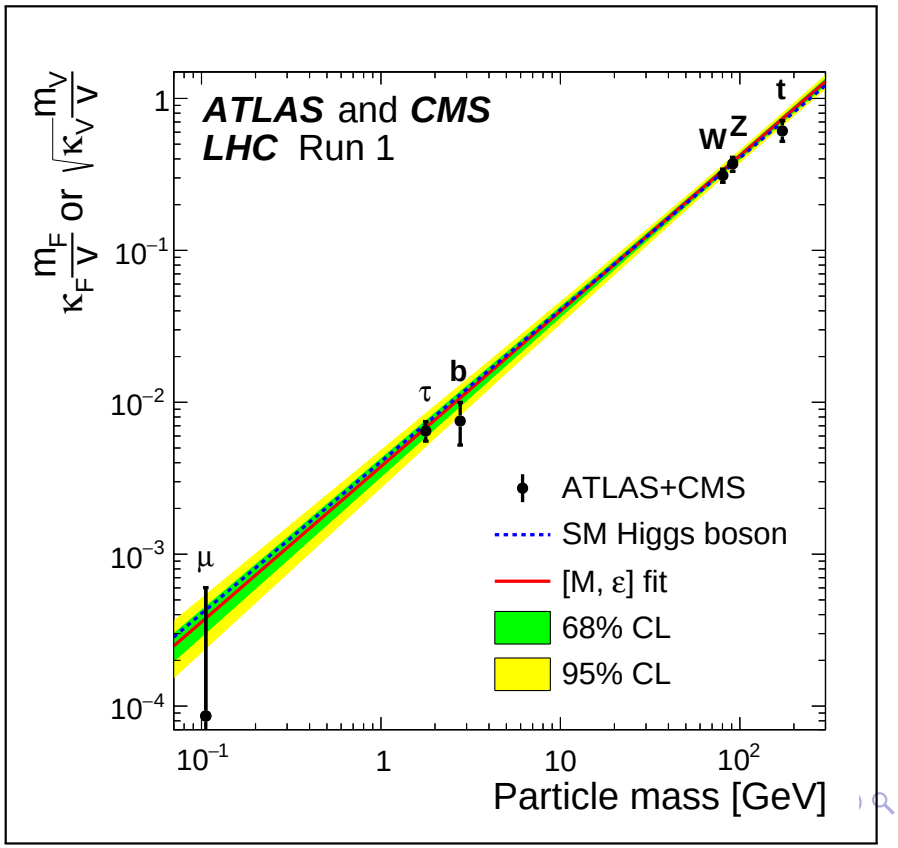
Likelihood profile of a given observable



Summary of Run-I Higgs Results

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



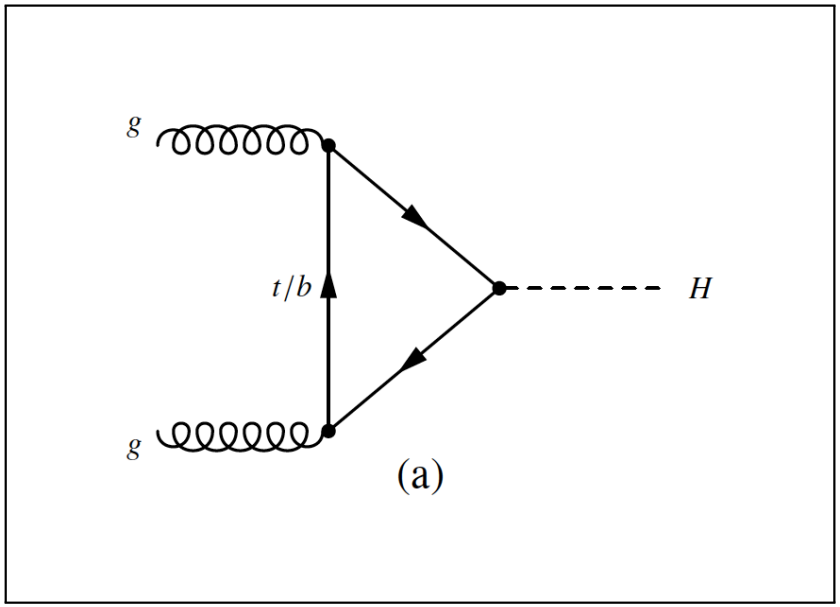


Introduction

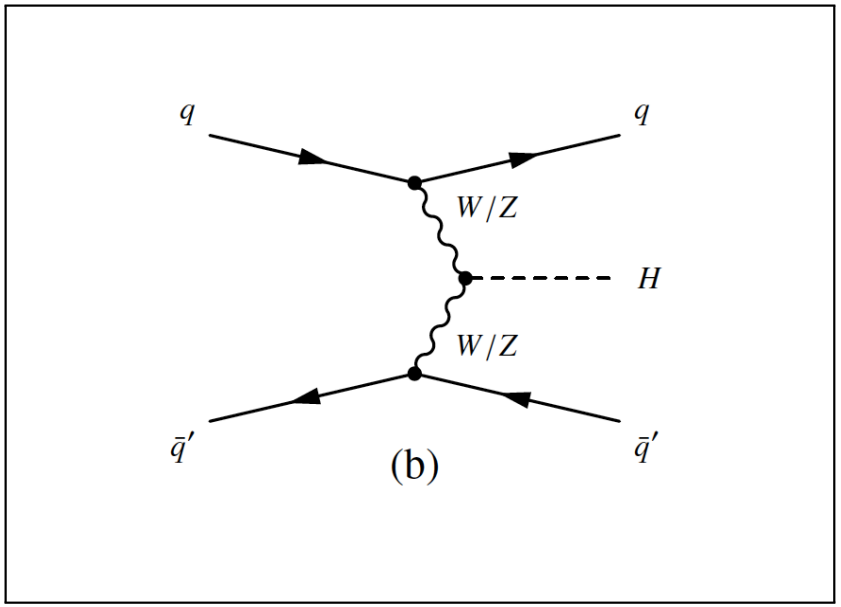
- Several ways to find Physics Beyond the Standard Model (BSM) within the Higgs sector:
  - measuring couplings and differential distributions of known SM Higgs boson decays:
    - main modes: ZZ, WW, $\gamma\gamma$, $\tau\tau$, $b\bar{b}$
    - (less) rare modes: $\mu\mu$, $\mathrm{Z}\gamma$, $\gamma^{*}\gamma$, ee
    - very difficult modes (at LHC): $s\bar{s}$, $c\bar{c}$, gg
    - couplings: $gg \rightarrow \mathrm{H}$, $qq\mathrm{H}$, VH, $\mathrm{t\bar{t}H}$, $tq\mathrm{H}$, $b\bar{b}\mathrm{H}$
  - searching for additional Higgs bosons:
    - direct searches for low mass (pseudo-)scalars (NMSSM...)
    - direct searches for heavy Higgs bosons (2HDM, $H^{\pm\pm}$...)
  - searching for particle decays involving Higgs bosons, e.g.:
    - $t \rightarrow c\mathrm{H}$
    - $\tilde{\chi}_1^0 \rightarrow \mathrm{H}\tilde{G}$, $\tilde{t}_2 \rightarrow \tilde{t}_1\mathrm{H} \rightarrow t\tilde{\chi}_1^0\mathrm{H}$, $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0 \rightarrow \mathrm{W}^{\pm}\tilde{\chi}_1^0\mathrm{H}\tilde{\chi}_1^0$
  - 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

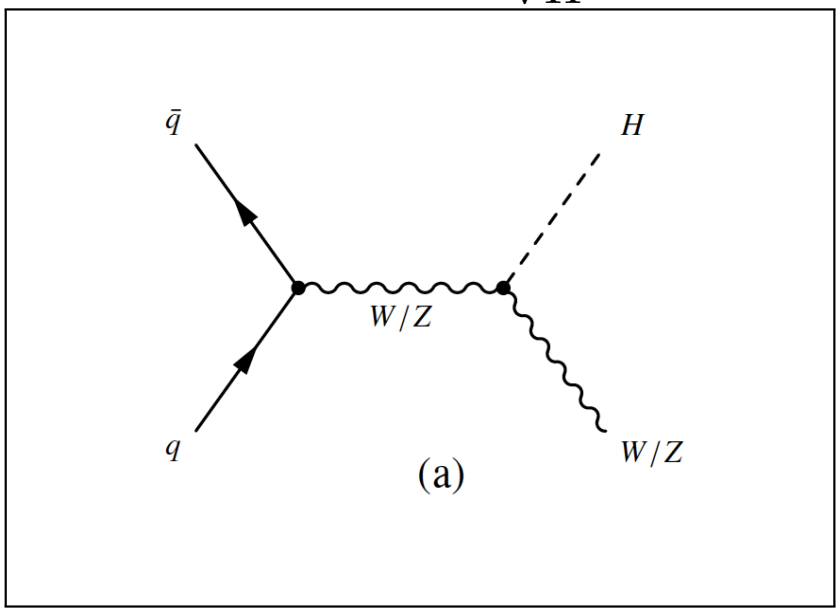
Gluon-fusion (ggH)



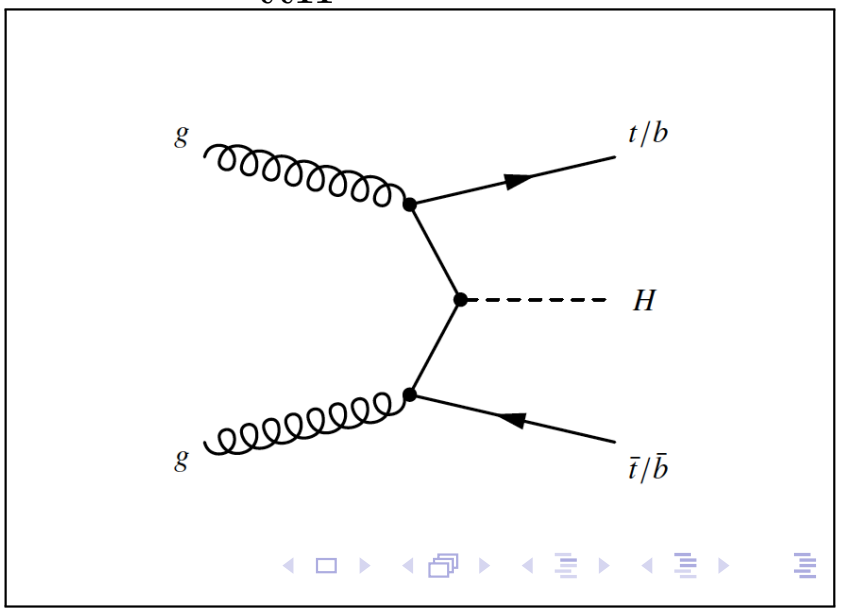
Vector Boson Fusion (VBF)



VH



$t\bar{t}H$



Extended Higgs Sector

- 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

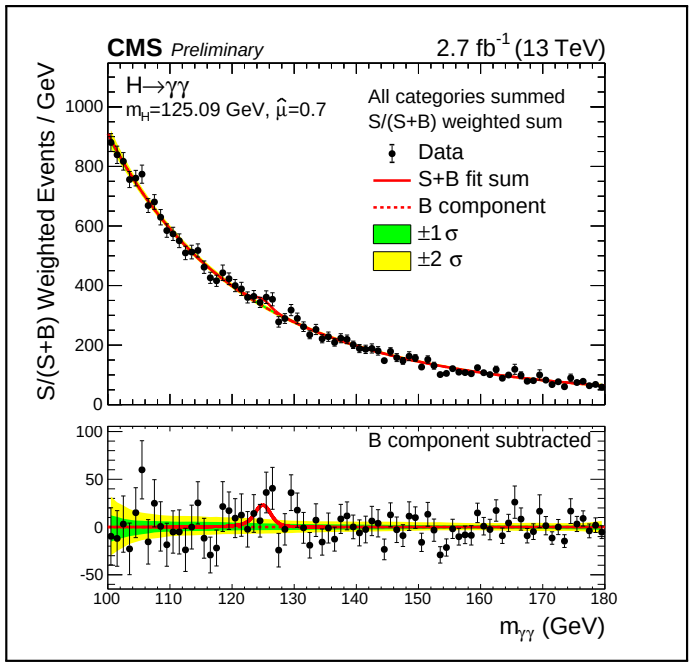
- "SM" Higgs boson and other neutral Higgs bosons
  - $\mathrm{H} \to \gamma\gamma/\mathrm{ZZ}/\mathrm{WW}/\tau\tau/bb/\mu\mu/\mathrm{Z}\gamma$
- Rare (or forbidden) Higgs boson decays
  - $\mathrm{H} \to \mathrm{inv.}/\mathrm{inv.} + \gamma/\mathrm{prompt\ electron} - \mathrm{jets}/\mathrm{long\ lived}...$
- Charged Higgs bosons
  - $\mathrm{H}^{\pm} \to \tau\nu/tb/cs/cb/\chi^0\chi^+/W\mathrm{H}/W\mathrm{Z}$
- Doubly charged Higgs bosons
  - $\mathrm{H}^{\pm\pm} \to \mathrm{WW}/4\ell$
- Higgs bosons to Higgs bosons decays
  - $\mathrm{H} \to \mathrm{Z}A/\mathrm{Z}h$
- Di-Higgs bosons
  - $\mathrm{H} \to hh \to bb\gamma\gamma/bb\tau\tau/bbbb/WW\gamma\gamma...$
  - $\mathrm{H} \to a_1 a_1 \to \mu\mu\mu\mu/\mu\mu\tau\tau/\tau\tau\tau\tau/bb\tau\tau$

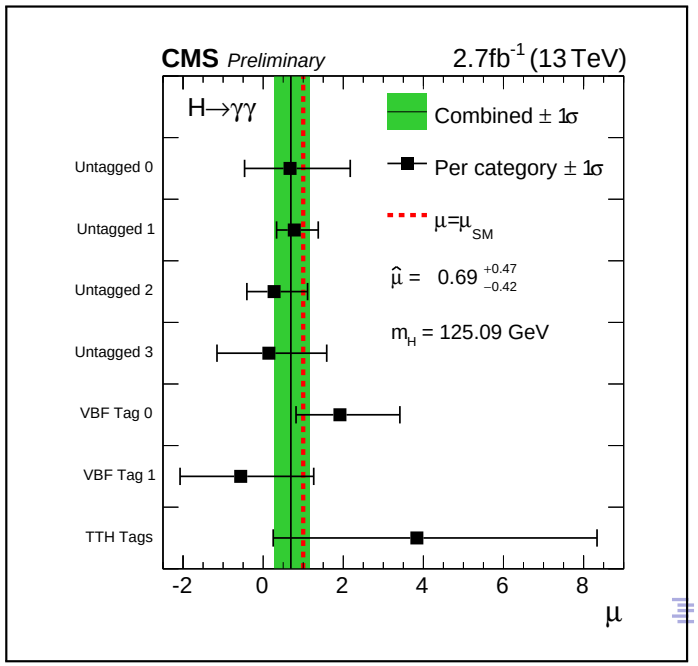
In case of a discovery, signatures of new Higgs bosons can also be due to other new particles (e.g. SUSY particles)

Neutral Higgs Bosons

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

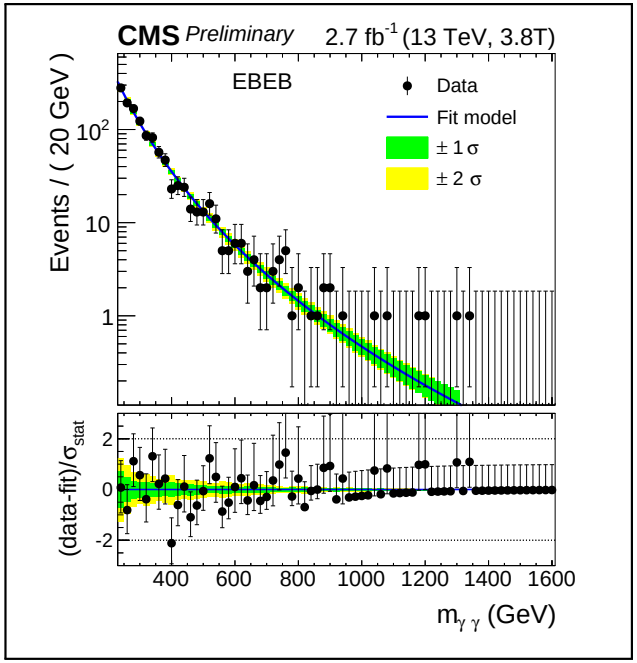
- Clean signature under a huge background
- Complicated analysis to squeeze all the data information
  - Best of the best ECAL calibrations
  - MVA to select event vertex
  - MVA to select photons
  - MVA to select photon pairs
- Split in many categories to improve signal-to-background ratio (S/B) and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

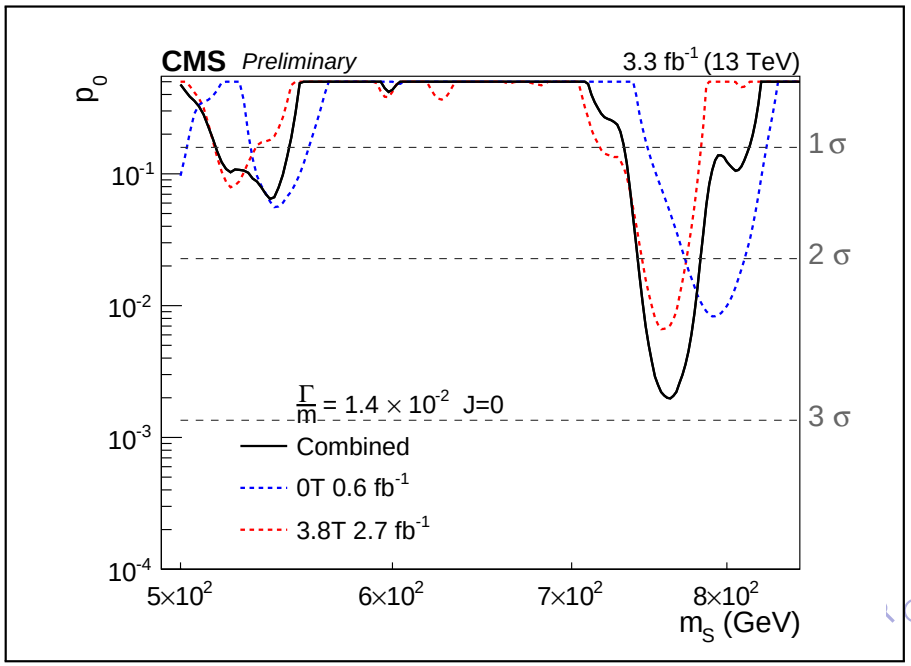




$H \rightarrow \gamma\gamma$ (High Mass) - EXO-16-018

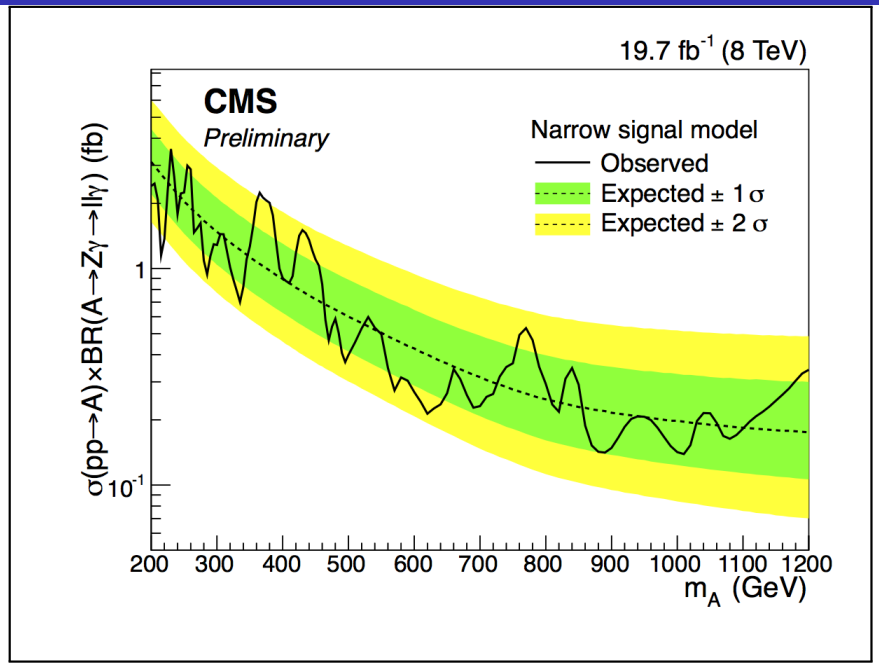
- Highlights of Run-II presented at December CERN seminar
  - ATLAS and CMS updated studies for Moriond
  - Local p-value: 3.4σ for CMS and 3.9σ for ATLAS
  - Global p-value: 1.6σ for CMS and 2.0σ for ATLAS
  - Observed Cross section $\sim$ 10 fb
  - Huge excitement and avalanche of papers ($\sim$400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

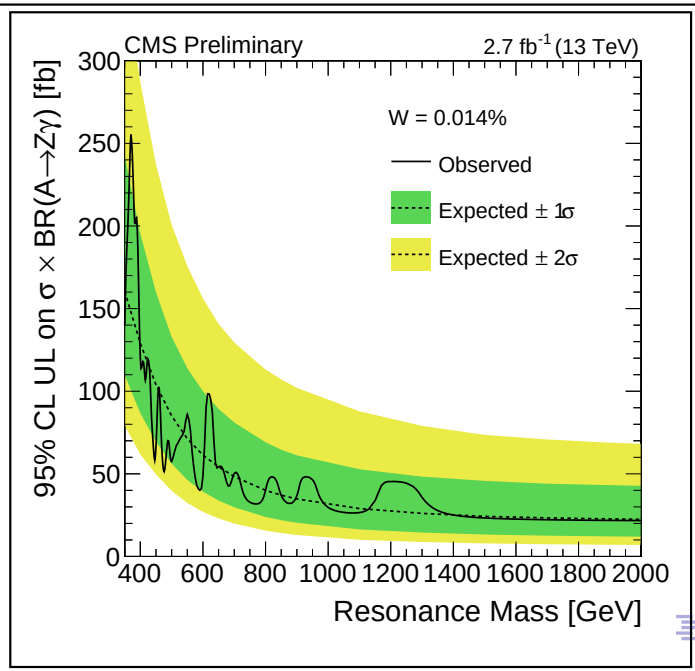




$H \to Z\gamma$ - HIG-16-014/EXO-16-019

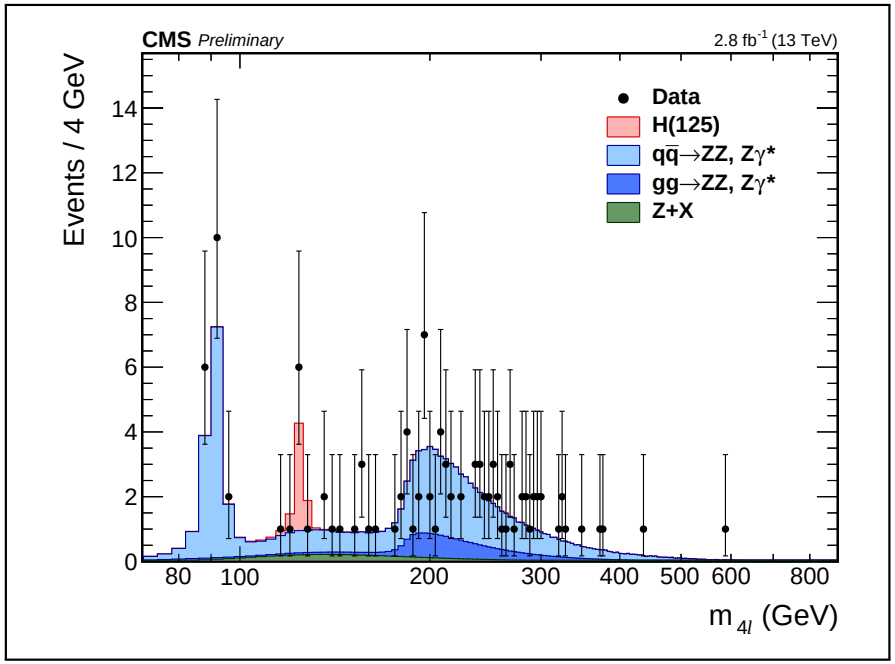
- Natural extension once something is seen in the $\gamma\gamma$ channel
- Search for $H \to Z\gamma$ (at high mass)
  - $Z \to ee/\mu\mu$ decays are the cleanest channels
  - $Z \to \nu\nu$ (mono-photon) and $Z \to qq$ decays are also doable
- No significant excess of events seen so far
- SM analyses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

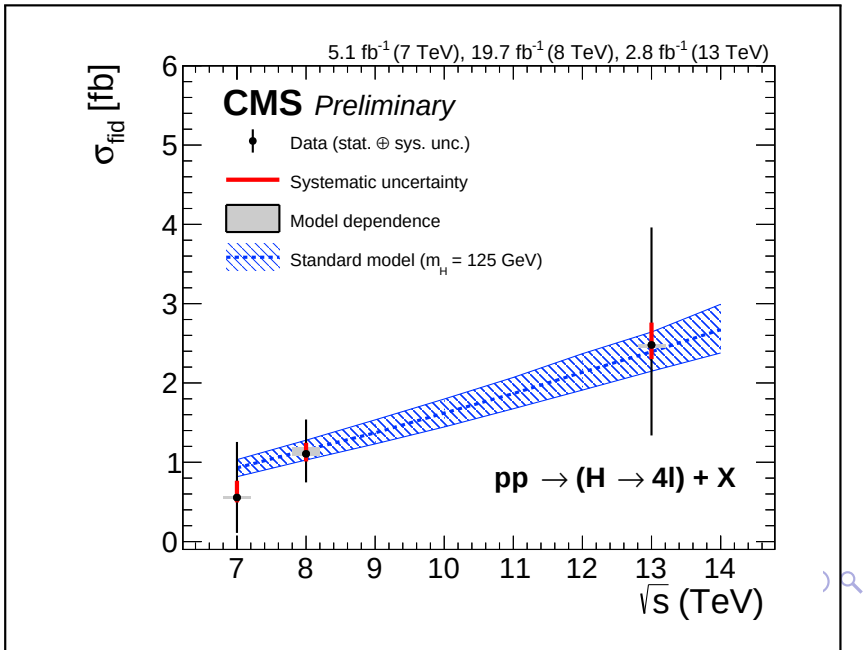




$H \to ZZ \to 4\ell$ - HIG-15-004

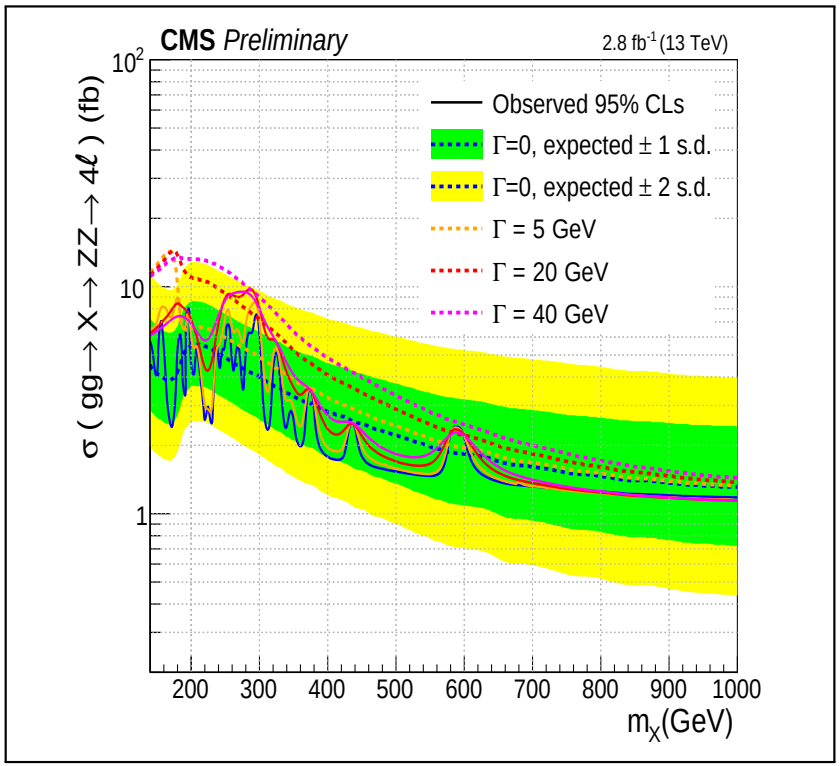
- Clean signature under a small background, but tiny signal yield
- Complicated analysis to add as much sensitivity as possible:
  - make use of $m_{4\ell}$ vs. kinematic discriminator vs. mode categorization
  - make use of low p_T leptons, sophisticated lepton selections
- Differential/fiducial cross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

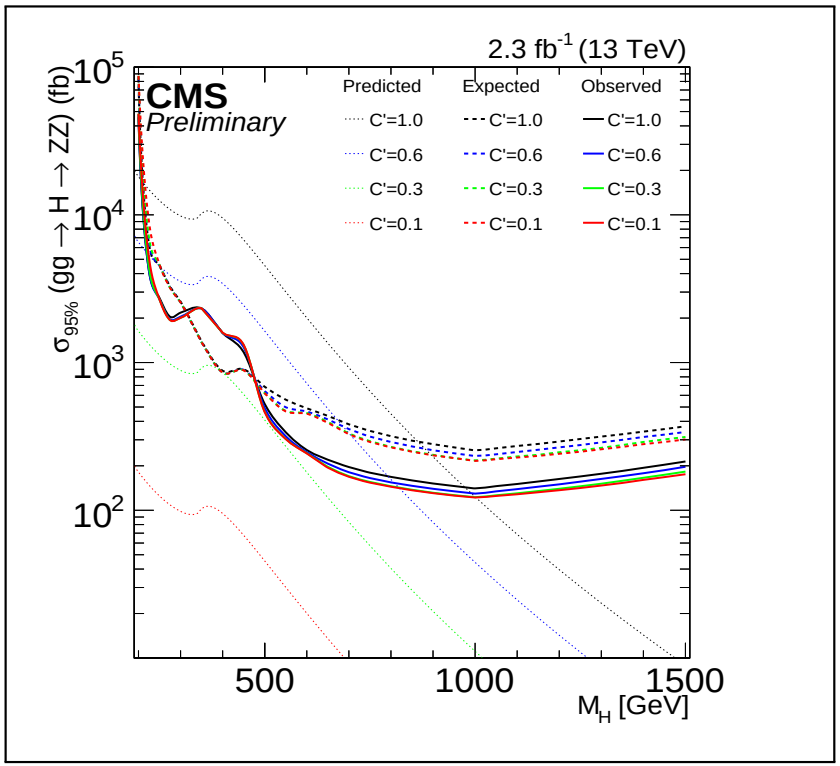




High Mass $H \to ZZ \to 2\ell 2\nu/4\ell$ - HIG-15-004/HIG-16-001

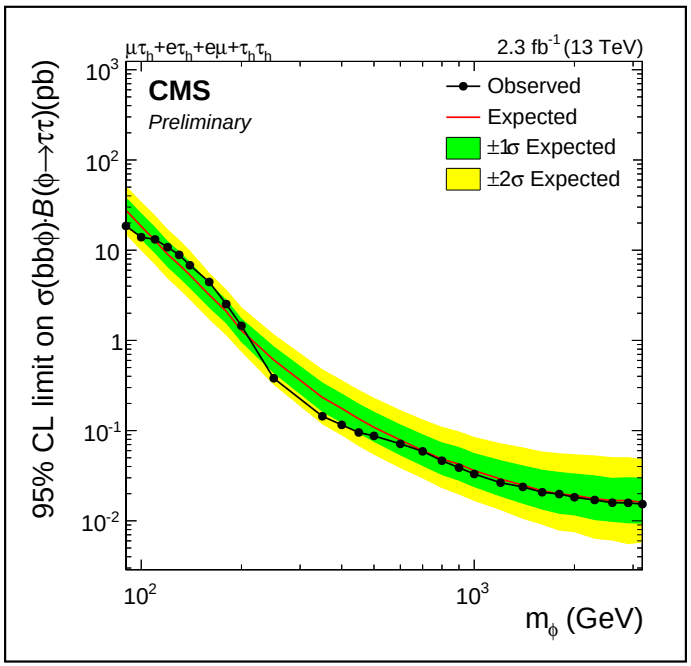
- $2\ell 2\nu$: search using m_T, results using an Electroweak Singlet model
- 4ℓ: search using $m_{4\ell}$, generic cross section limits for several widths

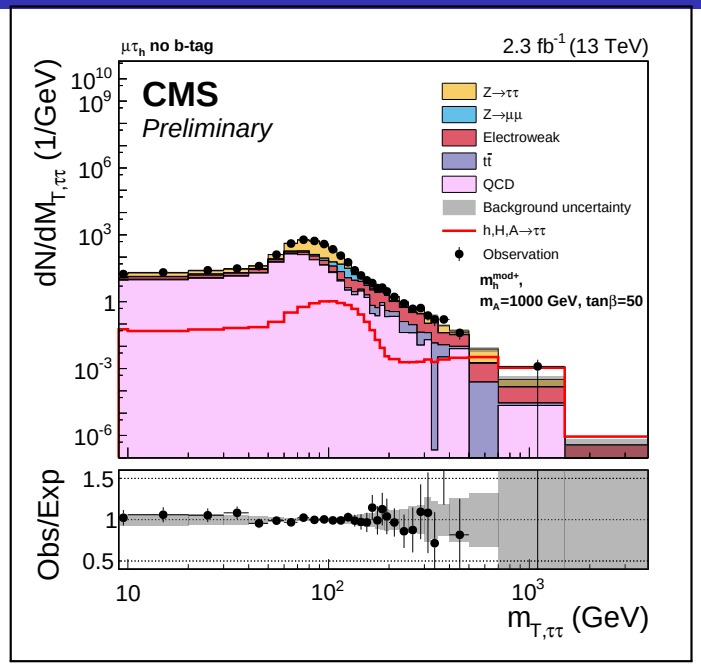


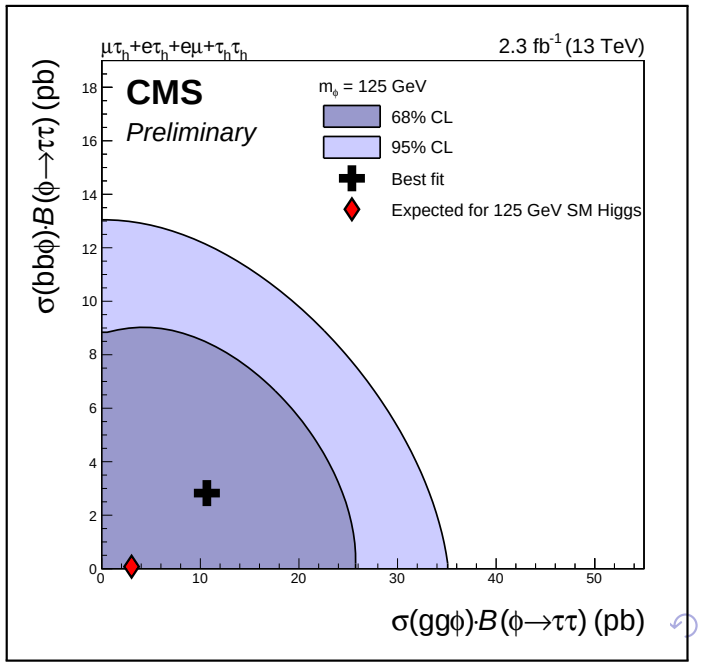


$H \rightarrow \tau\tau$ (Mostly MSSM) - HIG-16-006

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

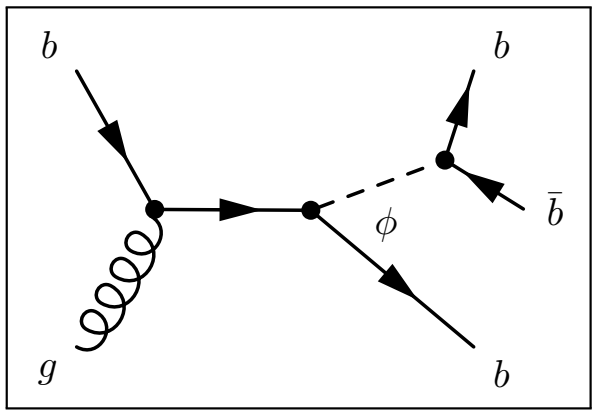






$H \rightarrow bb$ (MSSM) - HIG-14-017

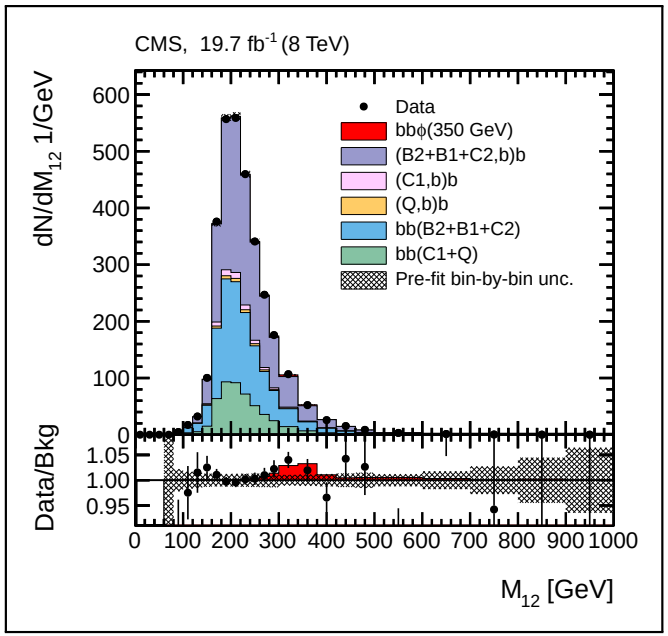
- Search for $H \rightarrow bb$ resonances at high mass
- Final states usually have additional b-quarks
- Dedicated trigger paths to select these events (no high p_T leptons/photons, no high E_T^{miss})

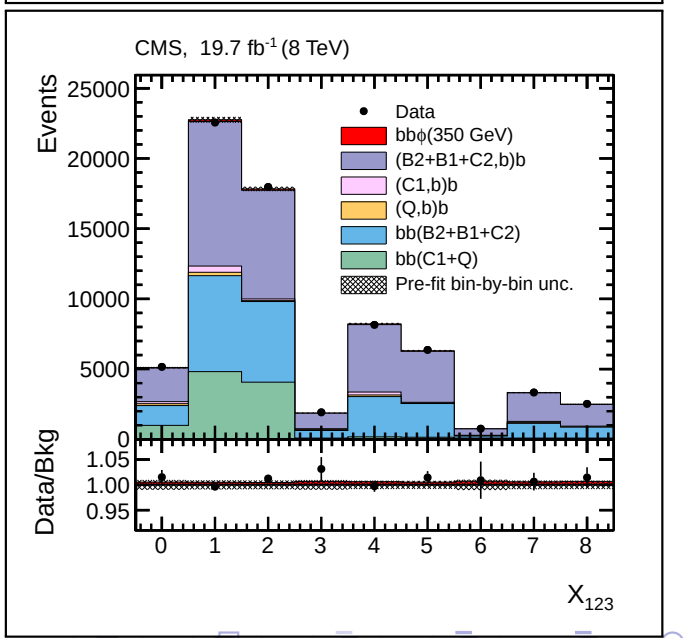


- $X_{123} = (B_1 + B2) + (B_3)$ to split in categories

$\Sigma M_{SV,j}$ [GeV]	B_j
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



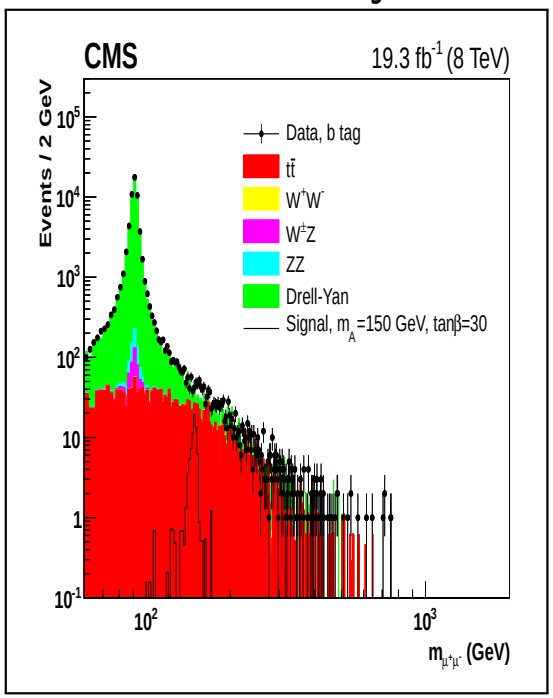


No significant excess seen

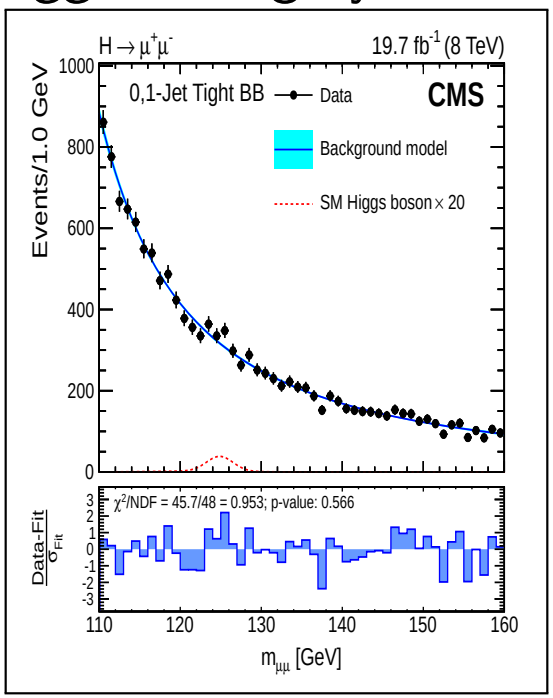
$H \rightarrow \mu^+\mu^-$ - HIG-13-024/HIG-13-007

- 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

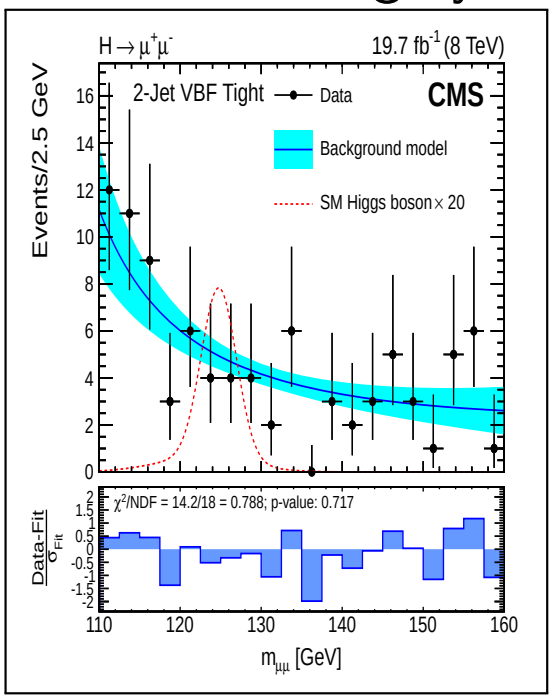
MSSM analysis



$gg\mathrm{H}$ category

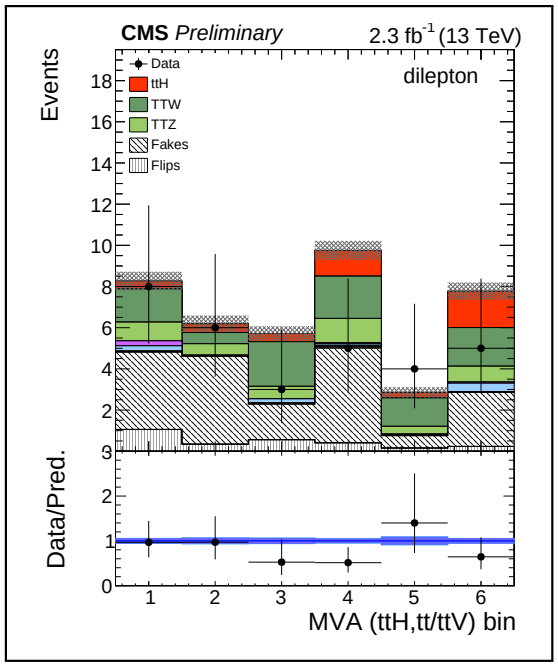


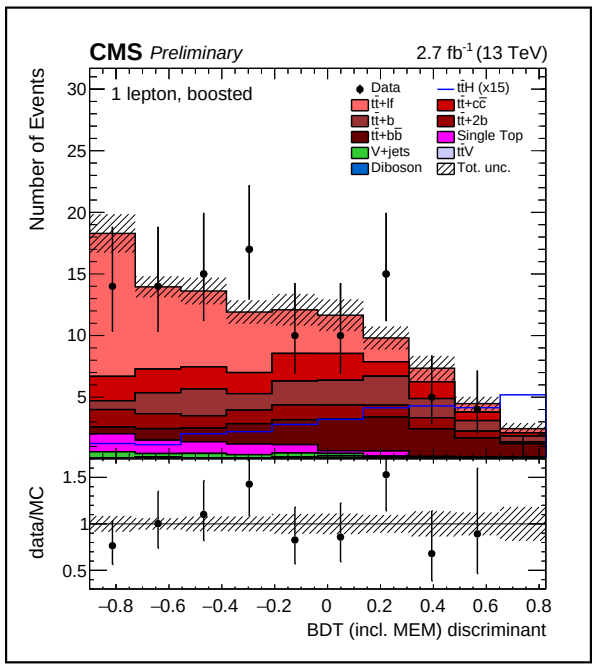
VBF category

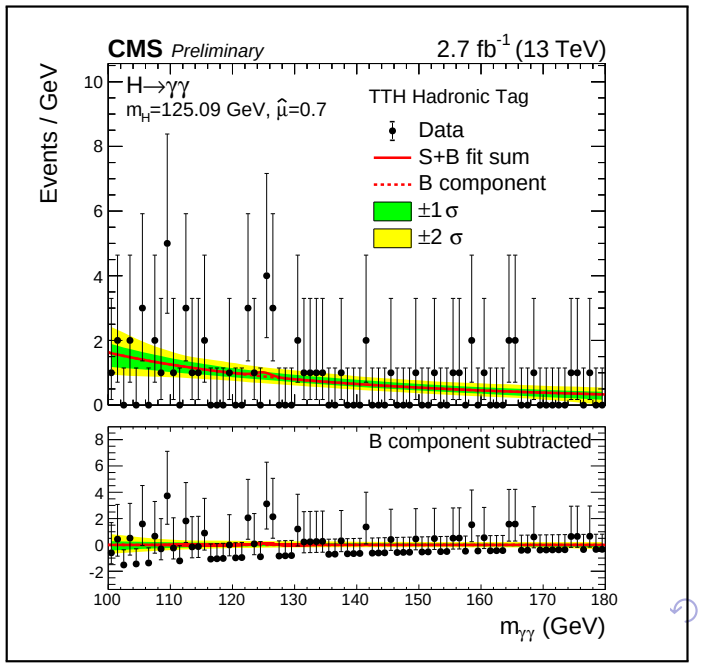


$t\bar{t}H$ (I) - HIG-16-004/HIG-15-008/HIG-15-005

- $\sigma^{13\ \mathrm{TeV}}_{t\bar{t}H} / \sigma^{8\ \mathrm{TeV}}_{t\bar{t}H} \sim 4$
- Sensitivity approaching Run 1
- Sensitive to potential new physics contributions
- Final states:
  - $H \rightarrow bb$: large BR, low S/B, make use BDT and MEM approaches
  - $H \rightarrow$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

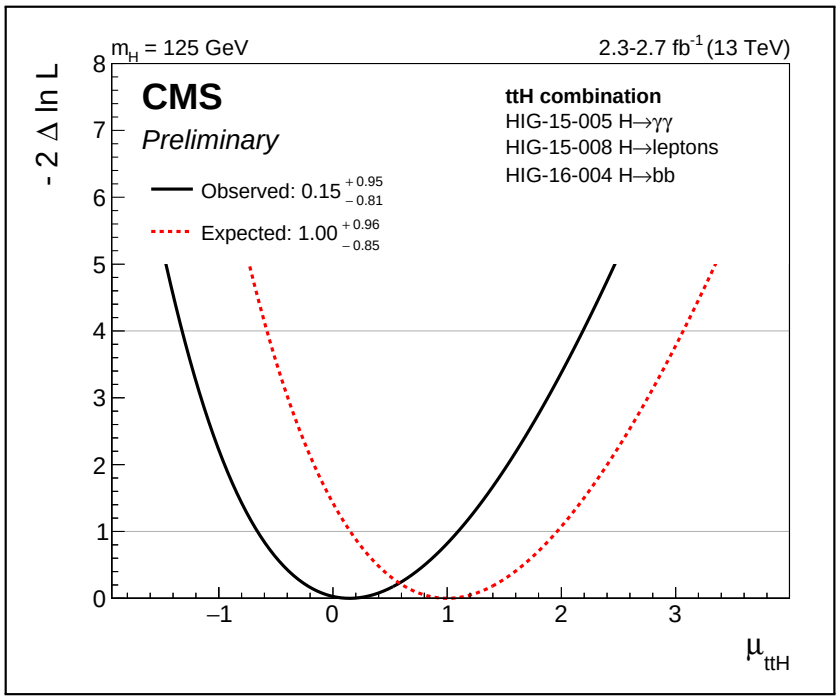


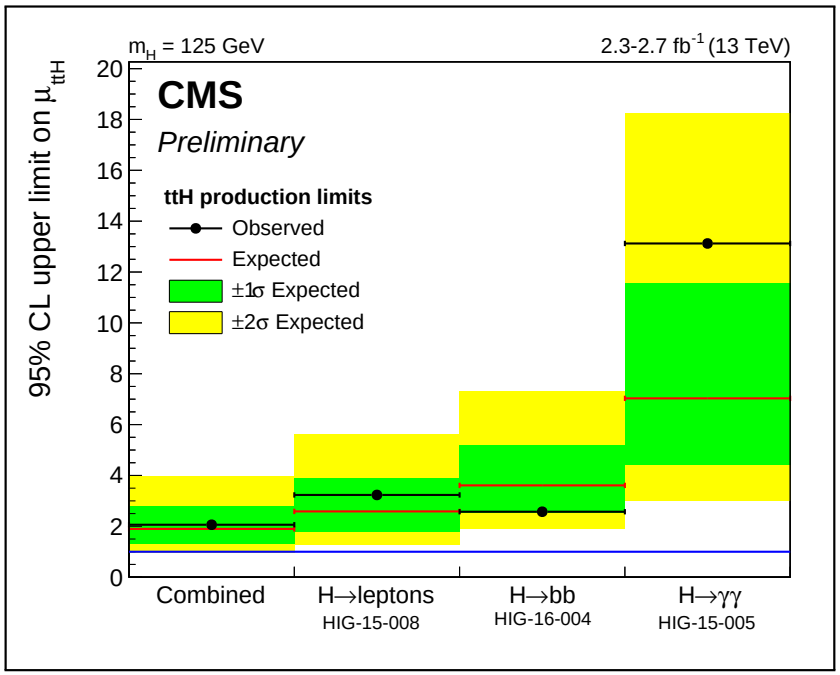




$t\bar{t}H$ (II) - 13 TeV Combination

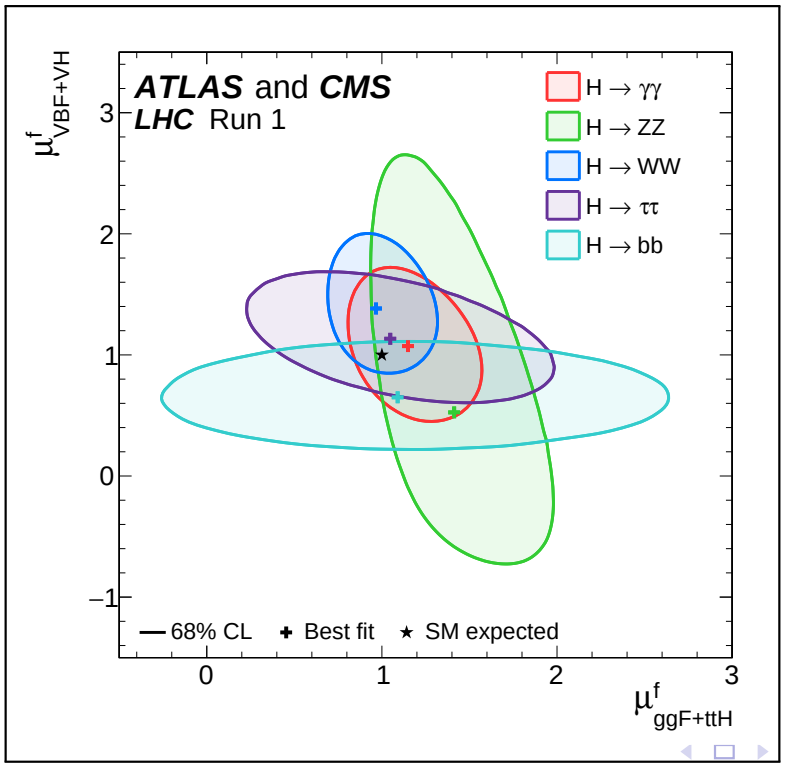
- Combined 13 TeV results more consistent with SM expectation than run-I results
- Need more data to assess conclusions
- High priority analyses in CMS, looking forward the ICHEP results





Event Rates $\longrightarrow$ Coupling Deviations

- $\sigma(xx \to \mathrm{H}) \times BR(\mathrm{H} \to yy) \propto \Gamma_{xx}\Gamma_{yy}/\Gamma_{tot}$
- Parameters: Γ_{WW}, Γ_{ZZ}, Γ_{tt}, $\Gamma_{\tau\tau}$, Γ_{bb}, $\Gamma_{\gamma\gamma}$, Γ_{gg}, Γ_{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): $\kappa_{\mathrm{V}} = \kappa_{\mathrm{W}} = \kappa_{\mathrm{Z}}$, $\kappa_f = \kappa_b = \kappa_{top} = \kappa_\tau$, $\kappa_\gamma = f(\kappa_V, \kappa_f)$
- All tests performed at a given mass, i.e. the measured m_{H} value



Rare Higgs Boson Decays

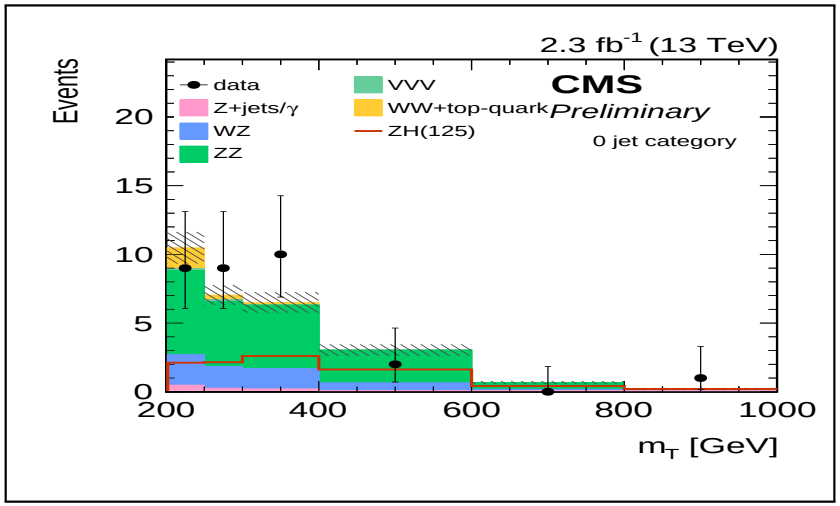
Invisible Higgs Decays (I)

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

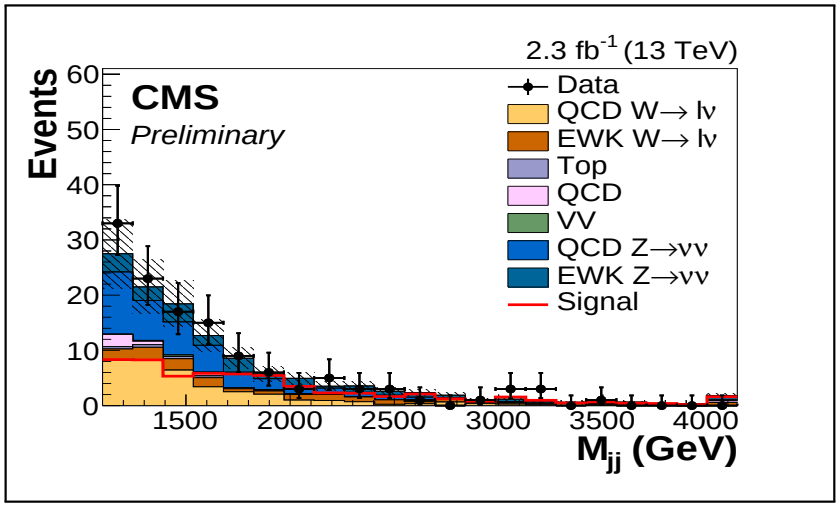
Invisible Higgs Decays (II)

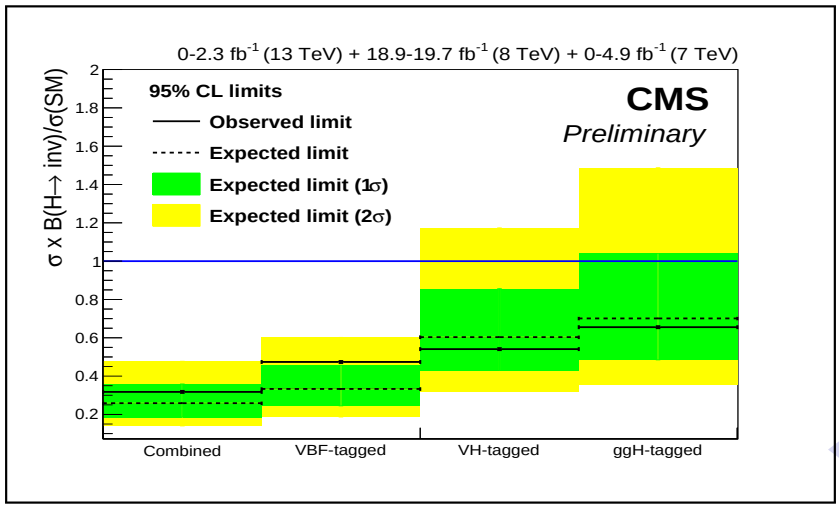
- A large set of analyses coming up
- More complex techniques exploited by having a single fit combining signal and background regions
- For $m_{\mathrm{H}} = 125\ \mathrm{GeV}$ will profit from a larger dataset

$\mathrm{Z}(\ell\ell)\mathrm{H}$



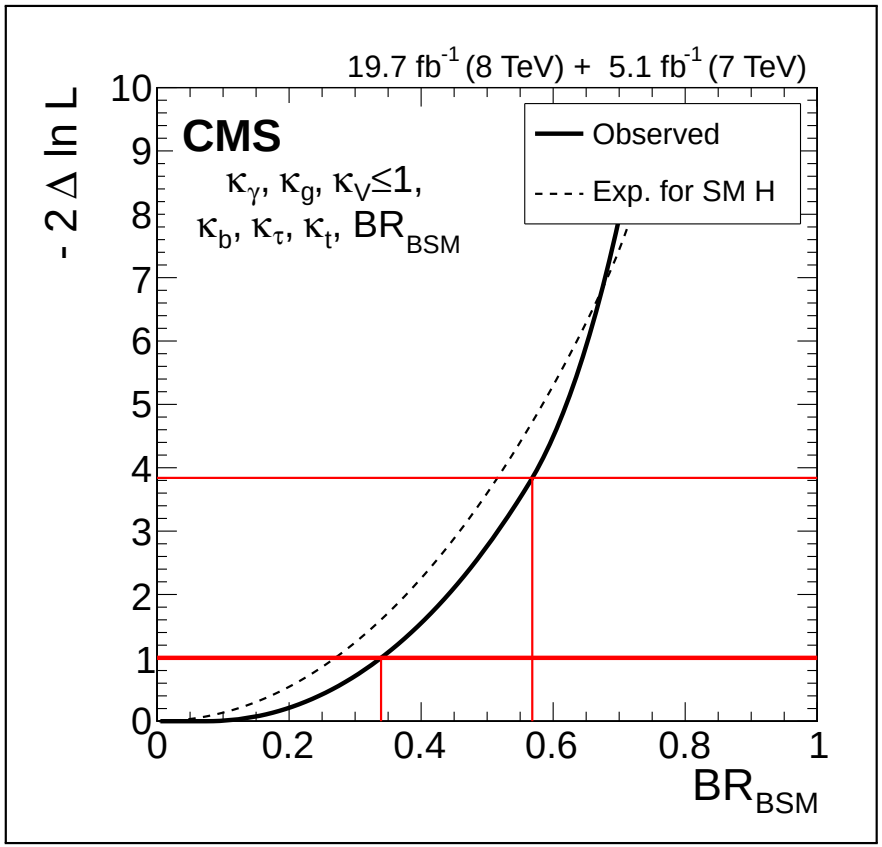
VBF



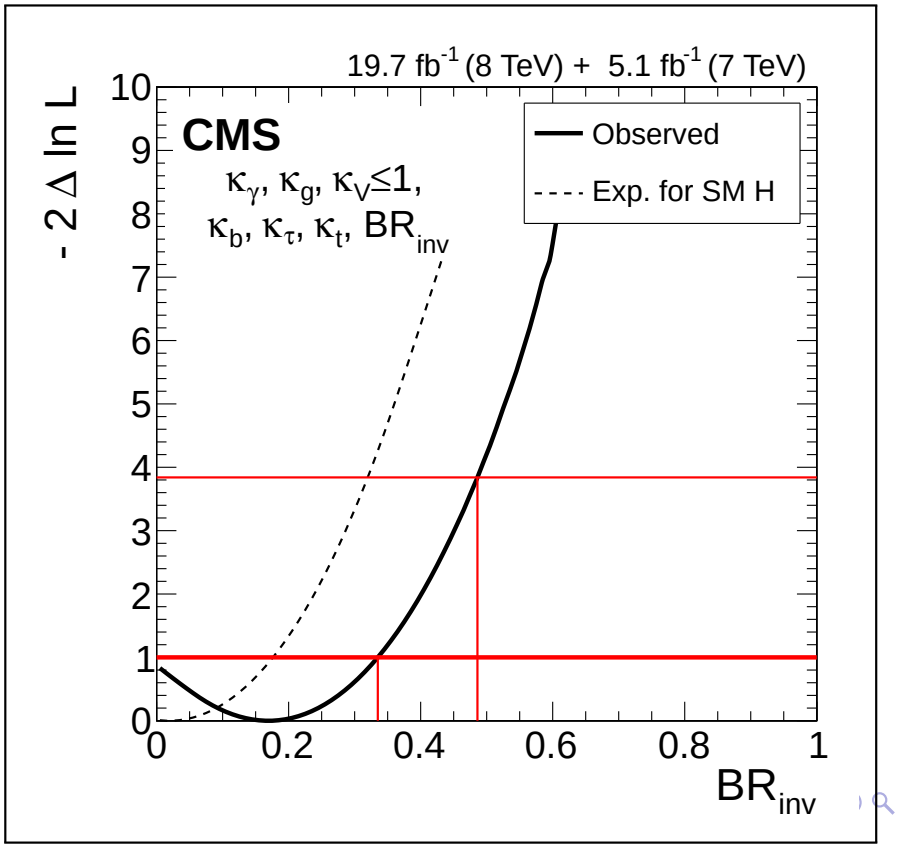


Indirect Limits on Invisible Higgs Decays

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

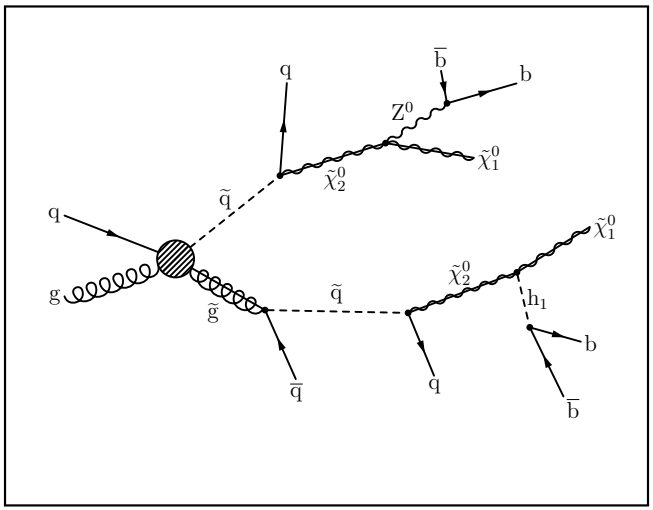


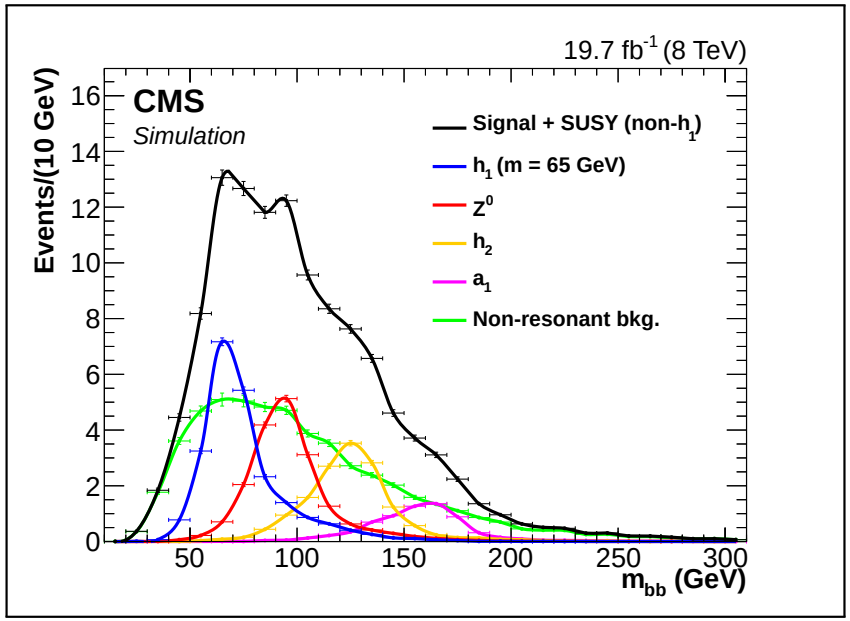
- $BR_{inv} = \Gamma_{inv}/\Gamma_{tot}$
  - Combining with data from the $\mathrm{H} \rightarrow \mathrm{inv}$ searches, thus assuming that $BR_{BSM} = BR_{inv}$, i.e. $BR_{undet} = 0$
  - All κ_i modifiers are profiled
  - $\kappa_V \leq 1$

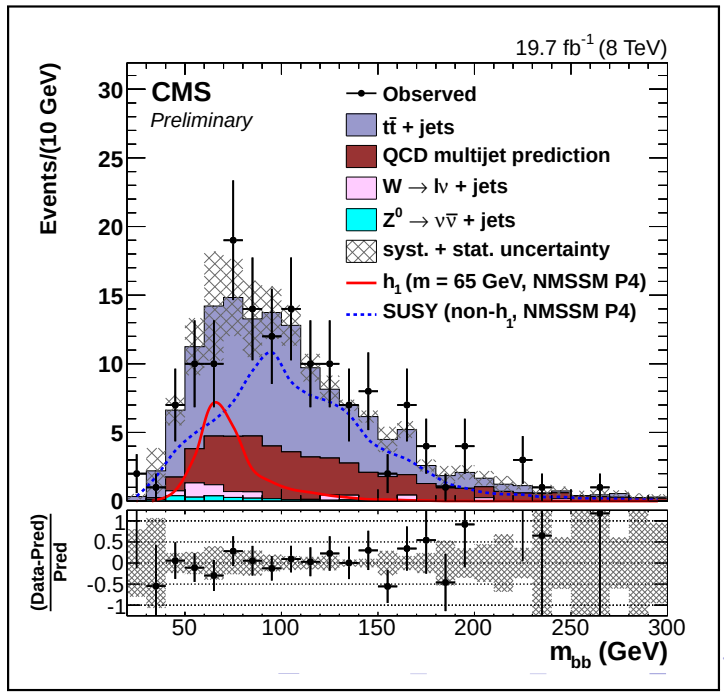


SUSY Cascades Decays - HIG-14-030

- 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

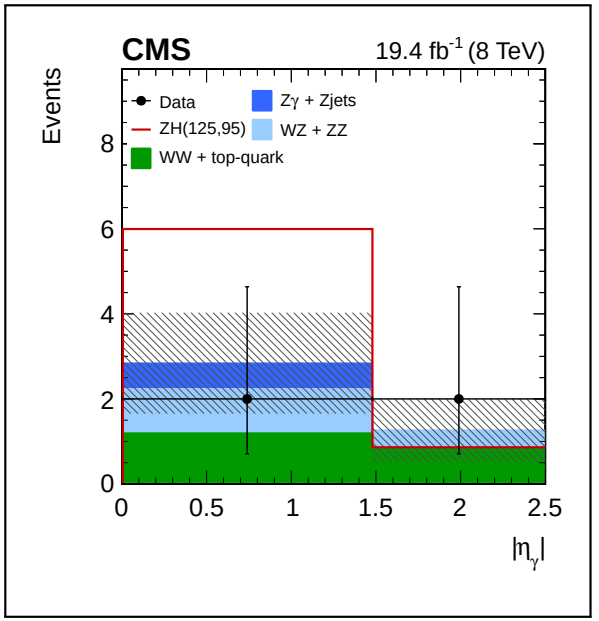


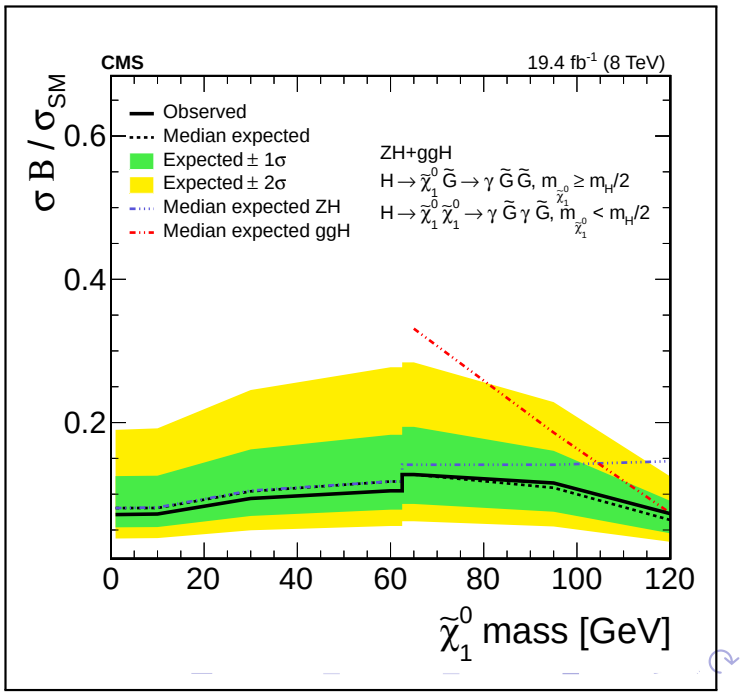


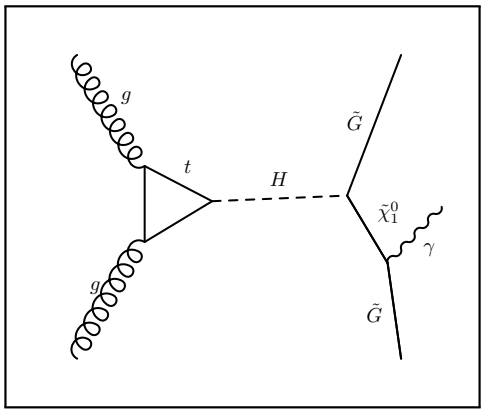


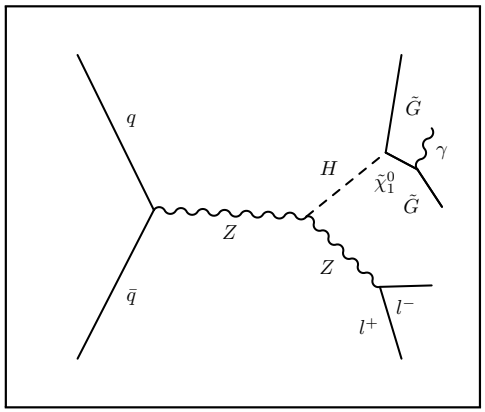
$H \to \gamma E_T^{miss}$ - HIG-14-025

- Search for $H \to \gamma E_T^{miss}$ decays in ggH and ZH modes
  - $\mathcal{B} \equiv \mathcal{B}(H \to \tilde{\chi}_1\tilde{\chi}_1)\,\mathcal{B}(\tilde{\chi}_1 \to \tilde{G} + \gamma)^2$ for $m_{\tilde{\chi}_1} < m_H/2$
  - $\mathcal{B} \equiv \mathcal{B}(H \to \tilde{\chi}_1\tilde{G})\,\mathcal{B}(\tilde{\chi}_1 \to \tilde{G} + \gamma)$ 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





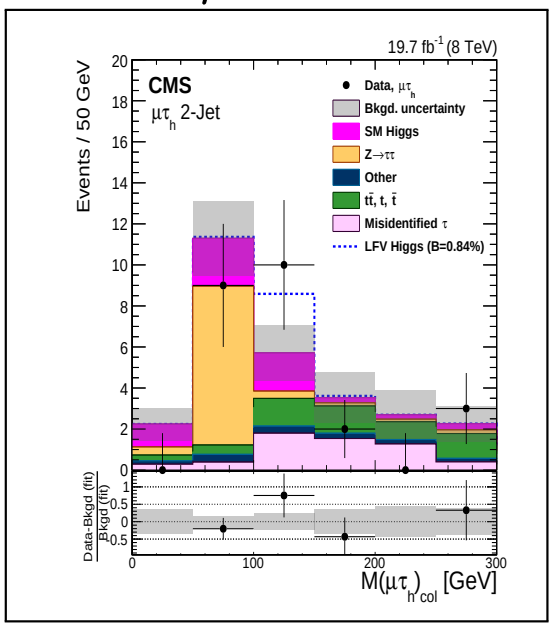




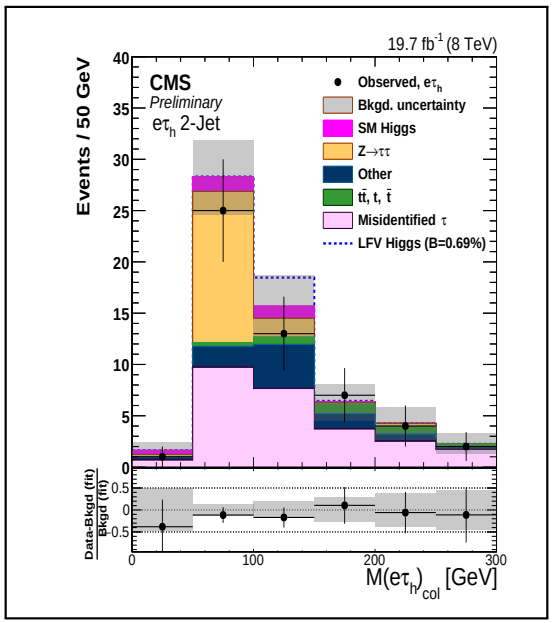
LFV $H \to \mu\tau/e\tau/e\mu$ (I) - HIG-14-005/HIG-14-040/HIG-16-005

- 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 $BR(H \to \mu\tau/e\tau/e\mu)$ can be established
- Interesting upper fluctuation in the $\mu\tau$ final state at 8 TeV

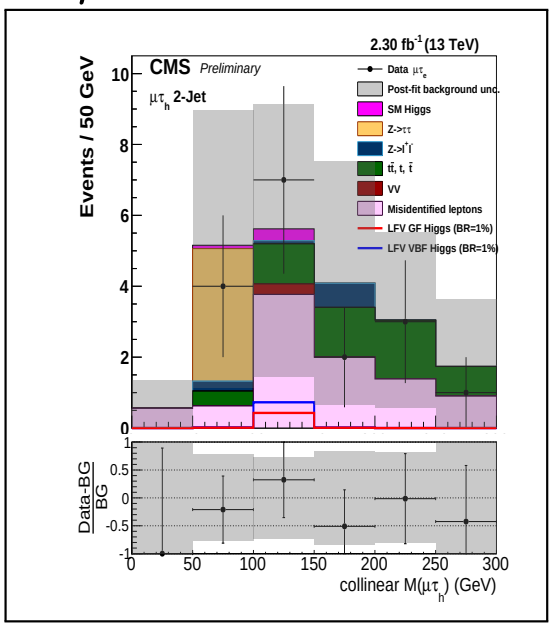
$\mu\tau$ 8 TeV



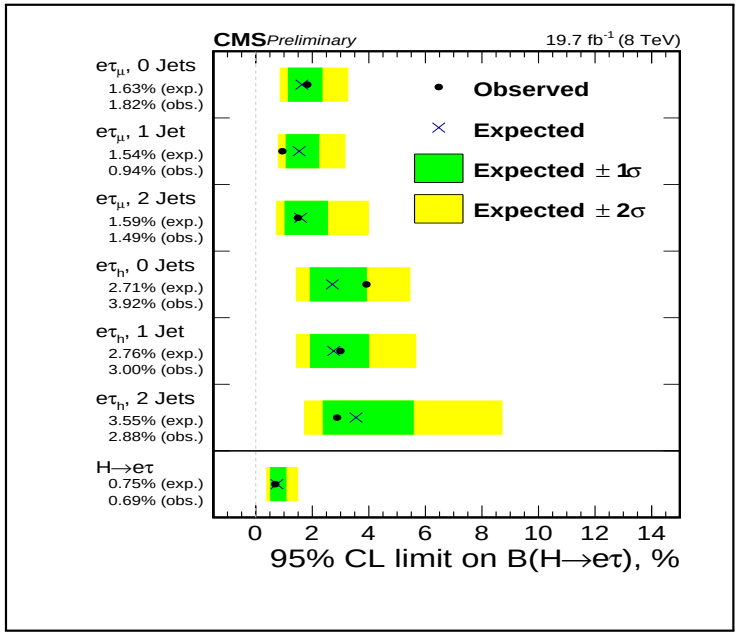
$e\tau$ 8 TeV

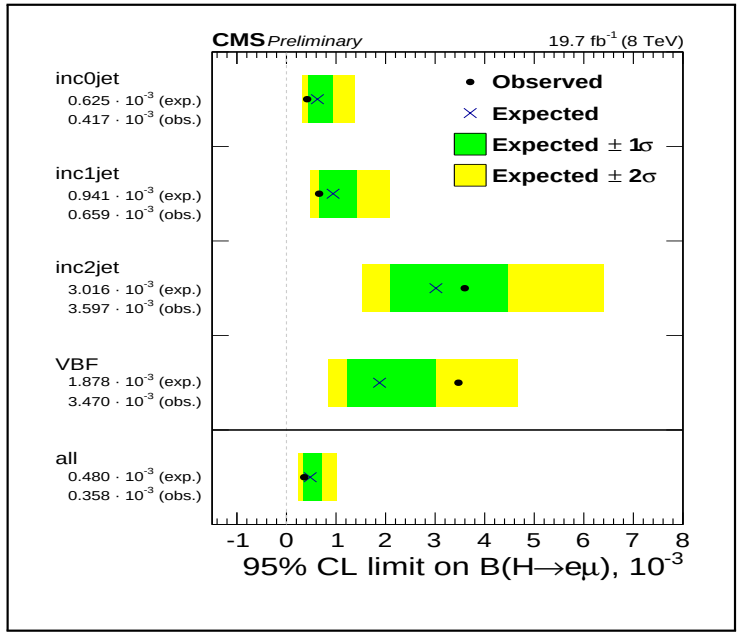


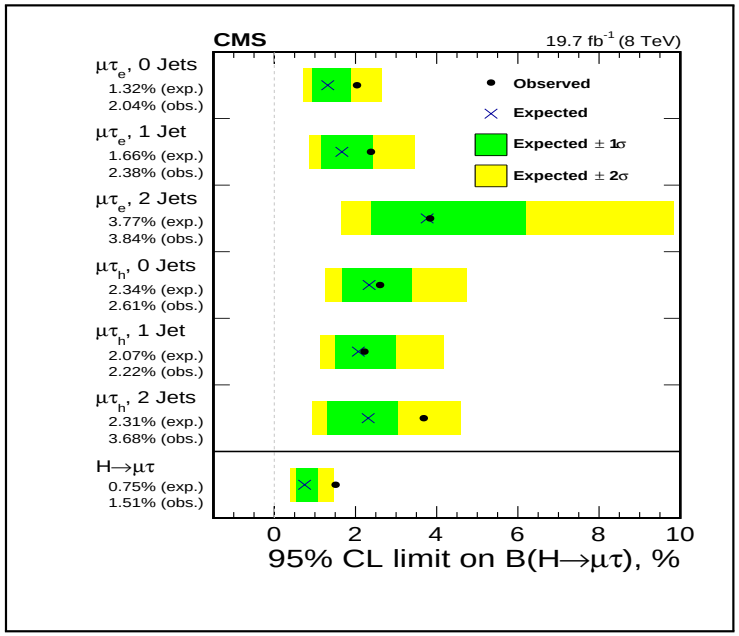
$\mu\tau$ 13 TeV

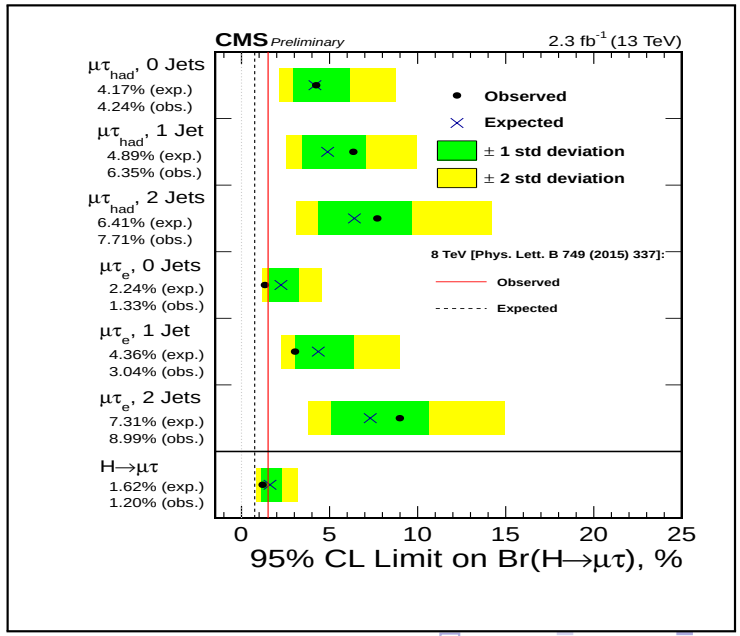


LFV H $\rightarrow \mu\tau/e\tau/e\mu$ (II) - HIG-14-005/HIG-14-040/HIG-16-005





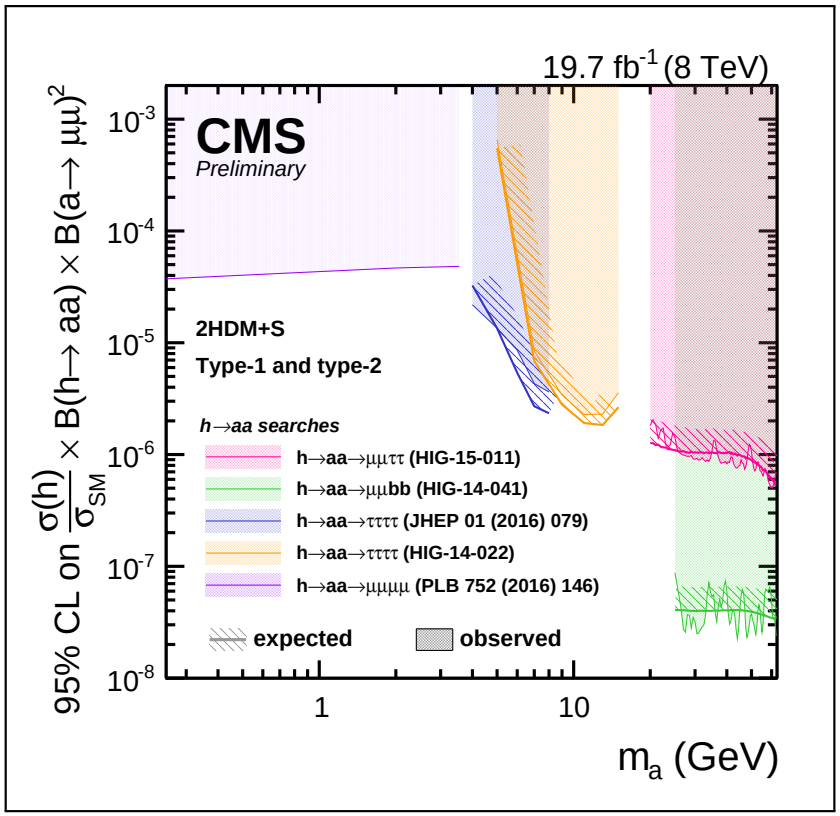


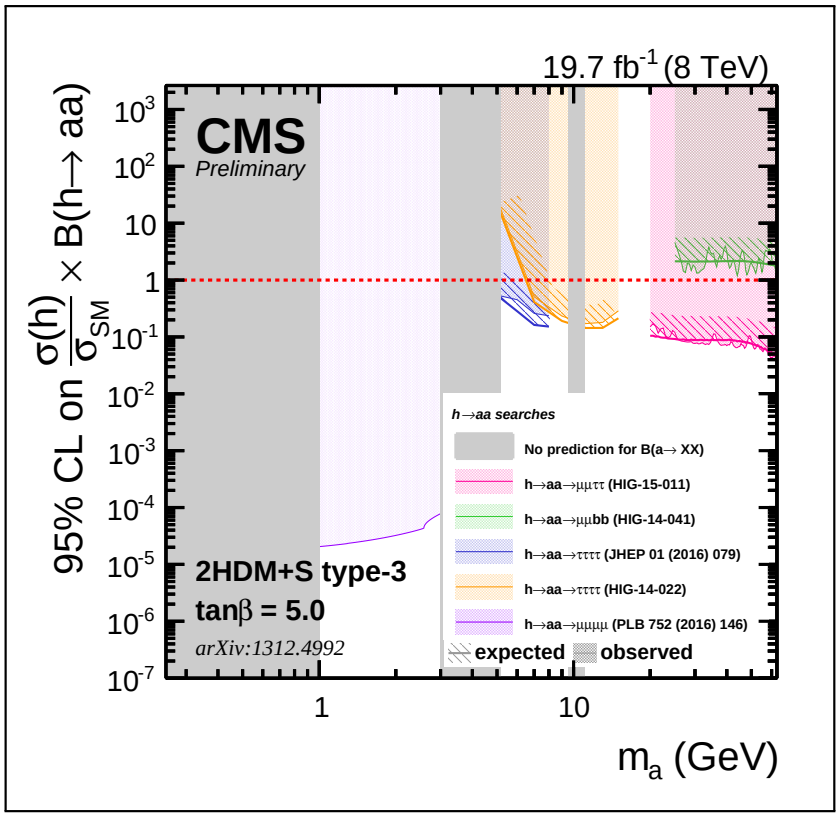


Need more 13 TeV data to take conclusions

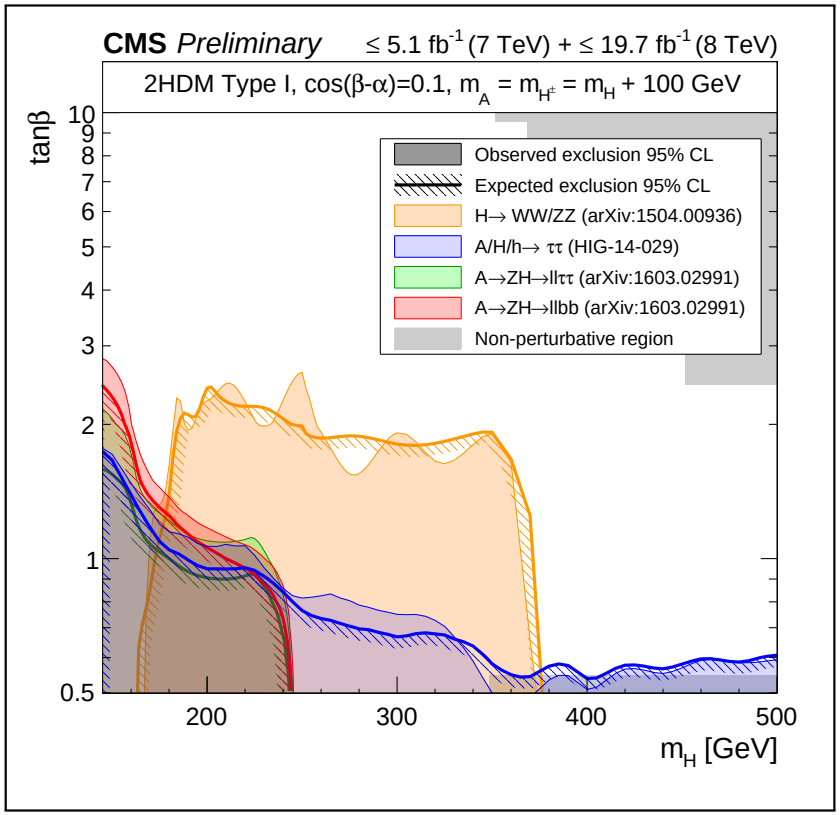
Summary of $H \to a_1 a_1$ Run-I Searches

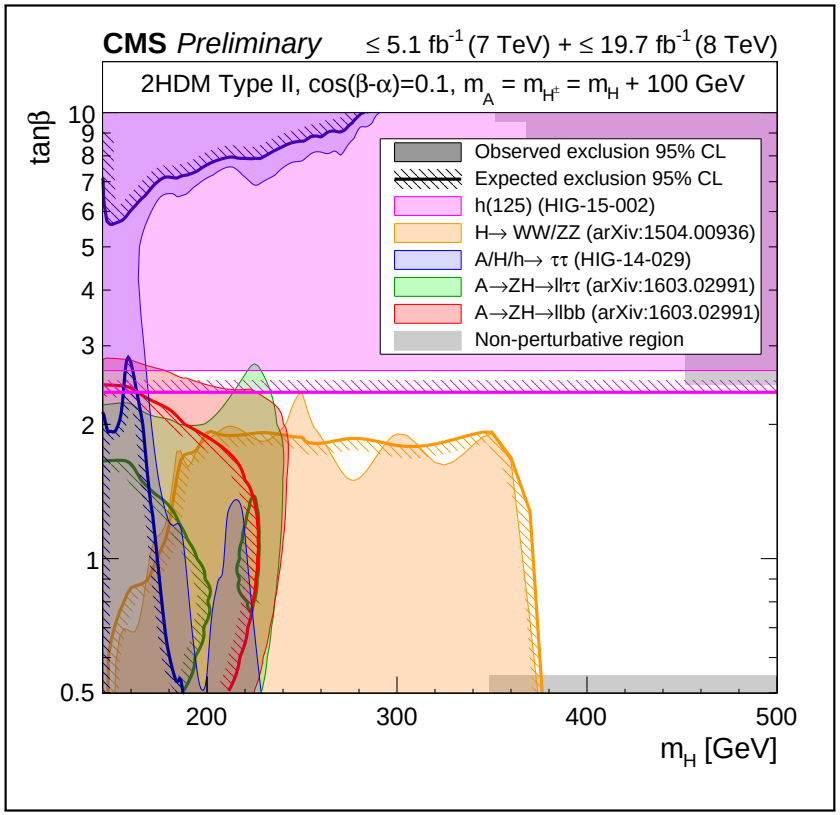
- Summary of several $H \to a_1 a_1$ Run-I searches for several scenarios
- $\sigma_{13\ \mathrm{TeV}}/\sigma_{8\ \mathrm{TeV}} \sim 2.3$
- These analyses more suitable for larger datasets at this point





Summary of BSM Run-I Searches (I)

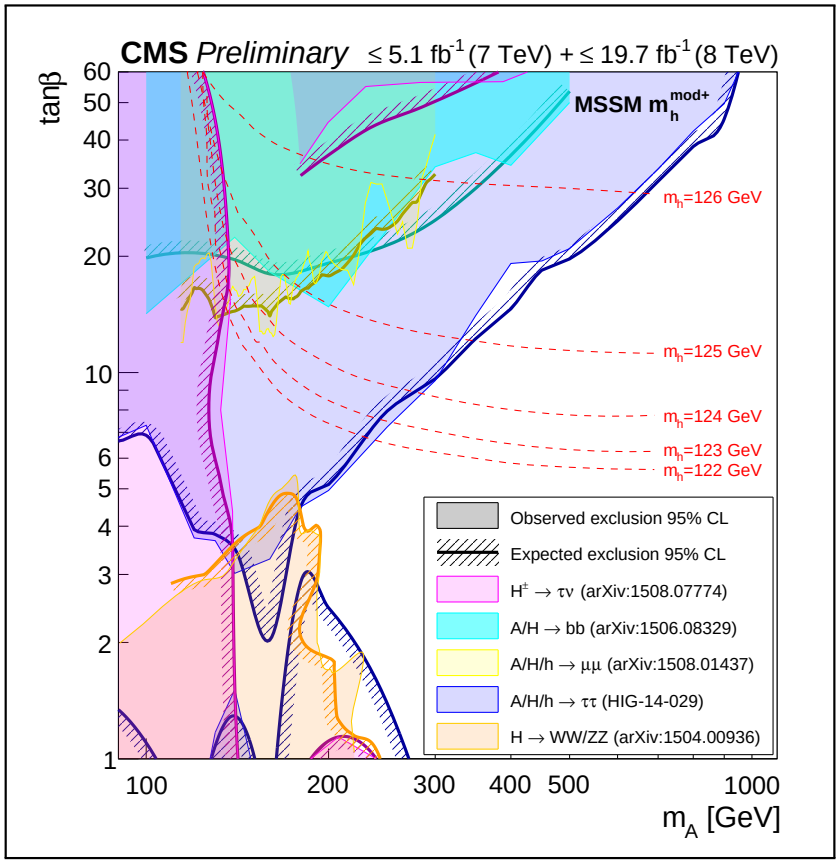


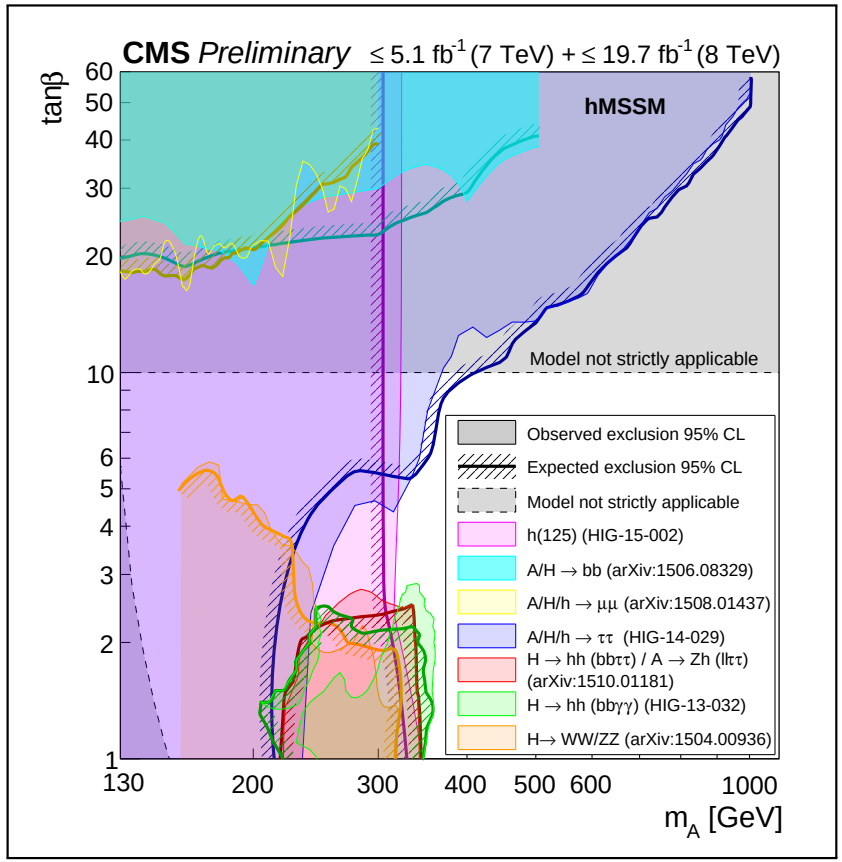


Parameter	Value (type I or type II)
m_h	125.09 GeV
m_A	$m_H + 100$ GeV
m_{H^+}	$m_H + 100$ GeV
$\cos(\beta-\alpha)$	0.1
m_{12}^2	$\max(1-\tan\beta^{-2}, 0) \cdot \frac{1}{2}\sin(2\beta)(m_A^2 + \lambda_5 v^2)$
	m_H and $\tan\beta$ scanned.

	2HDM		hMSSM
	type I	type II/MSSM	
κ_V	$\sin(\beta-\alpha)$	$\sin(\beta-\alpha)$	$\frac{s_d + s_u \tan\beta}{\sqrt{1+\tan^2\beta}}$
κ_u	$\cos(\alpha)/\sin(\beta)$	$\cos(\alpha)/\sin(\beta)$	$s_u \frac{\sqrt{1+\tan^2\beta}}{\tan\beta}$
κ_d	$\cos(\alpha)/\sin(\beta)$	$-\sin(\alpha)/\cos(\beta)$	$s_d\sqrt{1+\tan^2\beta}$

Summary of BSM Run-I Searches (II)





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	2HDM		hMSSM
	type I	type II/MSSM	
κ_V	$\sin(\beta-\alpha)$	$\sin(\beta-\alpha)$	$\frac{s_d + s_u \tan\beta}{\sqrt{1+\tan^2\beta}}$
κ_u	$\cos(\alpha)/\sin(\beta)$	$\cos(\alpha)/\sin(\beta)$	$s_u \frac{\sqrt{1+\tan^2\beta}}{\tan\beta}$
κ_d	$\cos(\alpha)/\sin(\beta)$	$-\sin(\alpha)/\cos(\beta)$	$s_d\sqrt{1+\tan^2\beta}$

Other Possible Rare Decays

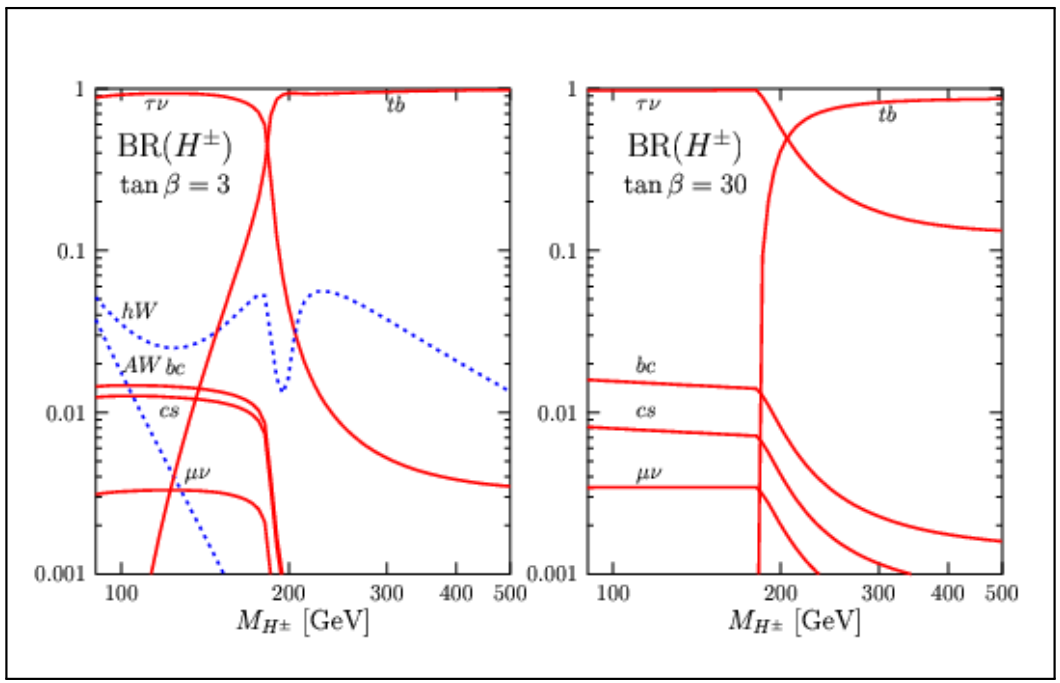
A summary can be found in e.g. arXiv1312.4992

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

Charged Higgs Bosons

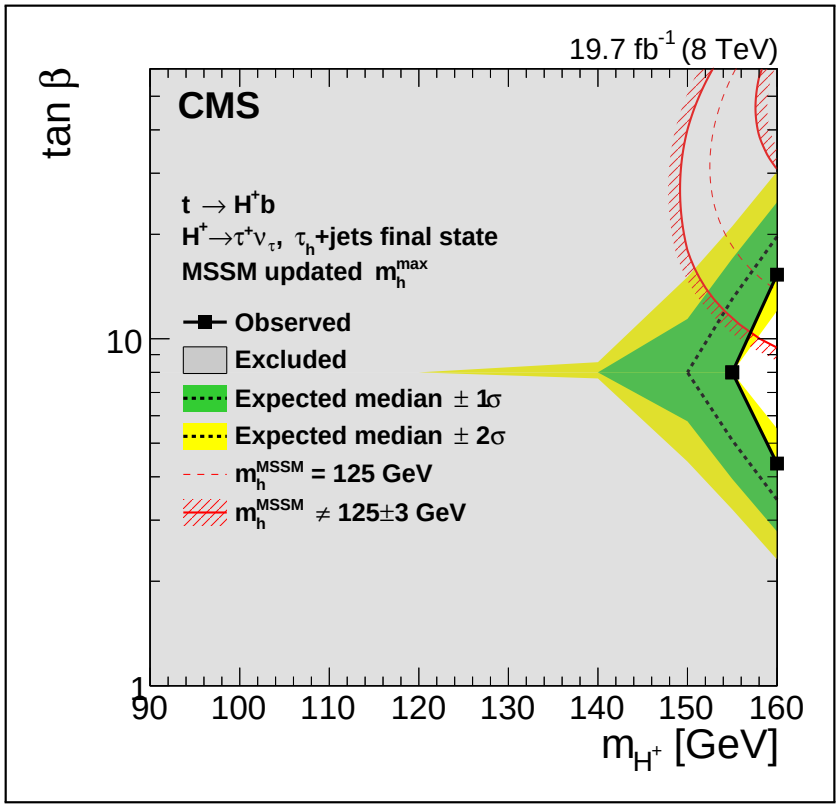
Search for Charged Higgs Bosons (I) - HIG-14-023/HIG-13-035

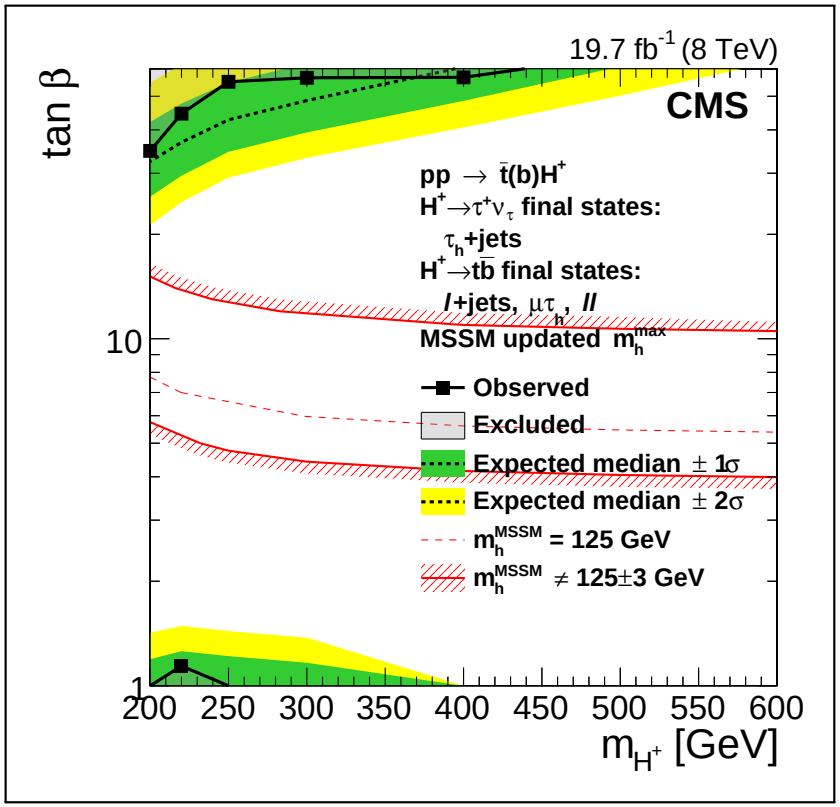
- Predicted in several new Physics scenarios
- For $m_{\mathrm{H}^\pm} < m_{top}$, search for $top \to \mathrm{H}^\pm b$ decays
- For $m_{\mathrm{H}^\pm} > m_{top}$, mostly search for $t\mathrm{H}^\pm(b)$ decays
- $\mathrm{H} \to \tau\nu$ dominates a large phase space, but several other decay modes possible
- 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

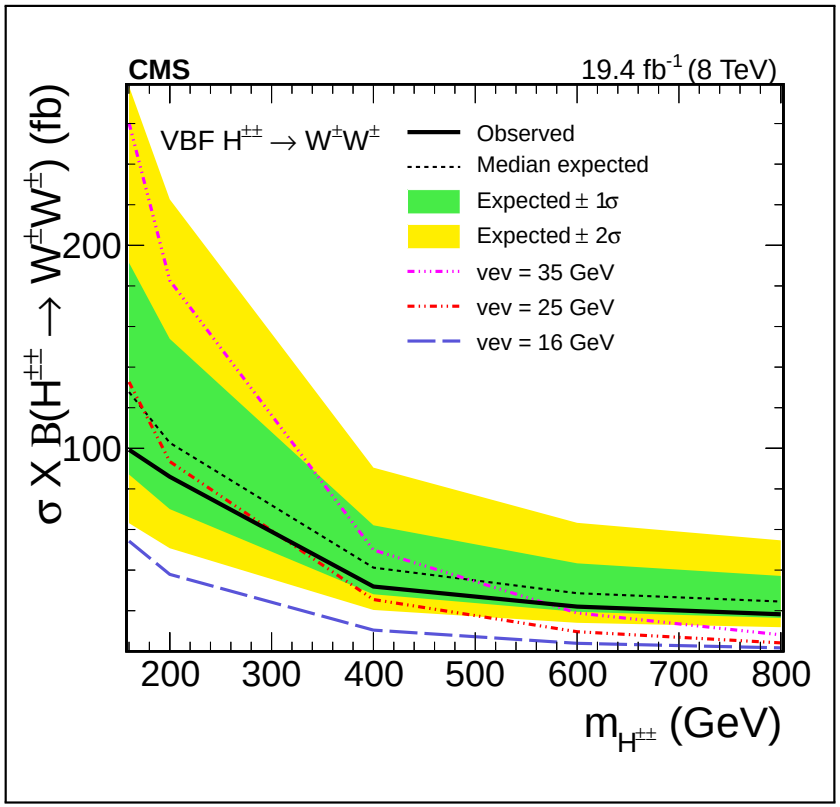


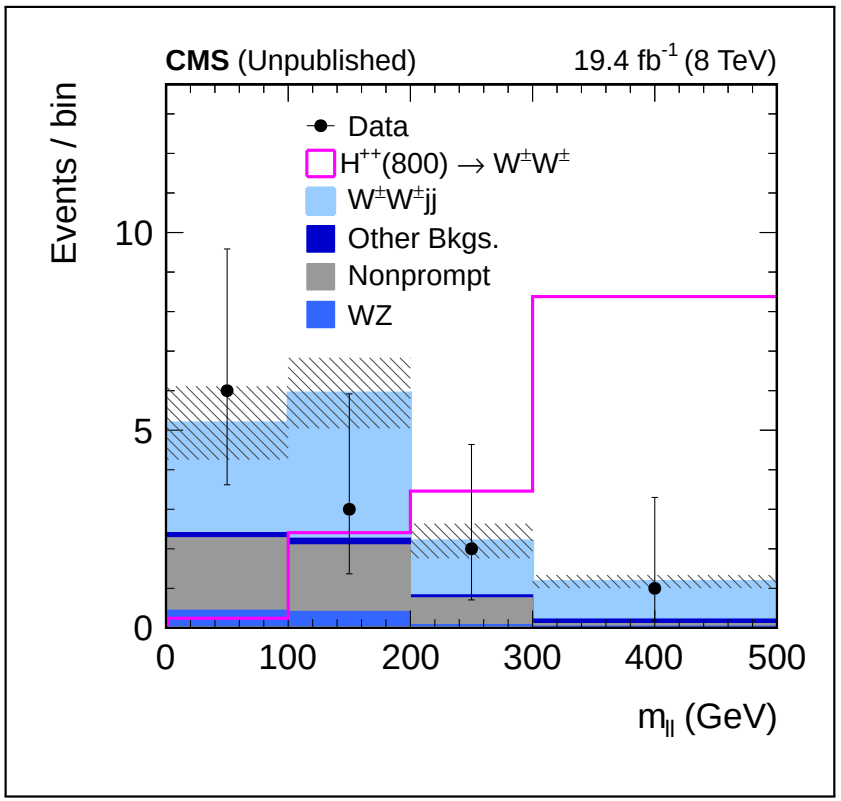


Doubly Charged Higgs Bosons

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

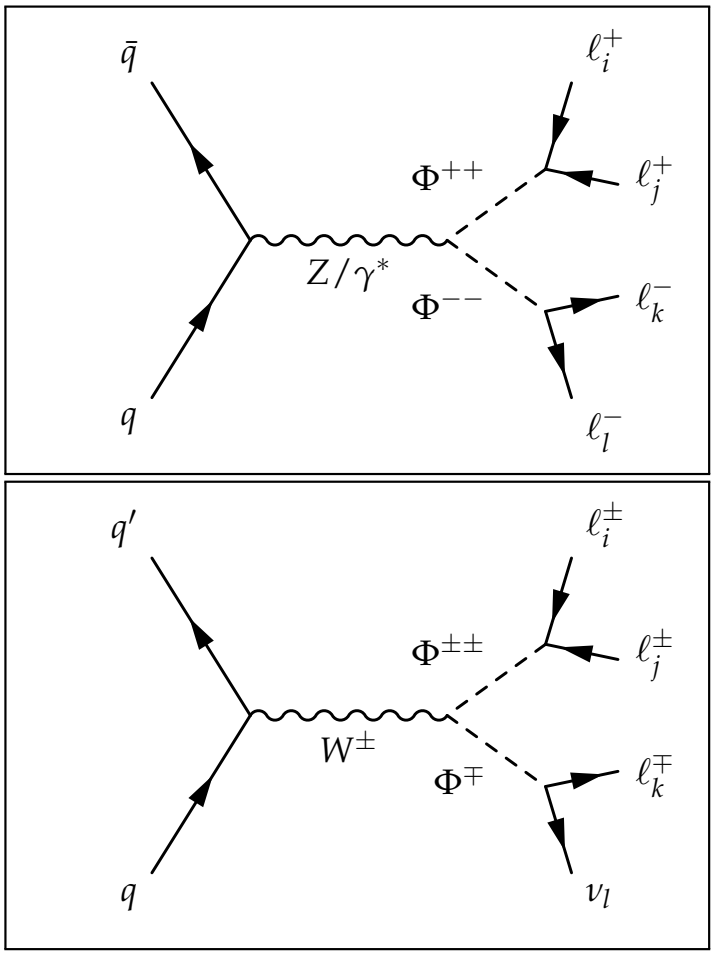
- $H^{\pm\pm} \to W^{\pm}W^{\pm} \to \ell^{\pm}\ell^{\pm}2\nu$ (vector boson scattering topology)
- Predictions from Georgi-Machack Higgs Triplet Models
- Spin-off of vector boson scattering measurement
- Large benefit from a larger dataset and increase on $\sqrt{s}$

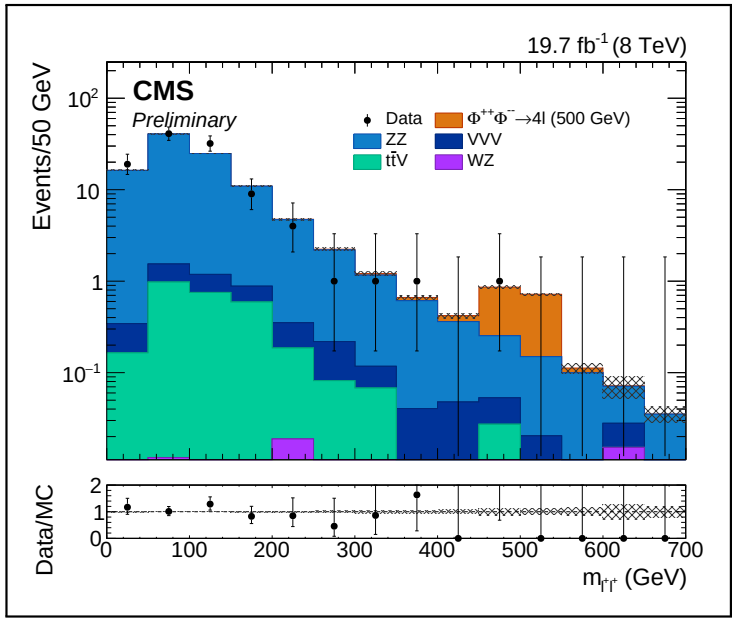


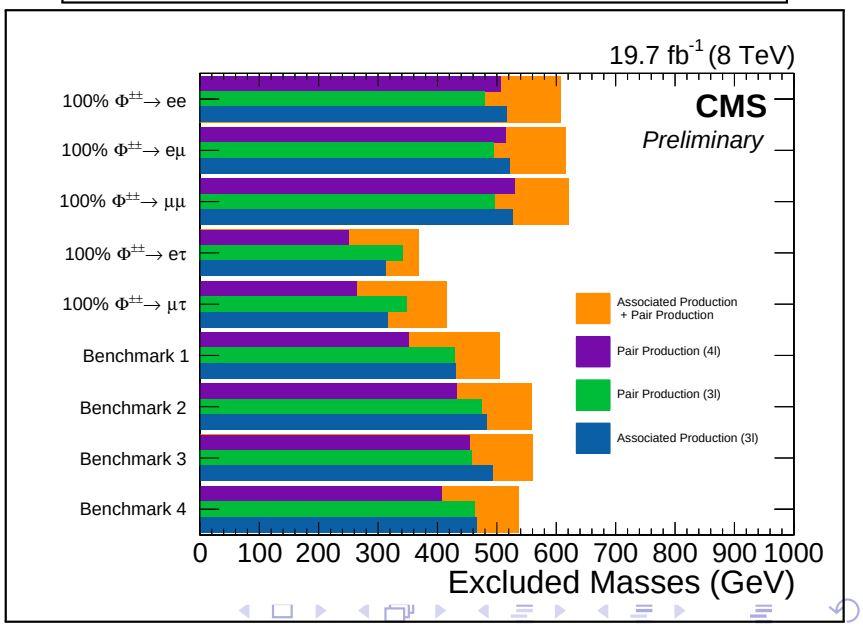


$H^{\pm\pm} \to 4\ell$ - HIG-14-039

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





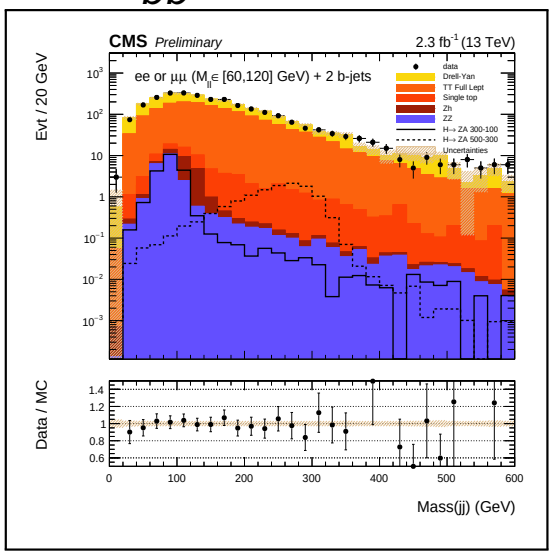


Higgs to Higgs Decays

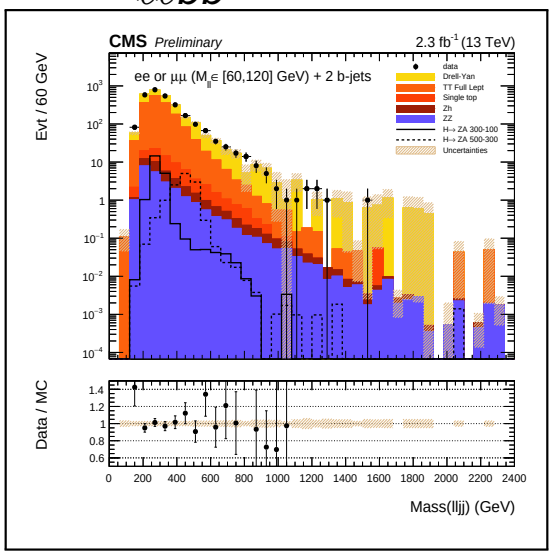
Search for $A/H \to ZH/A$ Decays - HIG-15-001/HIG-16-010

- Search for $A/H \to ZH/A \to \ell\ell bb$ decays, $H/A \to \tau\tau$ 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 $\sigma x BR$ for m_H hypotheses as function of m_A

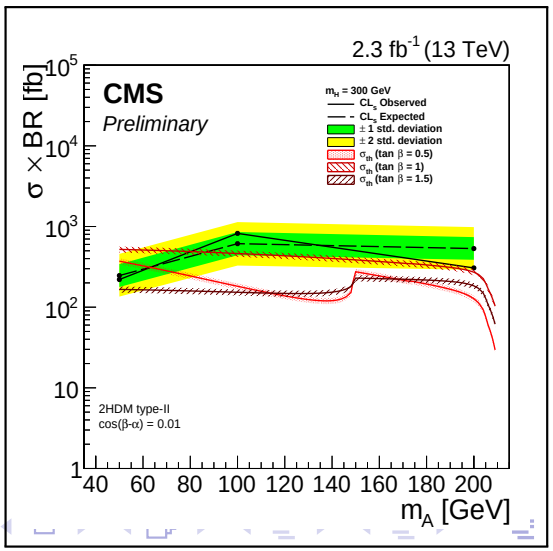
m_{bb}



$m_{\ell\ell bb}$



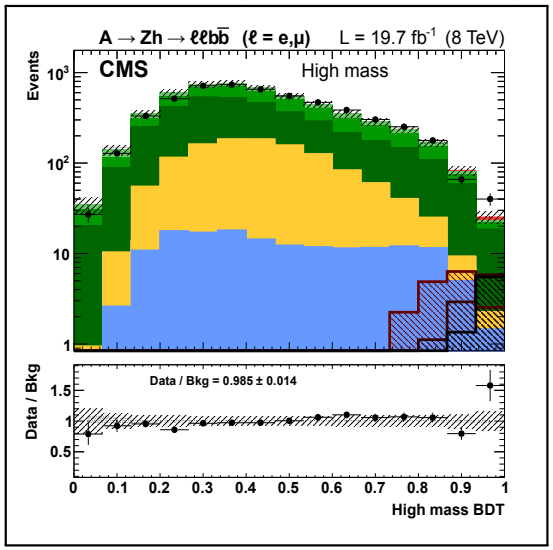
95% CL limits

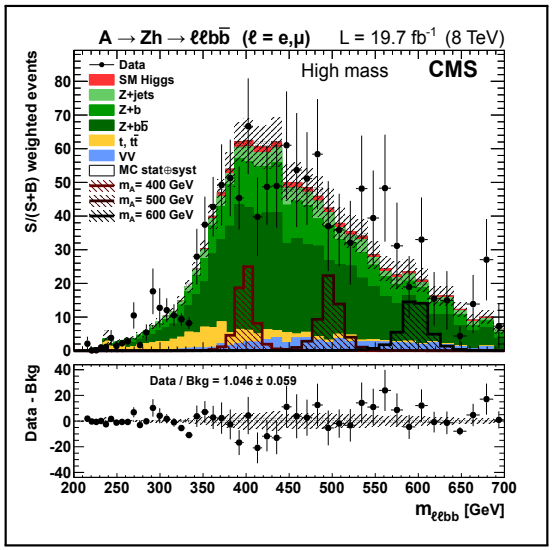


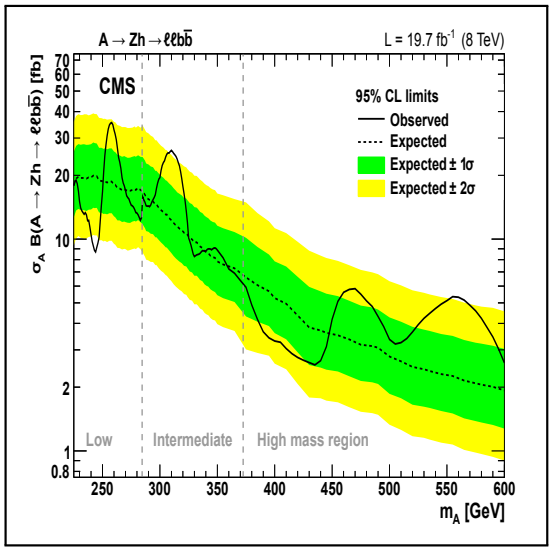
Search for $A \to Zh(125)$ Decays - HIG-14-011

- Search for $A \to Zh(125) \to \ell\ell bb$ 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. $m_{\ell\ell bb}$ to discriminate signal and backgrounds

BDT high mass region $m_{\ell\ell bb}$ at high BDT 95% CL limits



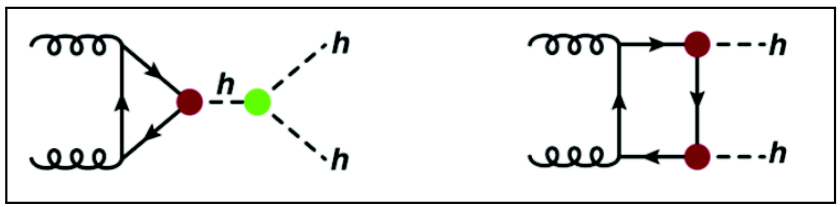




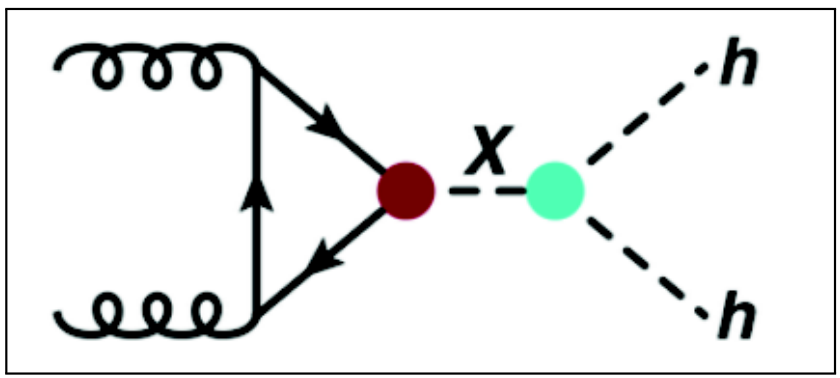
Double Higgs Boson Production

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

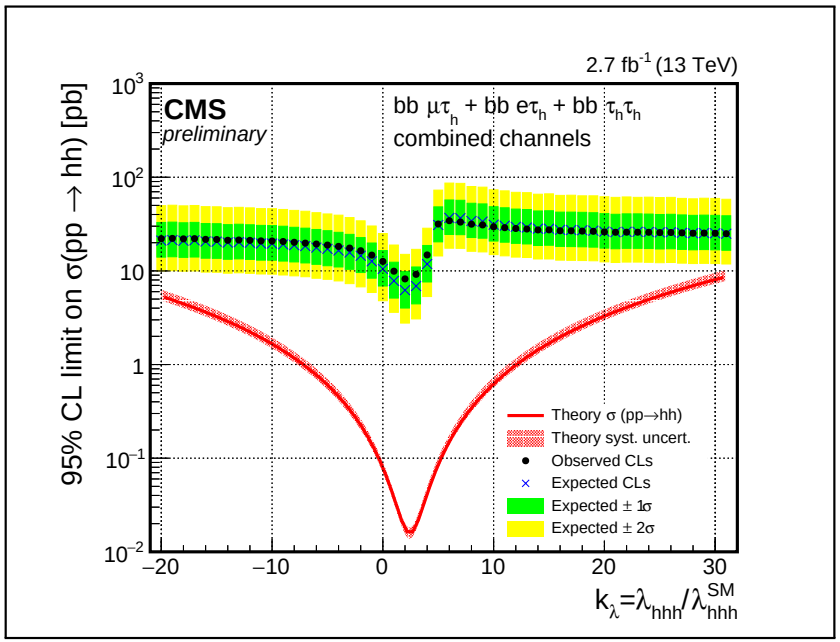


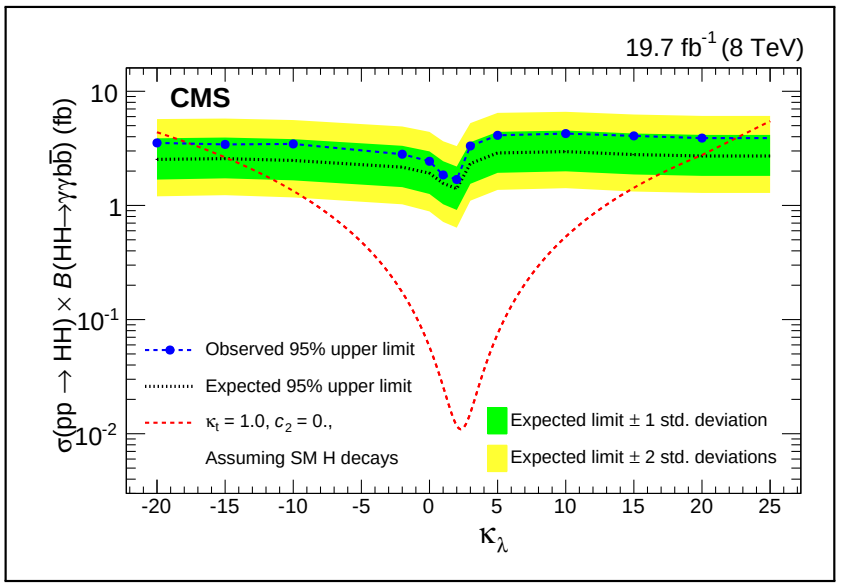
- Resonant production
  - enhance production cross section



Search for Non-Resonant HH Decays - HIG-13-032/HIG-15-013/HIG-16-012

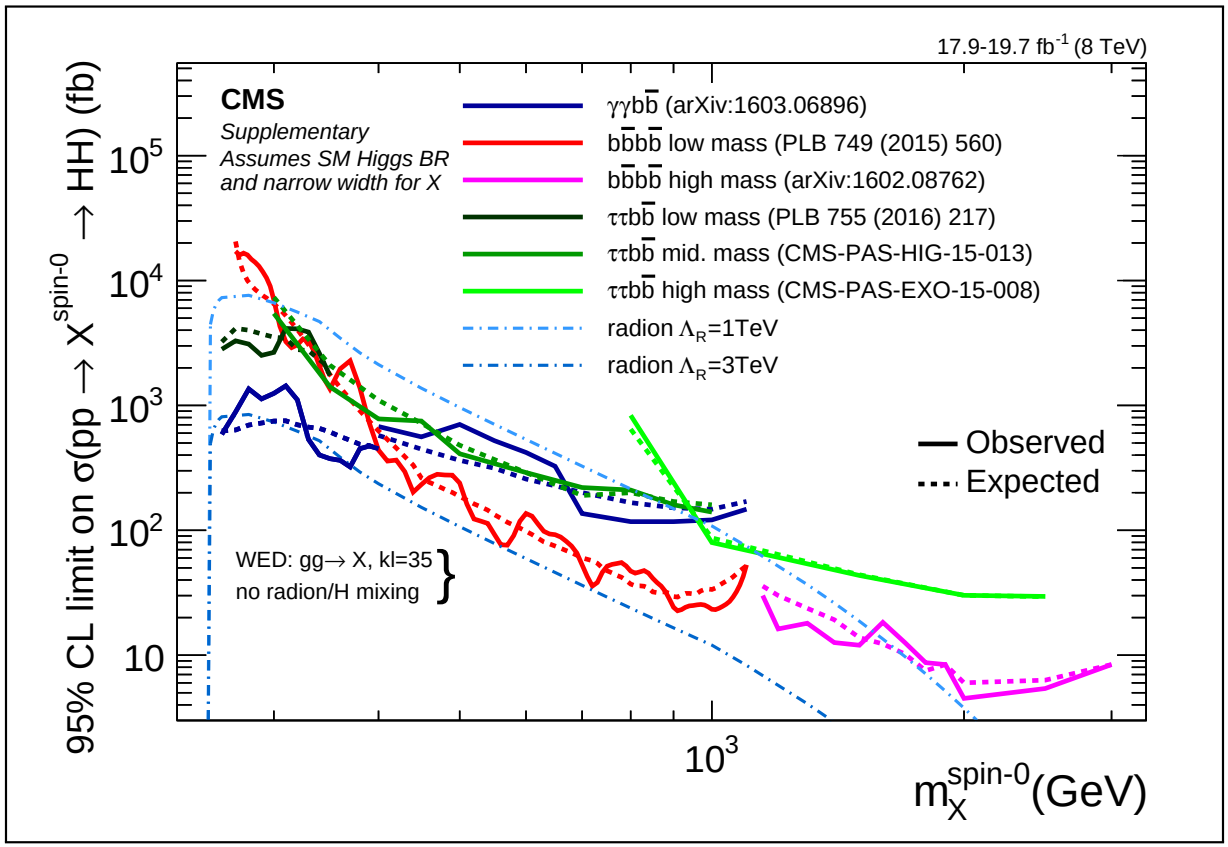
- Analyses getting mature, but a long way to get SM reach
- One of the high priority LHC analyses in the long term
- Room for improvements and new channels to be added





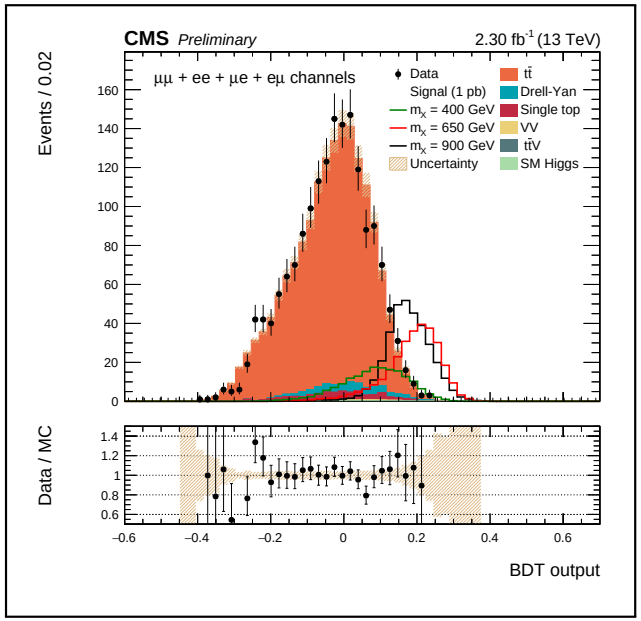
Search for Resonant $X \rightarrow HH$ Decays - HIG-16-002/HIG-16-011/HIG-16-013/...

- 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

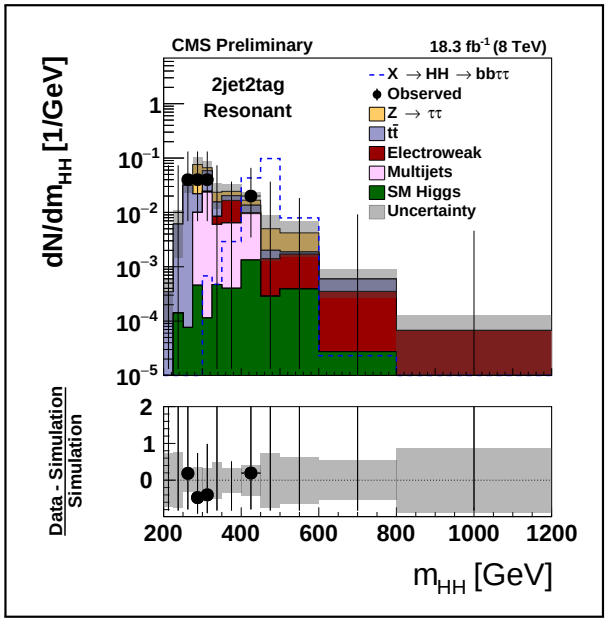


$X \rightarrow HH$ Analyses at 13 TeV - HIG-16-002/HIG-16-011/HIG-16-013

$bbWW$



$bb\tau\tau$



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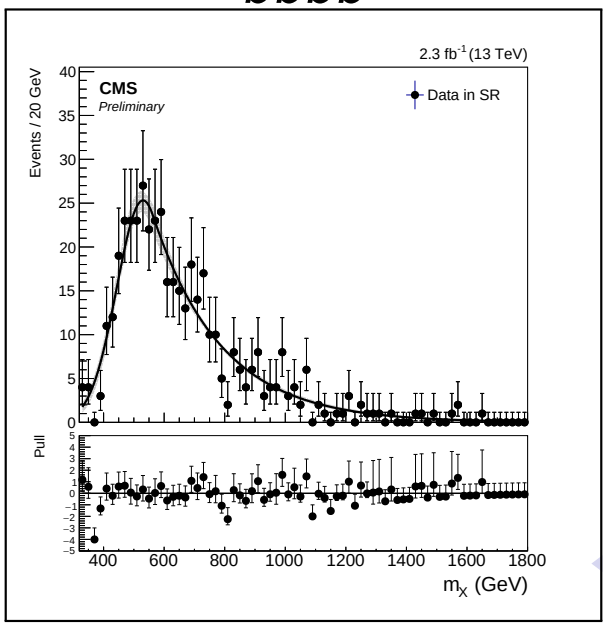

Summary

- The $\mathrm{H}(125)$ 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 $\sqrt{s} = 13\ \mathrm{TeV}$
- 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 $\Phi = \mathrm{h}$ & H; CP-odd A
    - 2 charged: $\mathrm{H}^{\pm}$
  - SM-like Higgs boson: h
- Neutral Higgs "Φ" decay modes:
  - $BR(\Phi \to b\bar{b}) \sim 90\%$
  - $BR(\Phi \to \tau\tau) \sim 10\%$
  - $BR(\Phi \to \mu\mu) \sim 0.1\%$
- Two main production modes:
  - $gg \to \mathrm{H}$
  - $b\bar{b}\mathrm{H}$
- 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 $\Phi \to \mu\mu$ case here, other analyses in Susan Gascon-Shotkin's talk