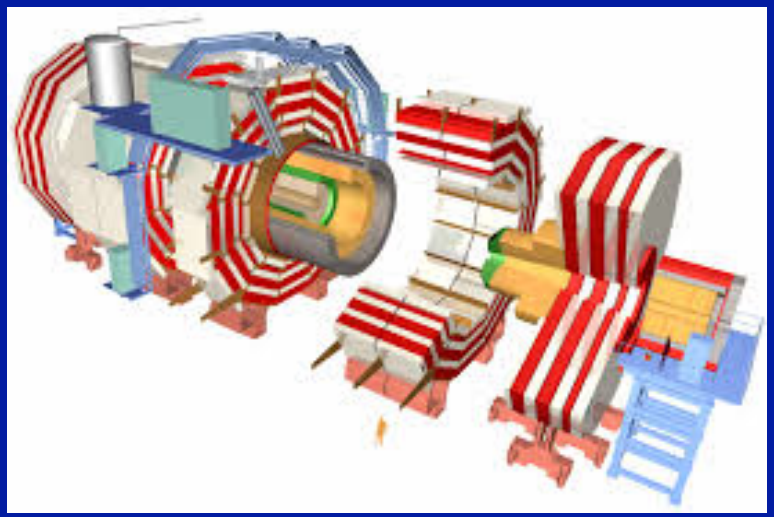
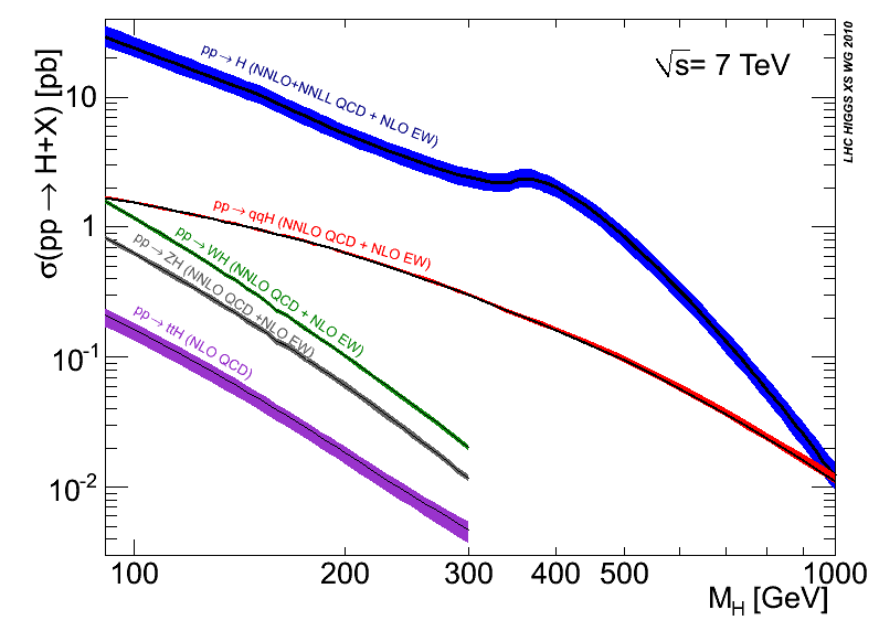
HIGGS RESULTS FROM CMS

Alexander A. Savin
University of Wisconsin-Madison, USA
for CMS Collaboration



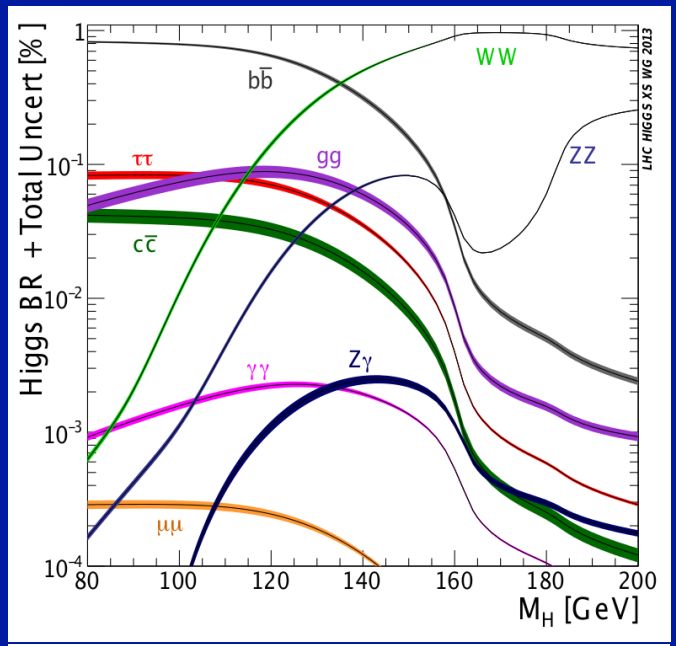
LC2013: ECFA Linear Collider Workshop 2013, 27-31 May 2013, DESY

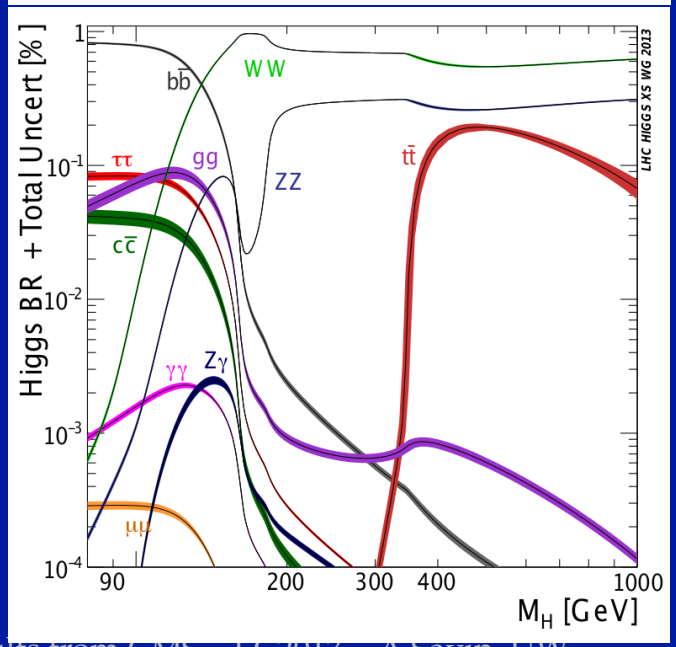
Introduction



SM Higgs production cross section

SM Higgs branching fractions





CMS currently is searching for the SM Higgs signal in the mass region 100 – 1000 GeV.
Sensitivity in each channel depends on the cross section and branching fraction, but what is even more important – on background contributions, which define how effective can we keep our selection requirements

CMS uses Particle Flow reconstruction !

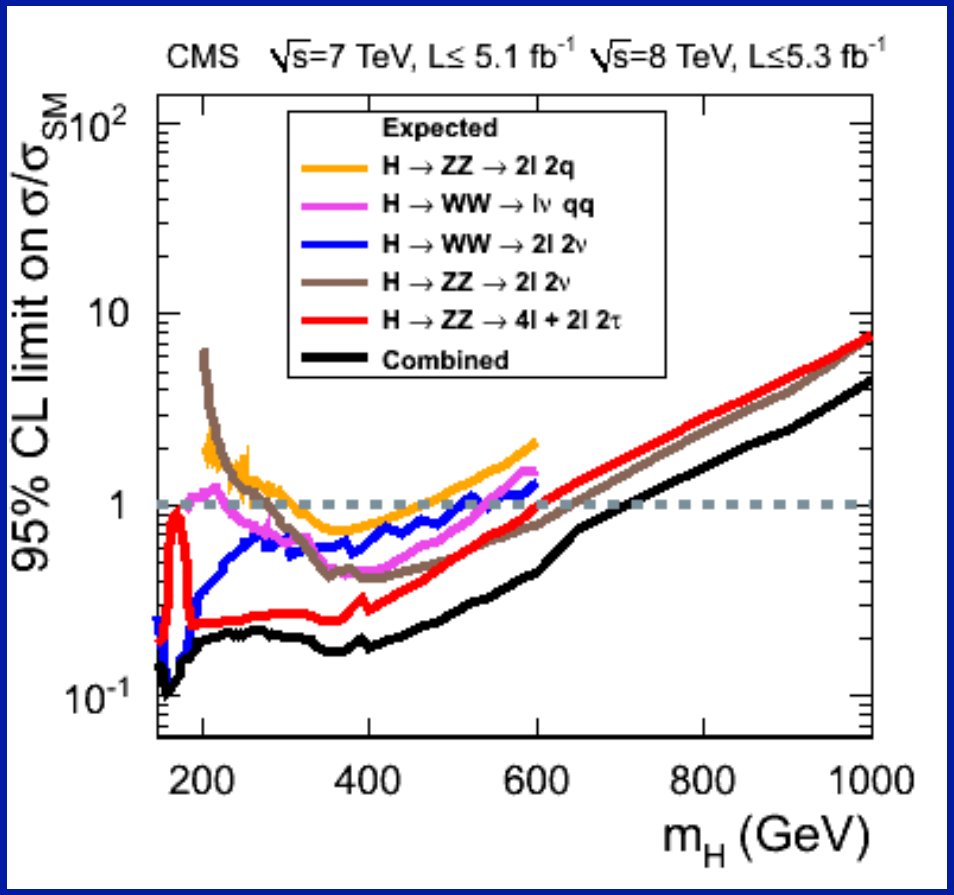
Main results

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsHIG

Date	Channel	PAS/PAPER	Mass range	Exp.Lm
May 2013 – 8 TeV	$VBF, H \to bb$	HIG-13-011	115 – 133 GeV	~3
May 2013 – 8 TeV	$ttH, H \to \gamma\gamma$	HIG-13-015	110 – 150 GeV	~10
May 2013 7+8 TeV	$VH, H \to bb$	HIG-13-012	110 – 135 GeV	~ 2
May 2013 8 TeV	$H \to WW \to l\upsilon j$	HIG-13-008	200 – 600 GeV	~2.5
May-2013 7+8 TeV	$H \to ZZ \to 2l2\upsilon$	HIG-13-014	200 -1000 GeV	~3-4
April-2013	*Combination*	HIG-13-005	120 – 130 GeV	
Mar-2013 7+8 TeV	$H \to \gamma\gamma$	HIG-13-001	110 – 150 GeV	0.5
Mar-2013 7+8 TeV	$H \to ZZ \to 4l$	HIG-13-002	110 – 1000 GeV	0.2
Mar-2013 7+8 TeV	$H \to WW \to 2l2\upsilon$	HIG-13-003	110 – 600 GeV	0. 3
Mar-2013 7+8 TeV	$H \to \tau\tau$	HIG-13-004	110 – 150 GeV	0.7
Mar-2013 7+8 TeV	$H \to Z\gamma$	HIG-13-006	110 – 180 GeV	10
Mar-2013 7+8 TeV	$H \to WWW \to 3l3\upsilon$	HIG-13-009	110 – 200 GeV	~ 3
Mar-2013 7+8 TeV	$VH \to \tau\tau$	HIG-12-053	110 - 145 GeV	4
Mar-2013	High mass WW/ZZ	arXiv:1304.0213	145 – 1000 GeV	

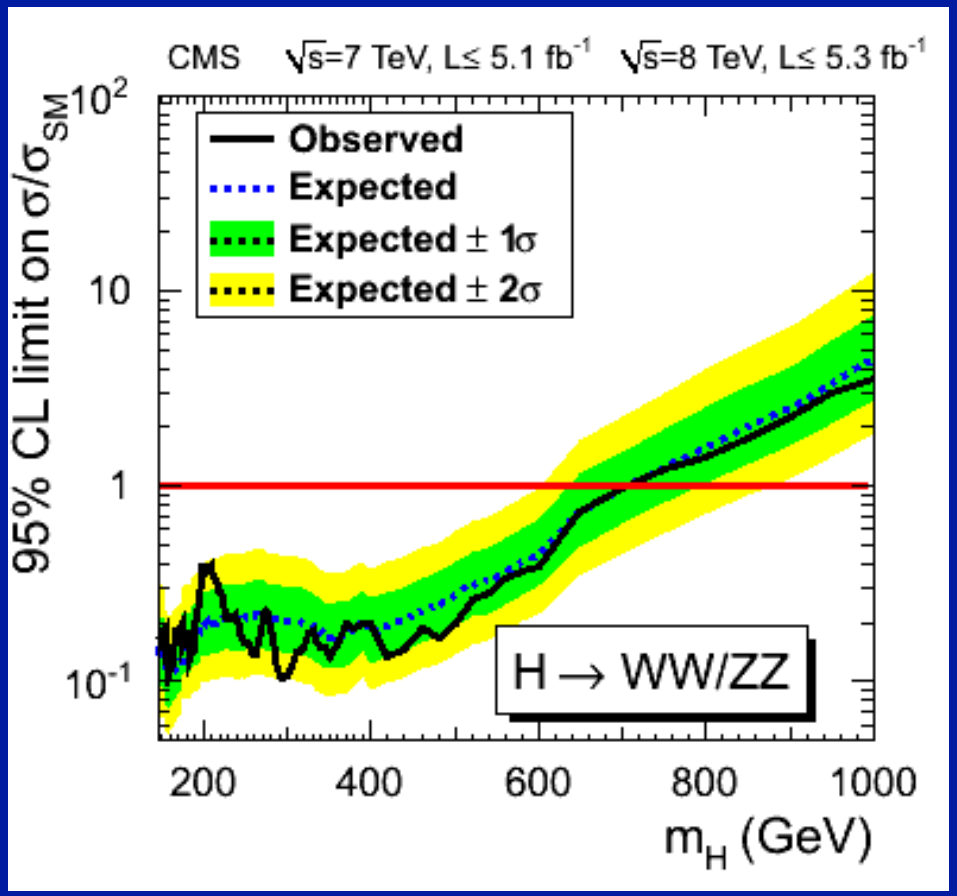
High mass region

- Major part of this talk is devoted to H125, but we start from the high mass region – sensitive to the Higgs line shape



Submitted to EPJ

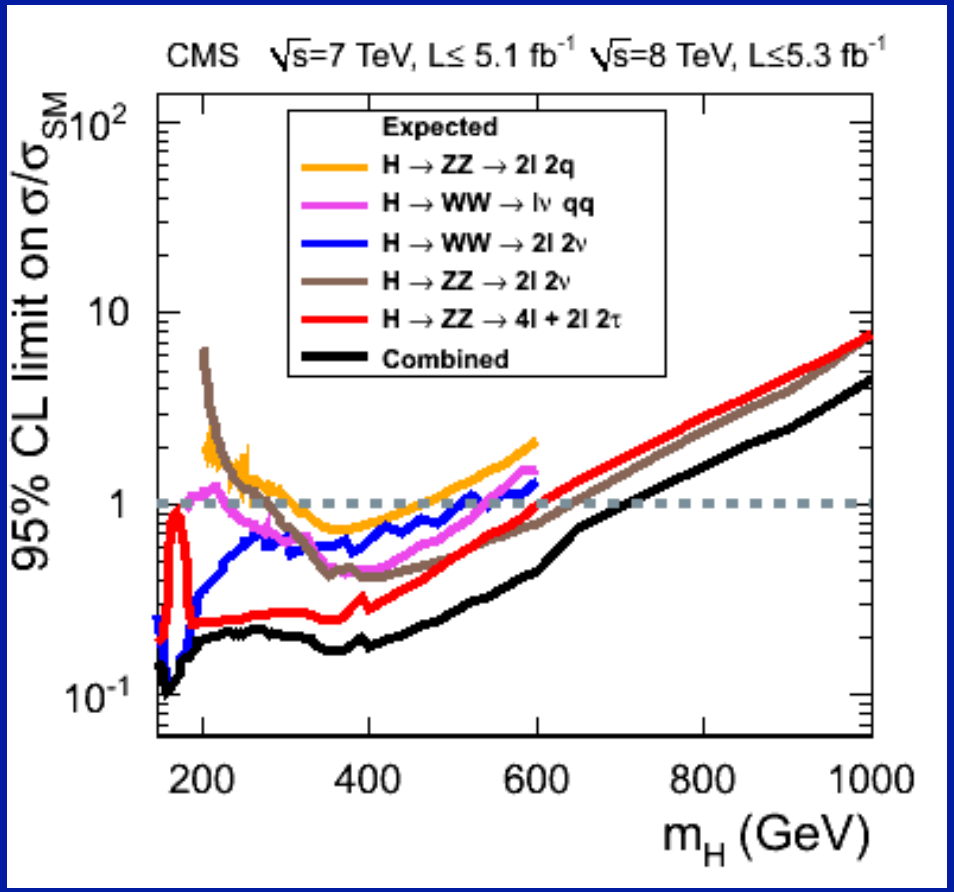
Part of statistics: 5 + 5 fb^{-1}

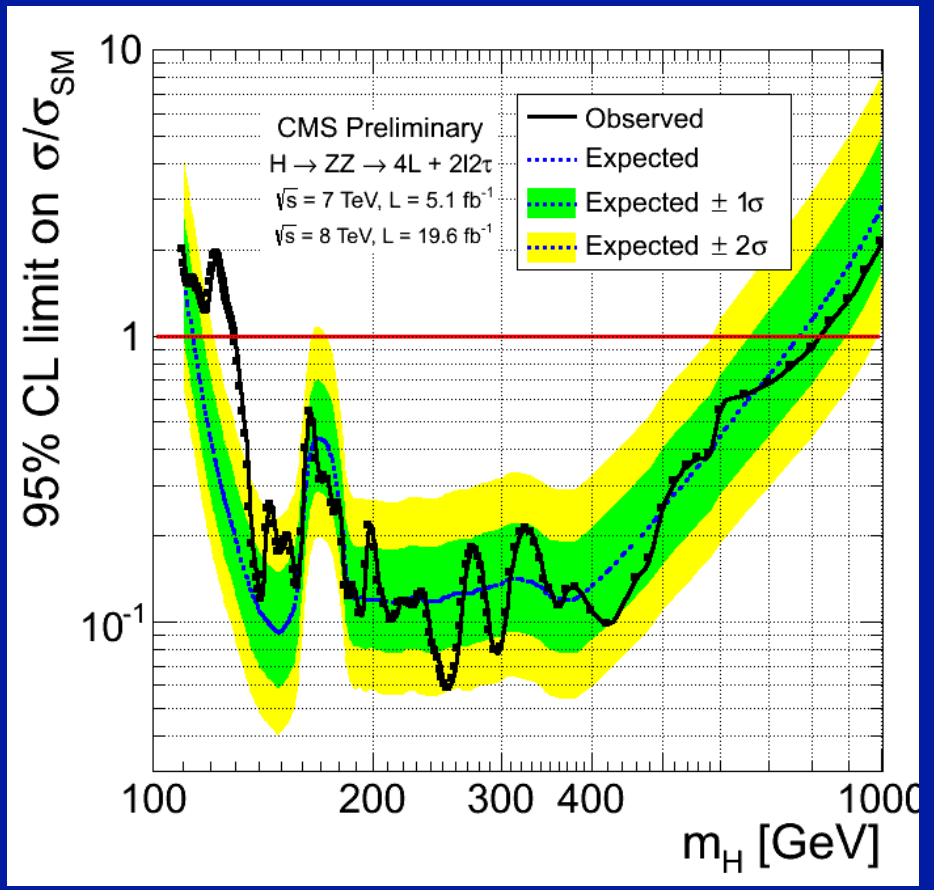


High mass region

- Major part of this talk is devoted to H125, but we start from the high mass region – sensitive to the Higgs line shape

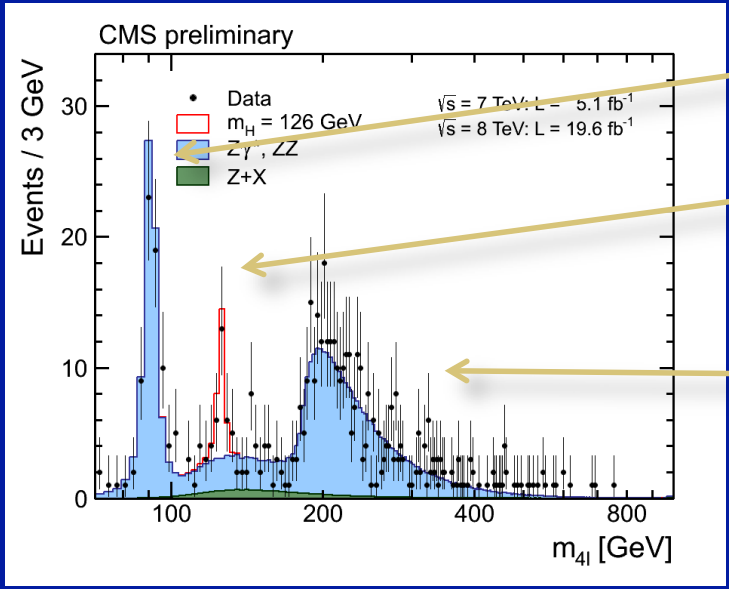
Full statistics: ZZ 4l only 5.1+19.6 fb^{-1}





$H \rightarrow ZZ \rightarrow 4l$

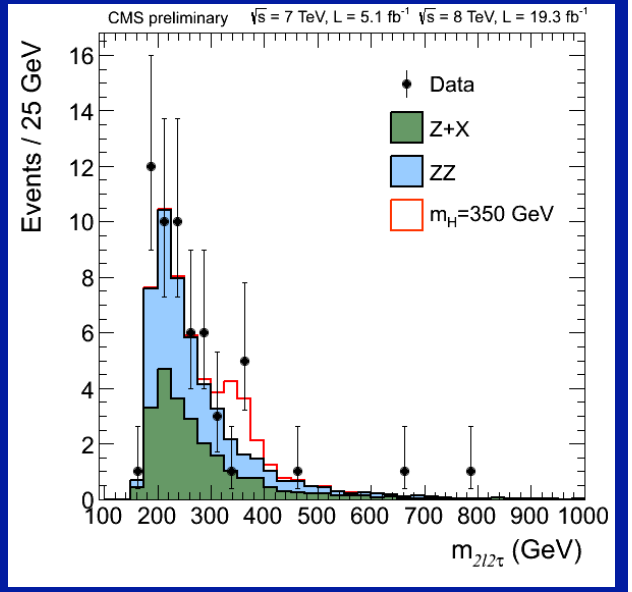
Golden channel – almost no background

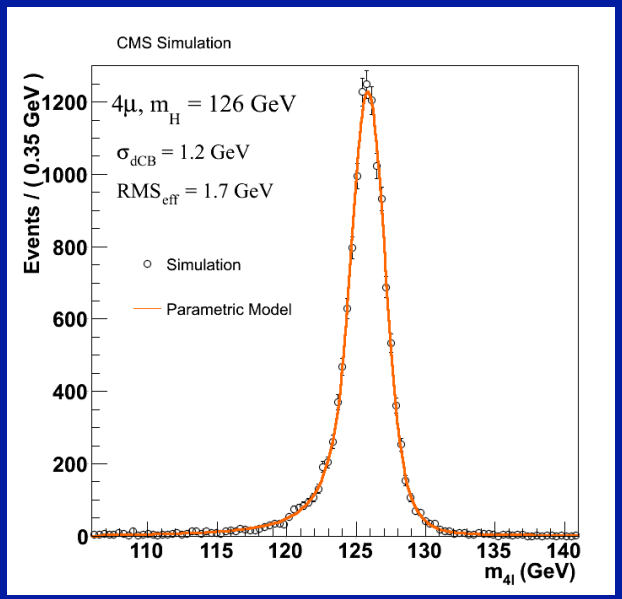


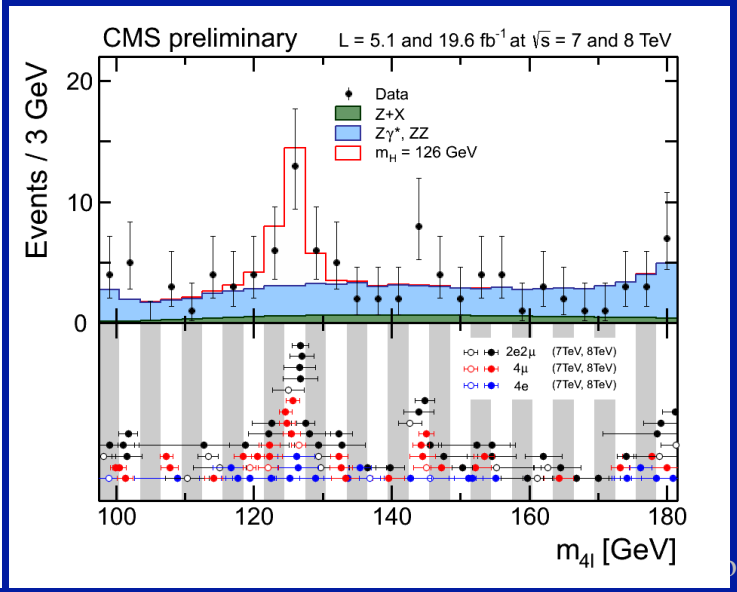
$Z \rightarrow 4l$

$H125 \rightarrow ZZ$

ZZ



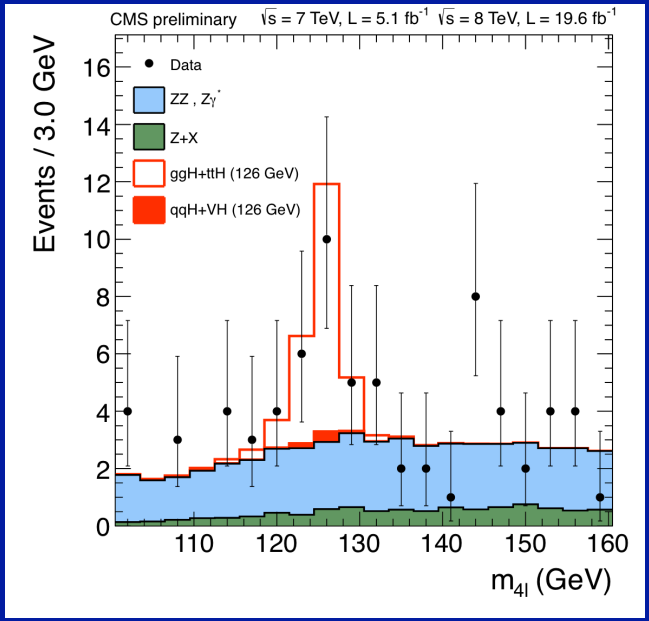


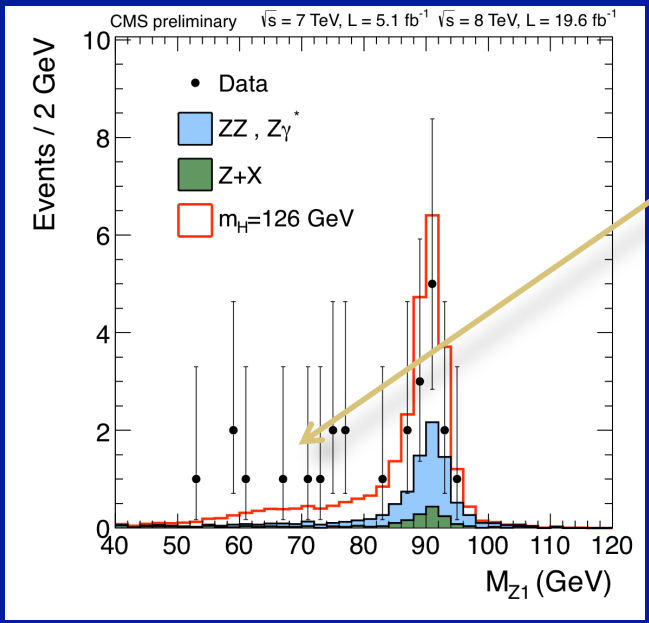


$ZZ \rightarrow 2l2\tau$

Four high-p_T reconstructed leptons, including taus for high masses.
Very narrow mass peak,
Very high selection efficiency.

Mass distributions





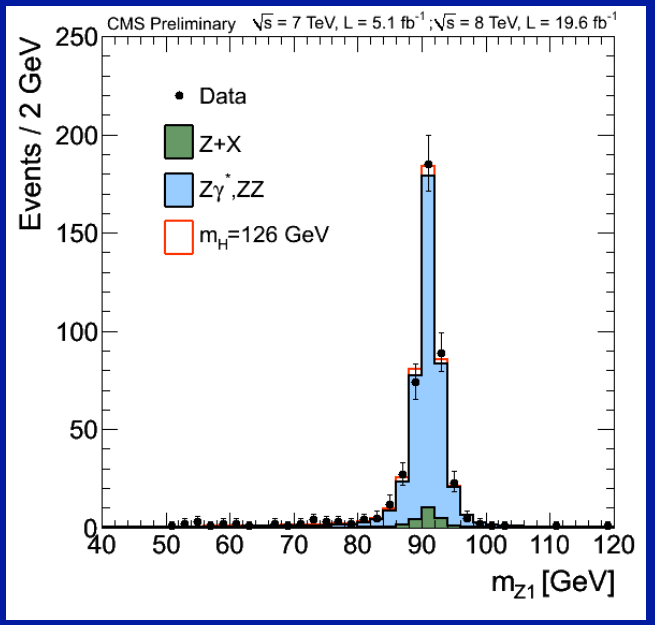
Data are analyzed in
2 categories:
0/1 jet
2 jets and more

Predictions describe the data well

Small excess in event yield, within statistical uncertainties

Z1 mass reconstructed for restricted 4l masses range: 121.5 – 130.5

All Z1 reconstructed



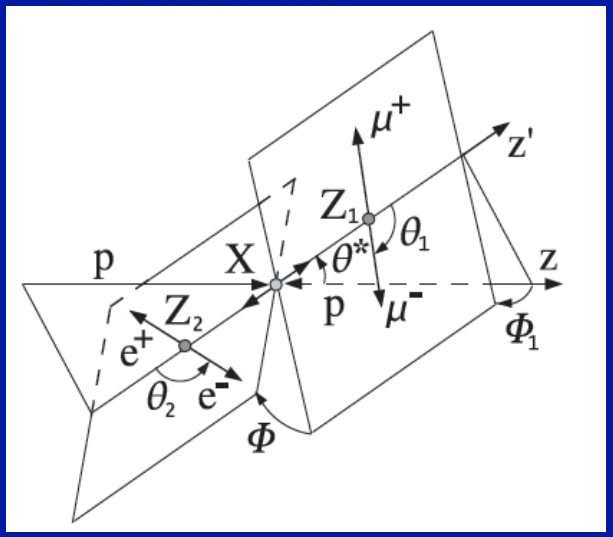
Kinematic Discriminant

Since the Higgs boson is spinless, the angular distribution of its decay products is independent of the production mechanism.

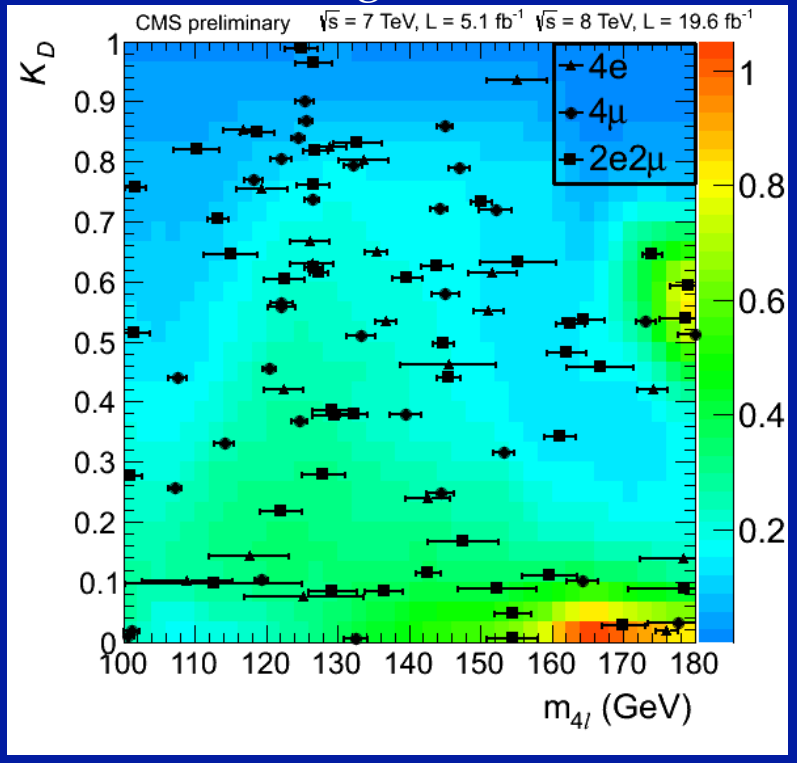
$$P_{S,B} = f(m_1, m_2, \theta_1, \theta_2, \Phi_1, \theta^*, \Phi^* \mid m_{4l})$$

$K_D = P_S/(P_S+P_B)$,

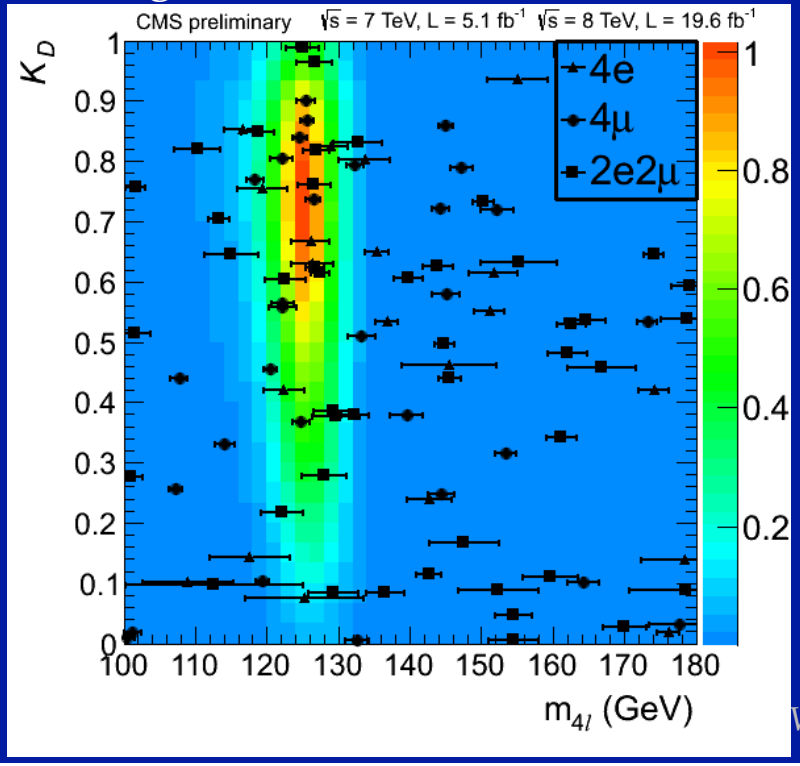
using a matrix element likelihood approach



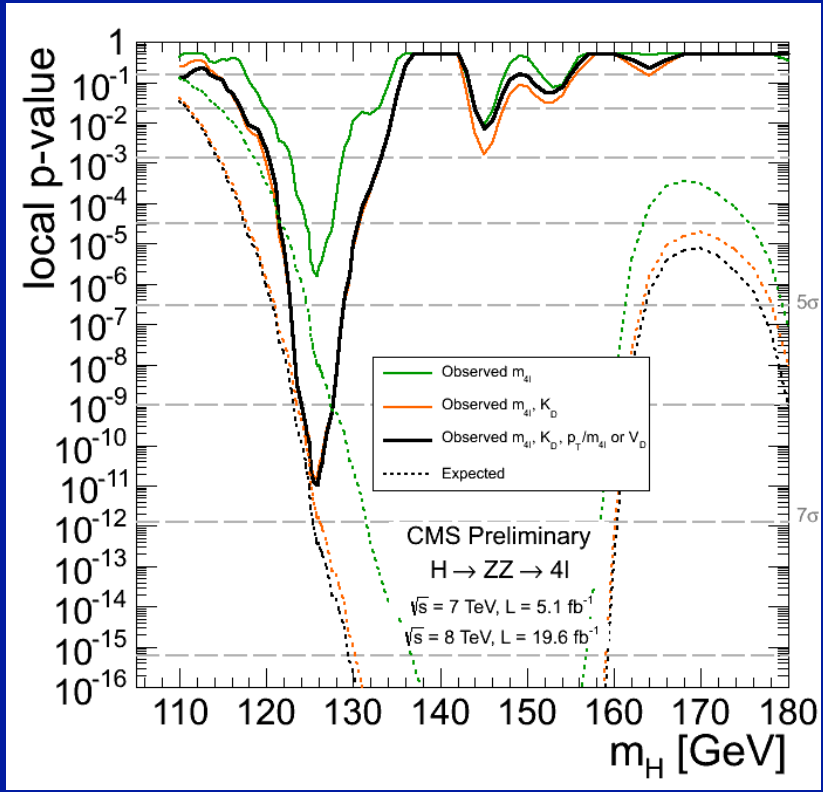
Background



Signal



Significance of the local access

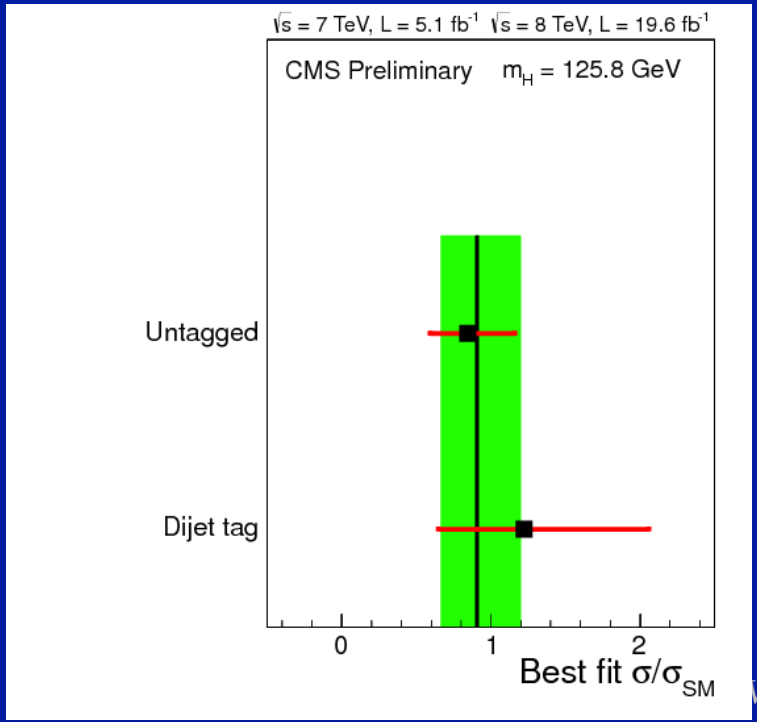


3D fit to m_{4l},K_D and $p_T(4l)/m4l$ or linear discriminant for VBF case

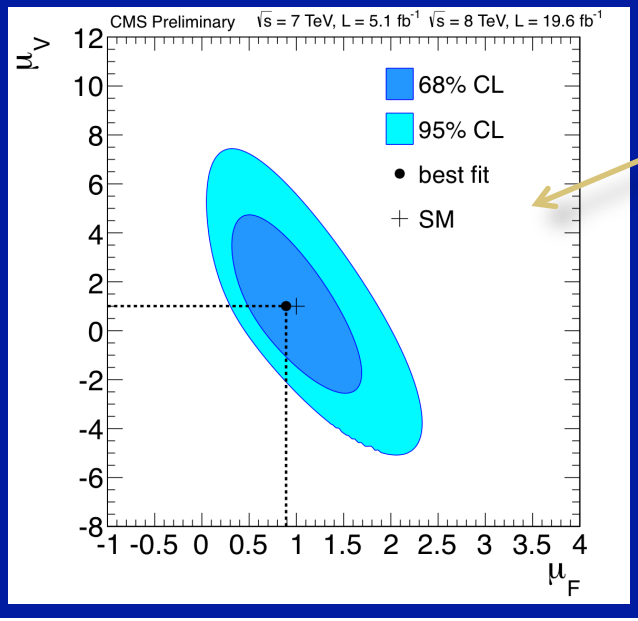
Significance for 125.8 GeV:
observed 6.7 ; expected 7.2

$$\sigma/\sigma_{SM} = 0.91^{0.30}_{-0.24}$$

$$m_H = 125.8 \pm 0.5(stat.) \pm 0.2(sys.)GeV$$

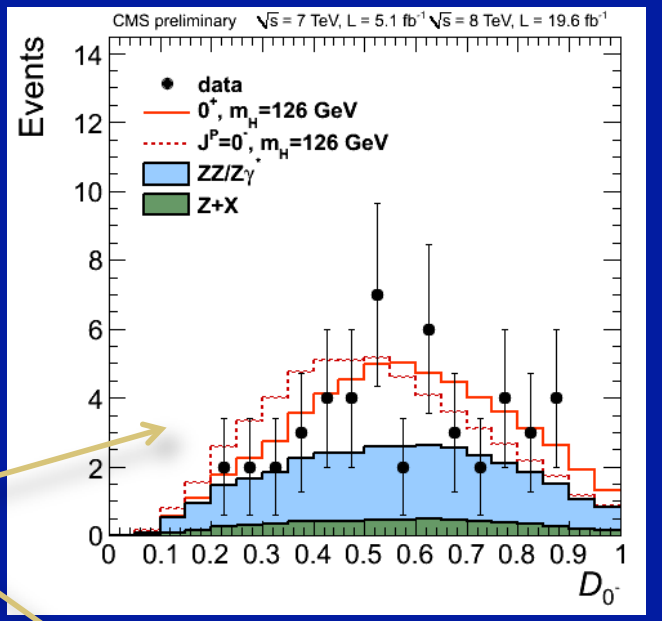


Production mechanism and spin-parity measurement

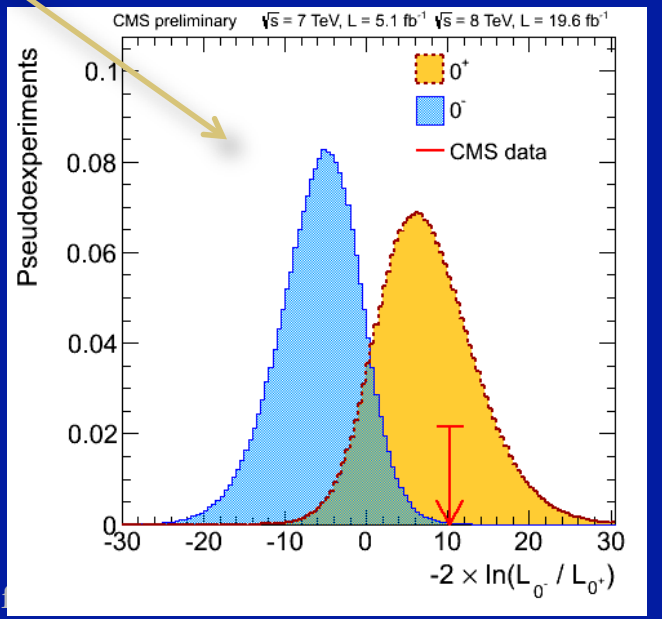


Signal strength modifiers associated with fermions and vector bosons

KD constructed for different J^P



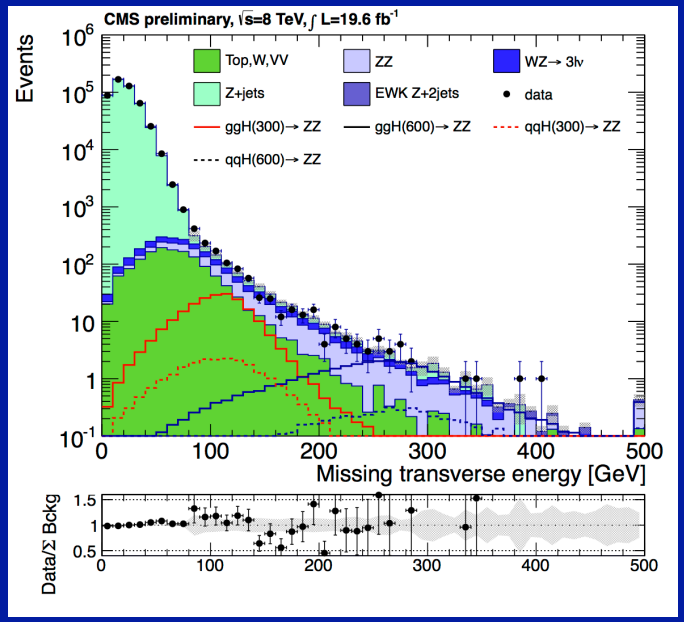
J^P	production	comment	expect (μ=1)	obs. 0^+	obs. J^P	CL_s
0^-	$gg \to X$	pseudoscalar	2.6σ (2.8σ)	0.5σ	3.3σ	0.16%
0_h^+	$gg \to X$	higher dim operators	1.7σ (1.8σ)	0.0σ	1.7σ	8.1%
2^+_{mgg}	$gg \to X$	minimal couplings	1.8σ (1.9σ)	0.8σ	2.7σ	1.5%
$2^+_{mq\bar{q}}$	$q\bar{q} \to X$	minimal couplings	1.7σ (1.9σ)	1.8σ	4.0σ	<0.1%
1^-	$q\bar{q} \to X$	exotic vector	2.8σ (3.1σ)	1.4σ	$>4.0\sigma$	<0.1%
1^+	$q\bar{q} \to X$	exotic pseudovector	2.3σ (2.6σ)	1.7σ	$>4.0\sigma$	<0.1%

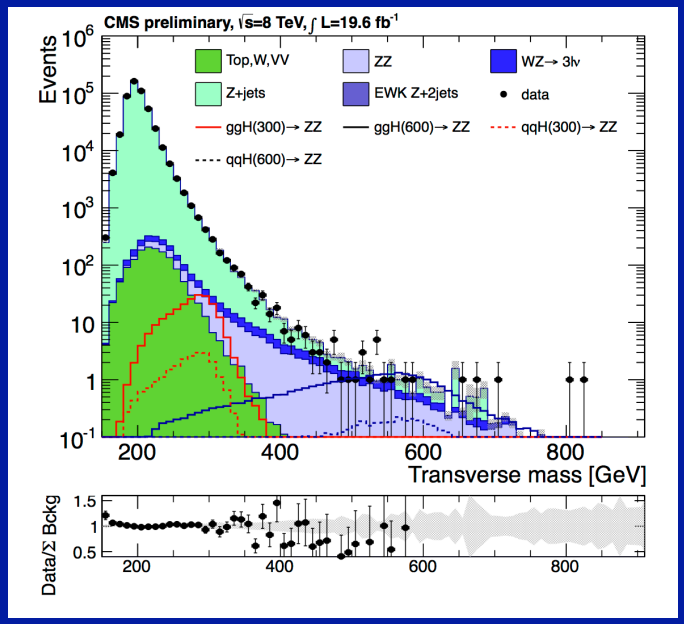


2D analysis (D_{bkg},D_{JP}) at mass 126 GeV

The distributions are examined with generated samples of background and signal of seven types (SM 0+ and six J^P) for m_H = 126 GeV.

$H \rightarrow ZZ \rightarrow 2l2\nu$



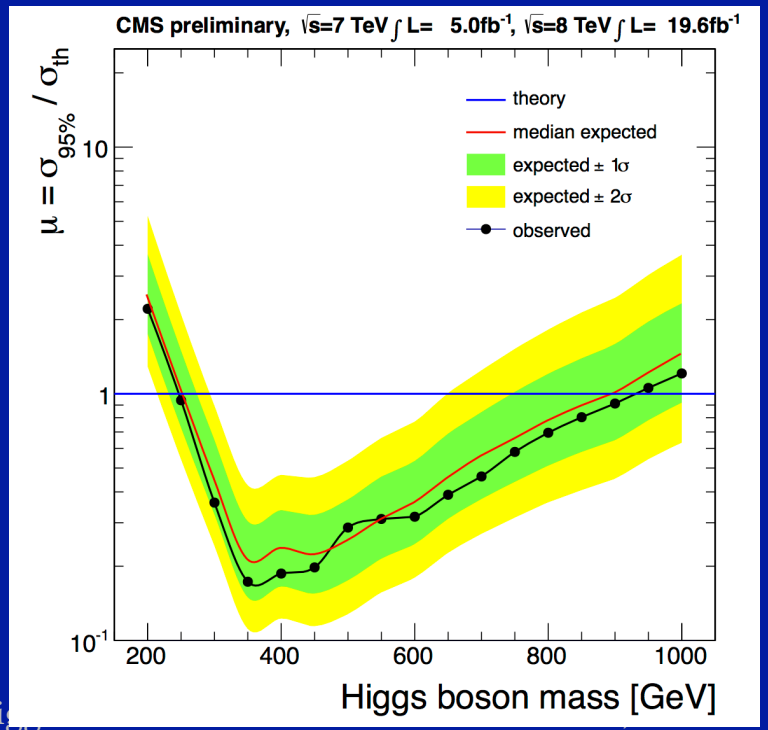


Two leptons from the Z and large MET

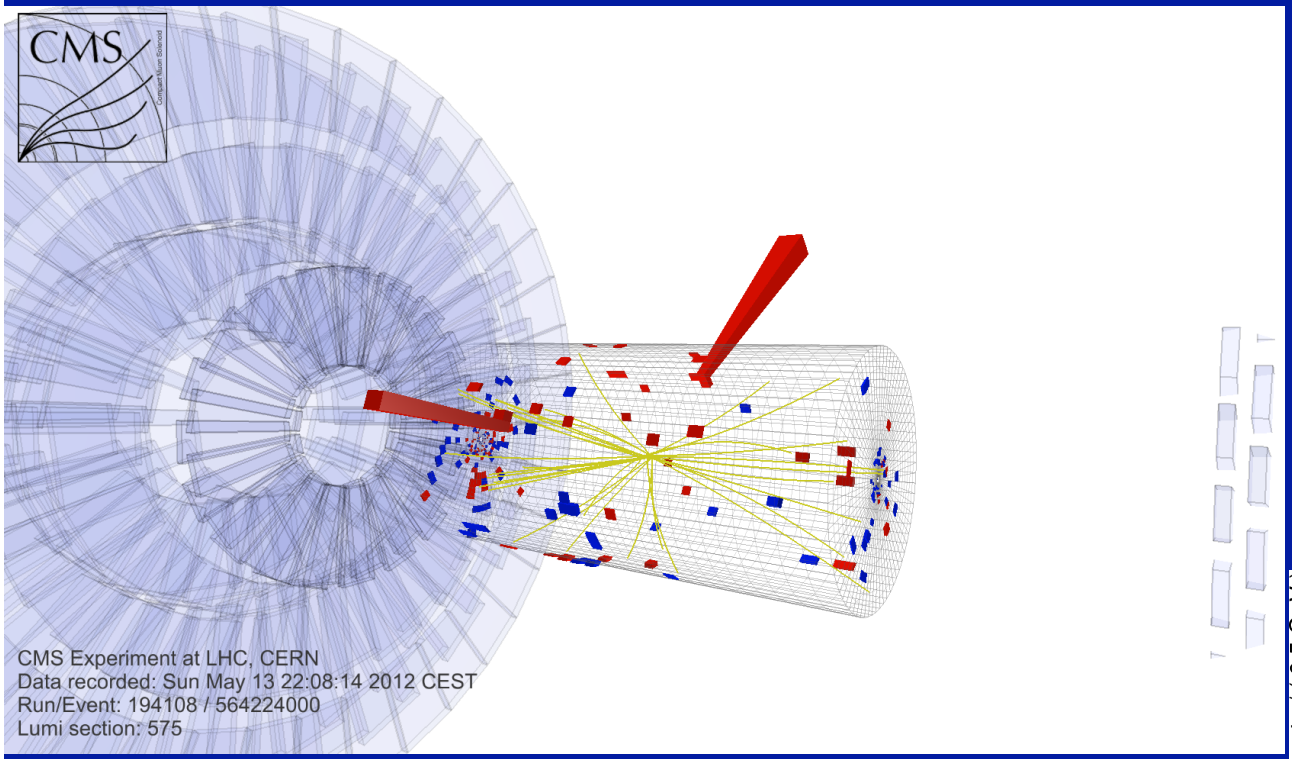
Cut- and shape analyses based on transverse mass and missing energy

BSM interpretation of the results: search for an EW singlet scalar mixing with the new boson, Excluded for various widths and branching ratios to new particles

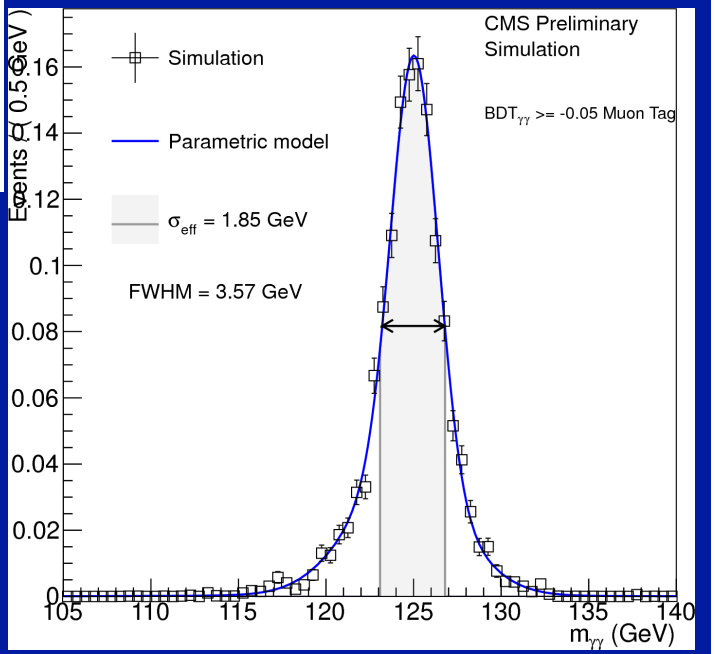
Excluded:
248-930 GeV



$H \rightarrow \gamma\gamma$



MVA is used for the photon identification and vertex determination
(cut-based analysis is used as cross check)



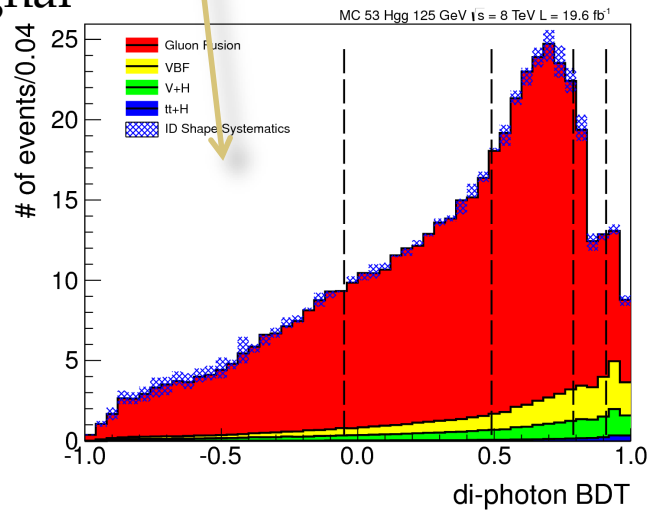
Two high-p_T photons required with narrow mass distribution at the prompt diphoton spectra

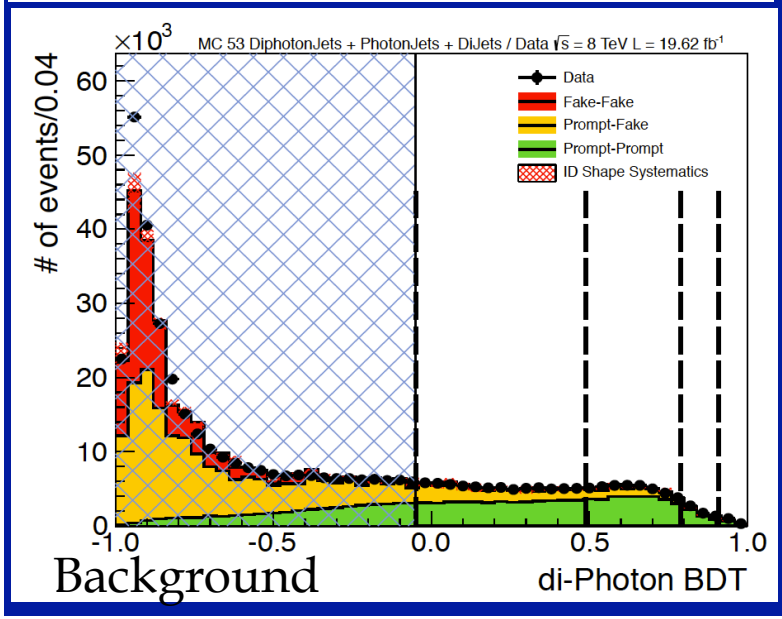
The events are separated into classes based on their mass resolution and signal to background ratio. Individual results combined in a simultaneous statistic treatment of all event classes.

Diphoton MVA score

These events are discarded from the analysis

Signal

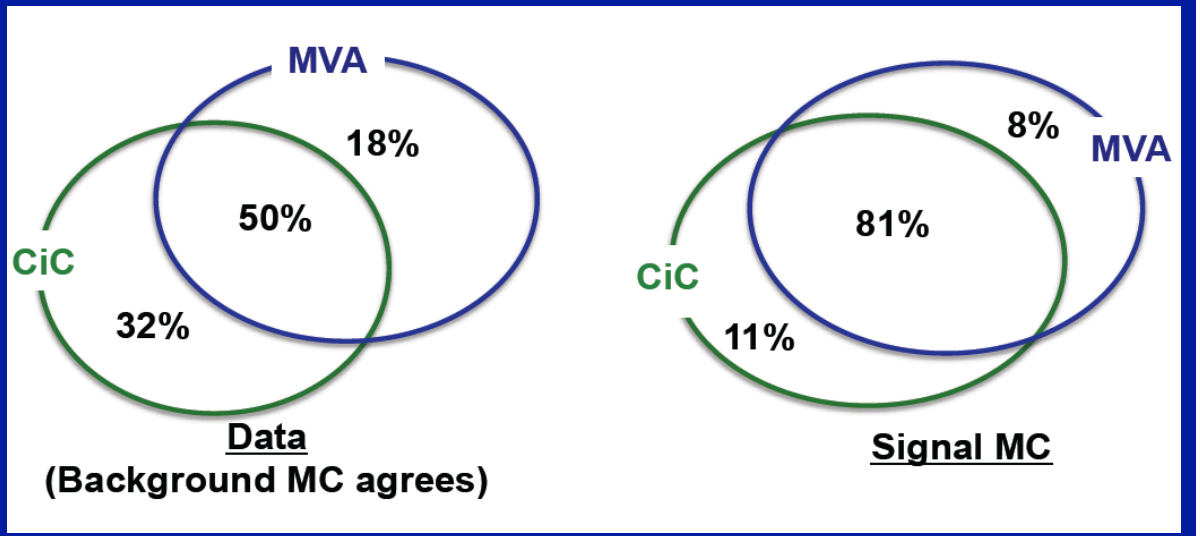




MVA
- Shower topology variables ;
- Isolation variables ;
- Energy density per unit area per event

Cut-based, set of discriminating variables
- ECAL/HCAL ratios ;
- PF isolations ;
- Shower shape variables

Overlap between cut-based and MVA

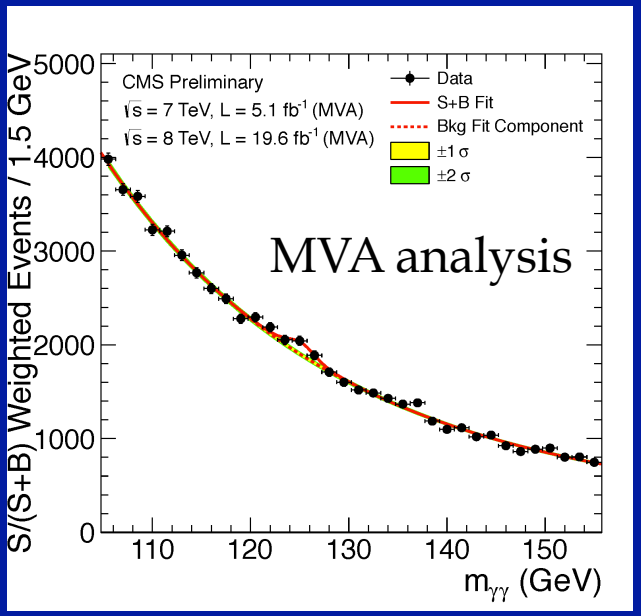


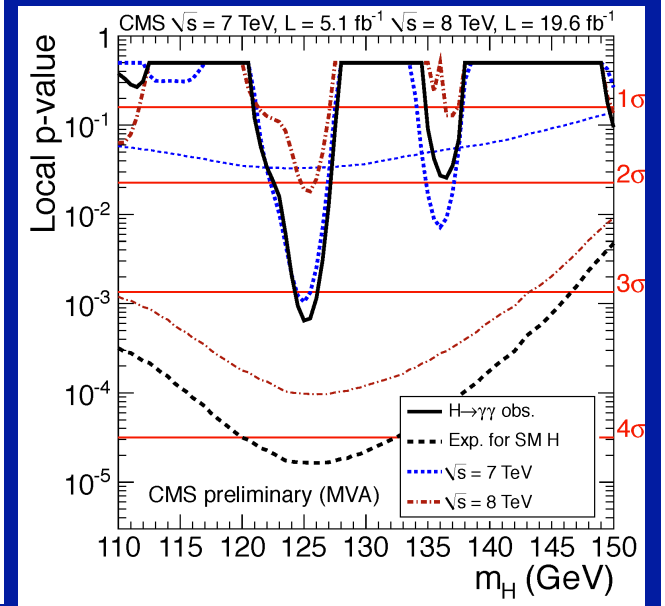
$H \rightarrow \gamma\gamma$

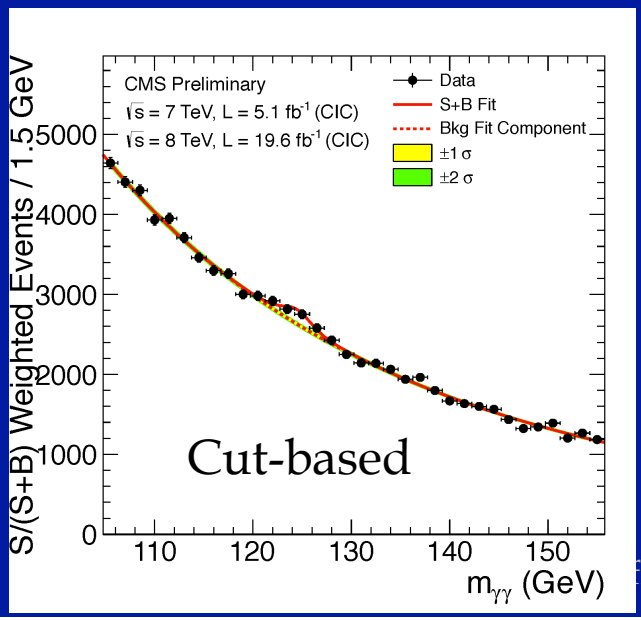
Polinomial of orders
2 to 5 are used to describe
background shapes

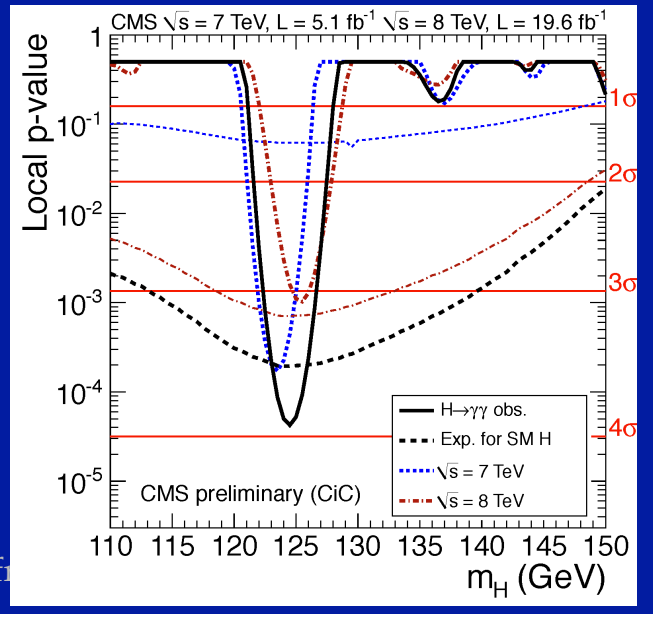
Signal strength
MVA: $0.78^{+0.28}_{-0.26}$
Cut-based: $1.11^{+0.32}_{-0.30}$

After taking into account
the correlations MVA and
cut-based analyses are
compatible within
1.5 sigma

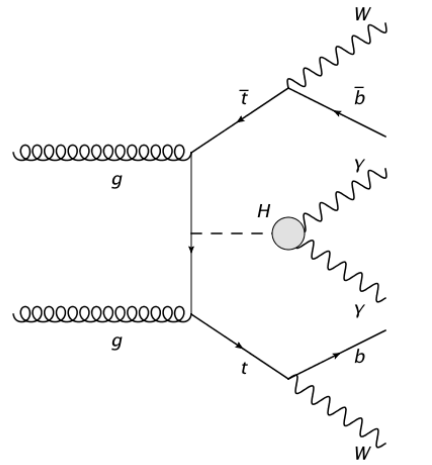


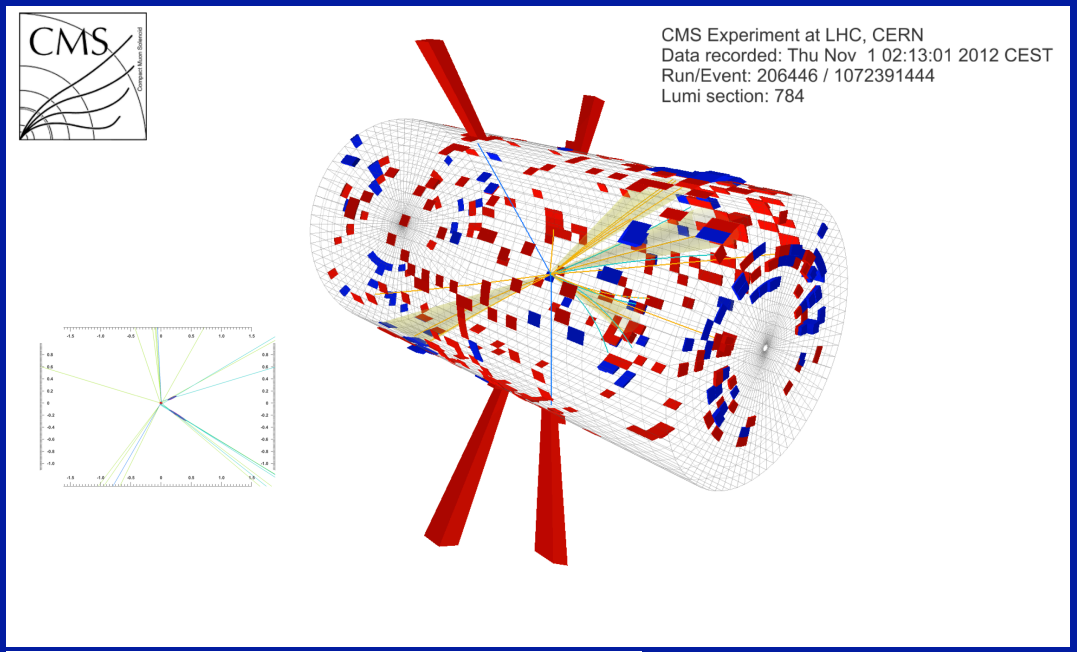






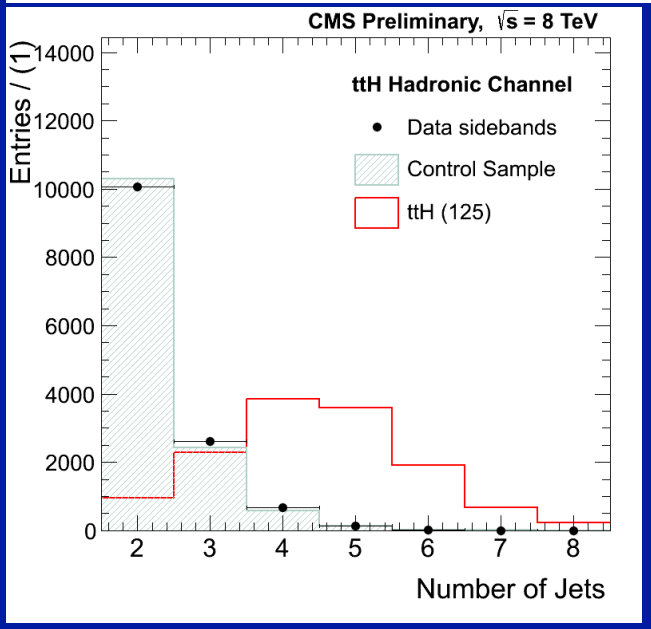
$ttH \rightarrow tt\gamma\gamma$



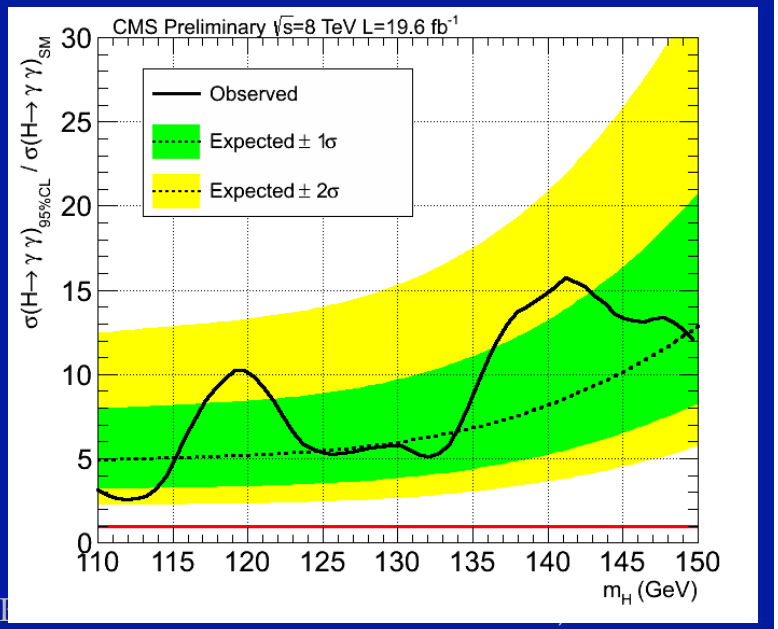


Two analyses optimized for leptonic and hadronic tt decays

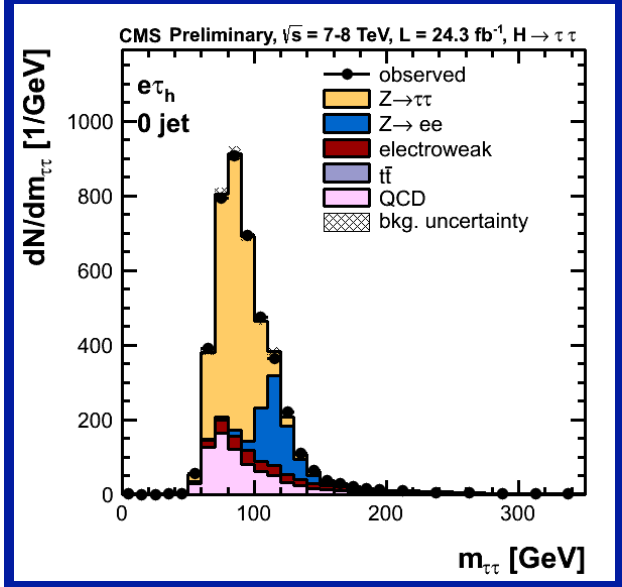
$$(t\bar{t} \rightarrow b\bar{b}q\bar{q}q\bar{q})(H \rightarrow \gamma\gamma)$$
$$(t\bar{t} \rightarrow b\bar{b}q\bar{q}l\bar{\nu})(H \rightarrow \gamma\gamma)$$

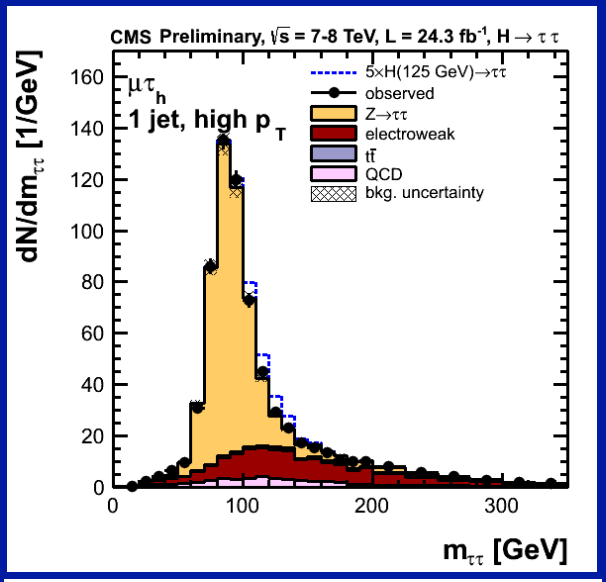


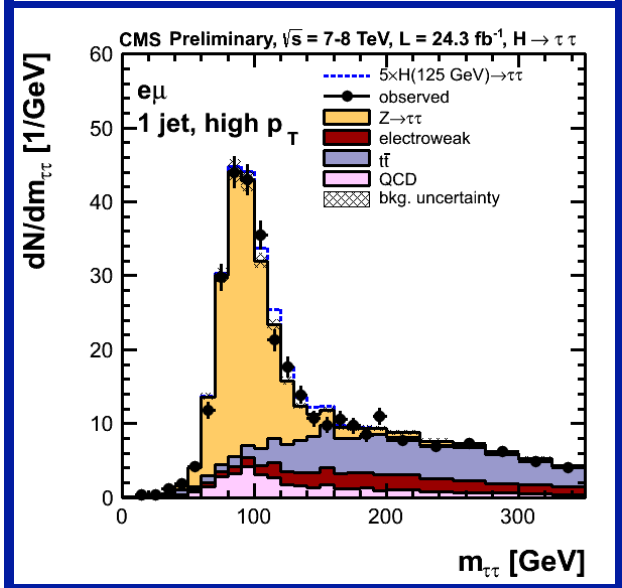
No significant excess is observed in the mass spectra over the background expectations.

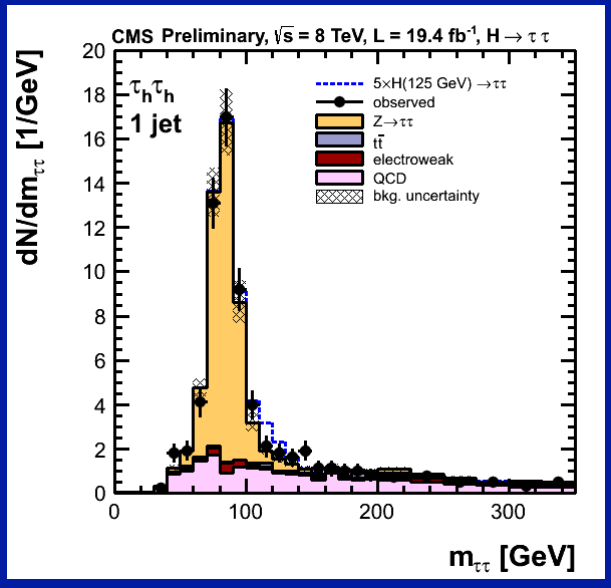


$H \rightarrow \tau\tau$

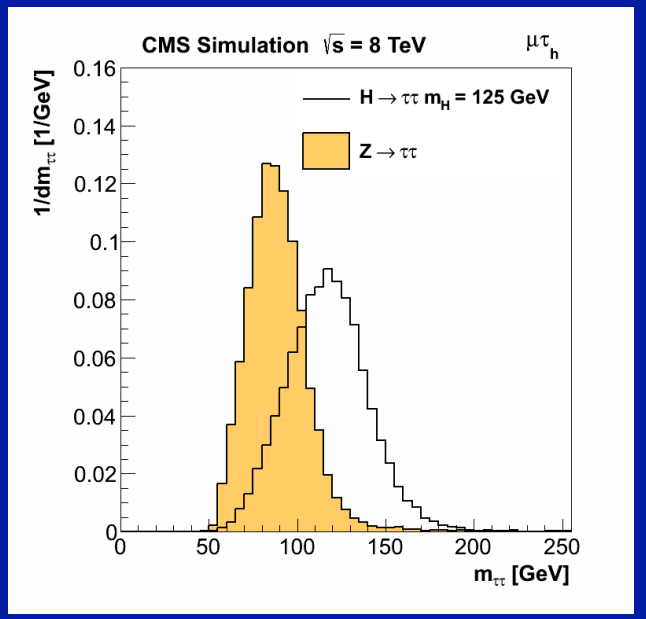








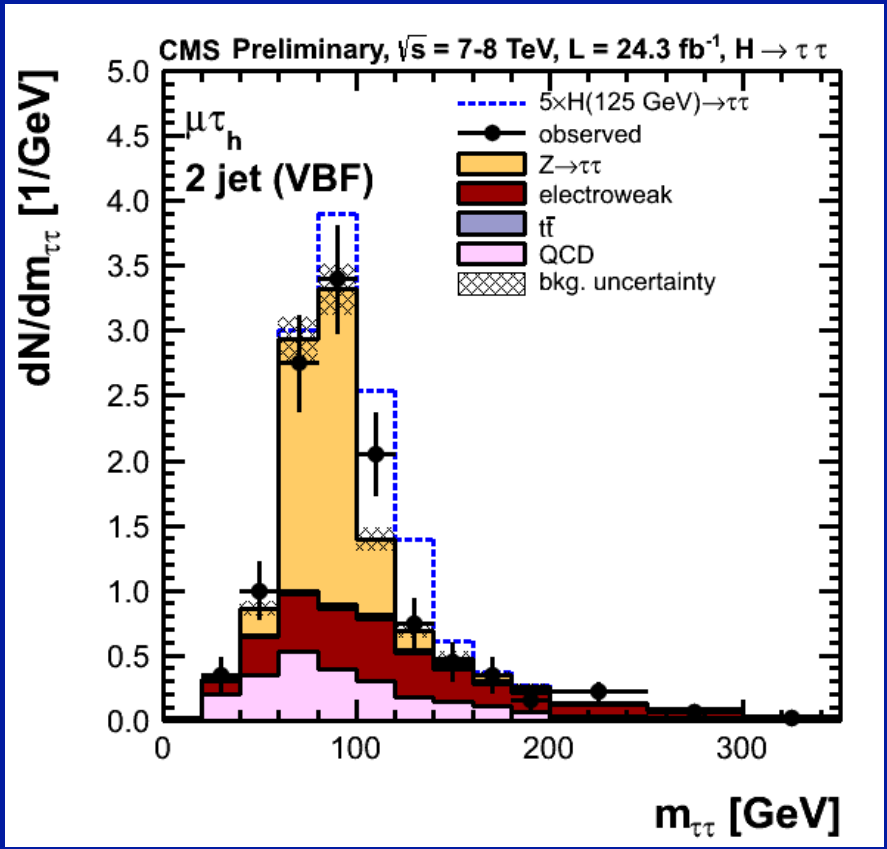
Different categories in number of jets 0, 1 and VBF and in four lepton flavors.



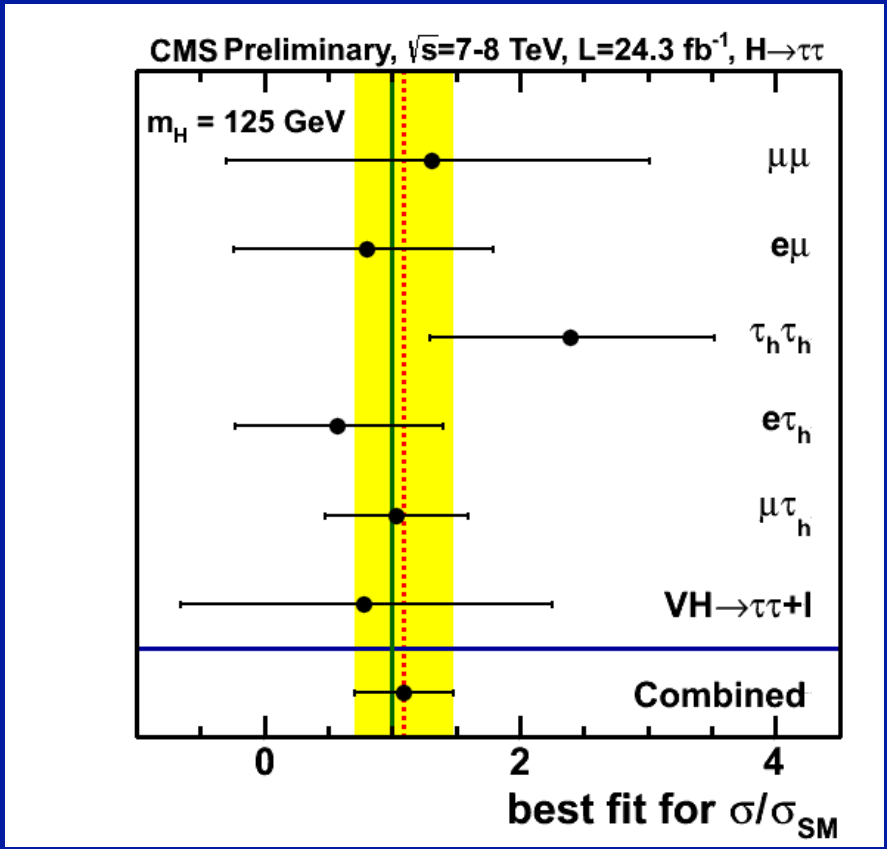
Normilized distributions of the SVFit mass obtained from the MC simulation

To perform this measurement CMS developed very efficient tau reconstruction algorithm

$H \rightarrow \tau\tau$



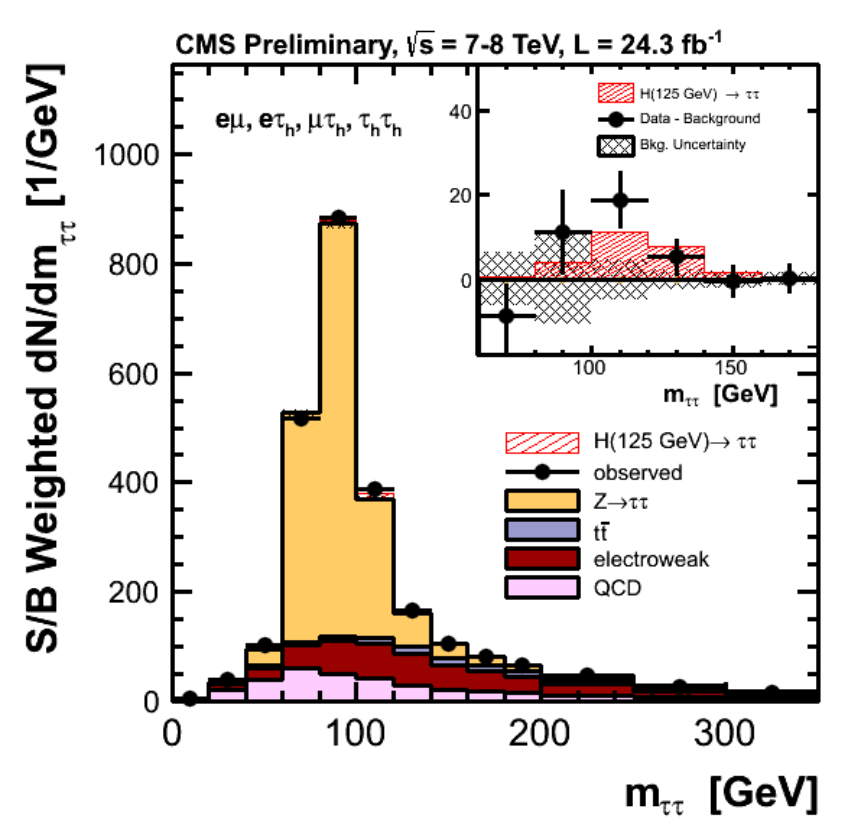
Expected and observed distributions in 2 jet (VBF) category



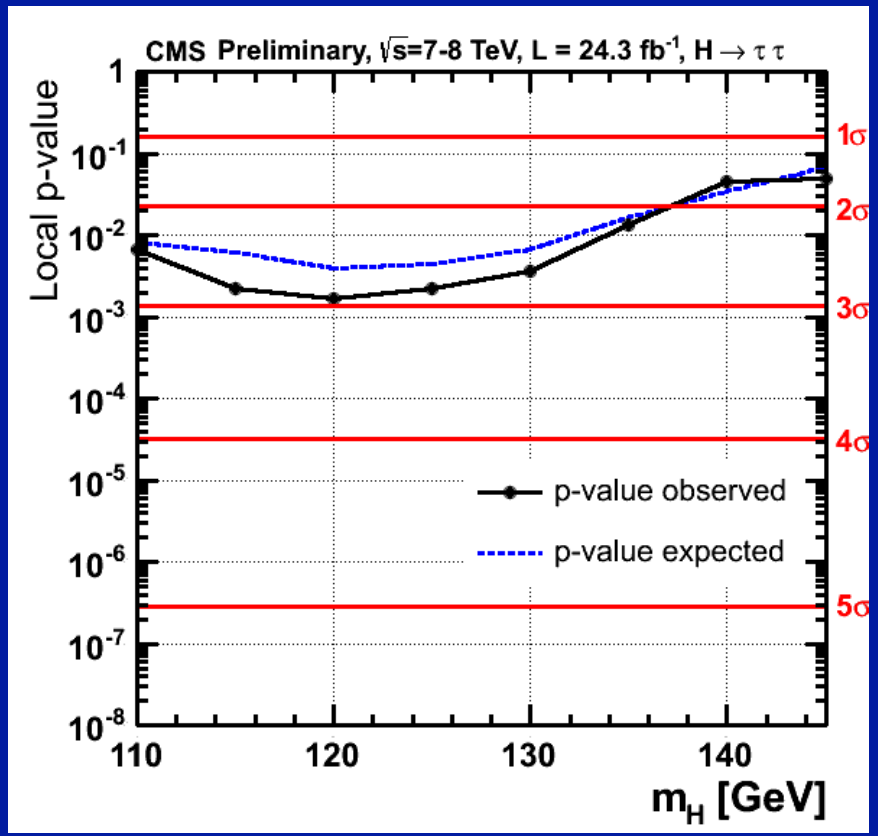
Best-fit signal strength values for independent channels

1.1 +/- 0.4

$H \rightarrow \tau\tau$

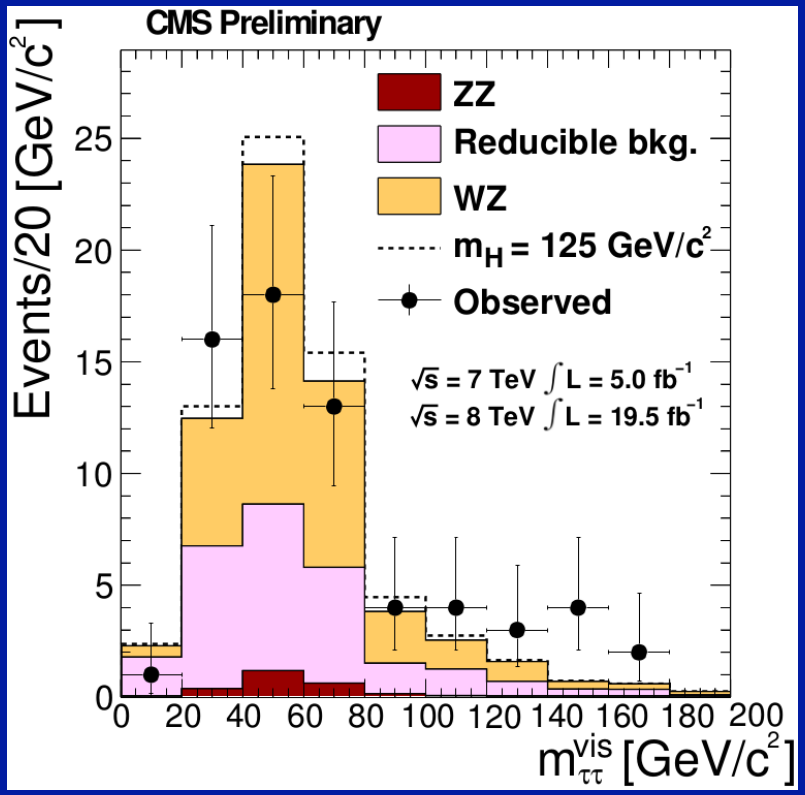


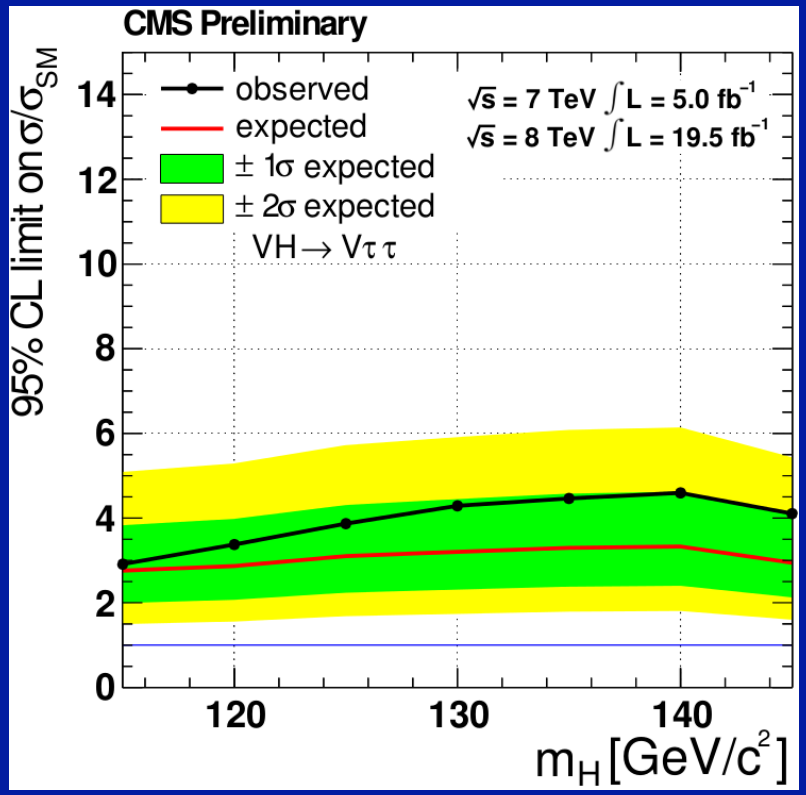
Combined observed and expected mass distributions



Observed and expected p-values

$(Z/W)H \rightarrow (Z/W)\tau\tau$





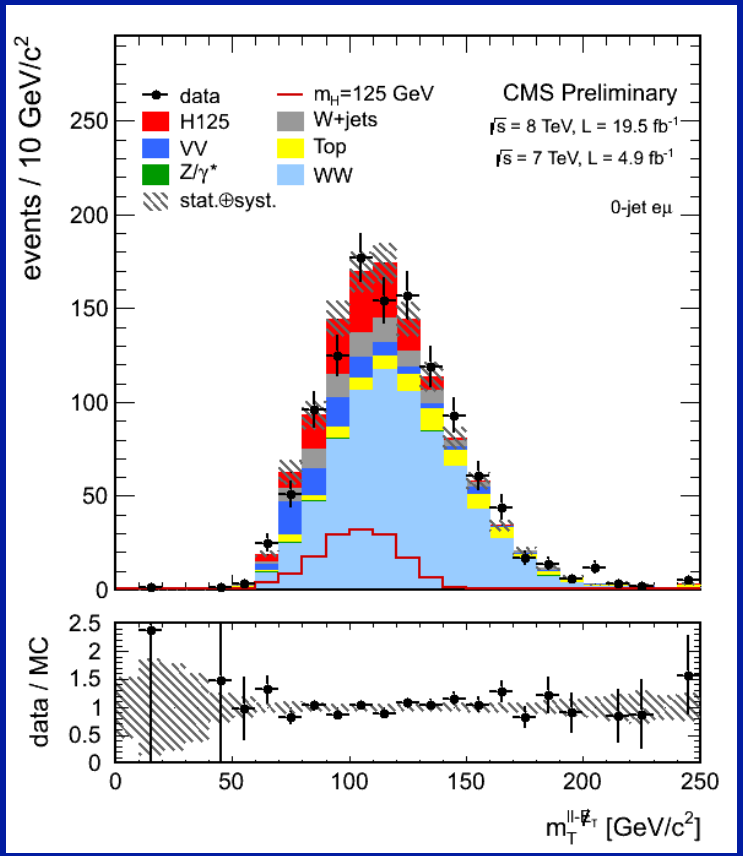
$WH \rightarrow ll\tau$

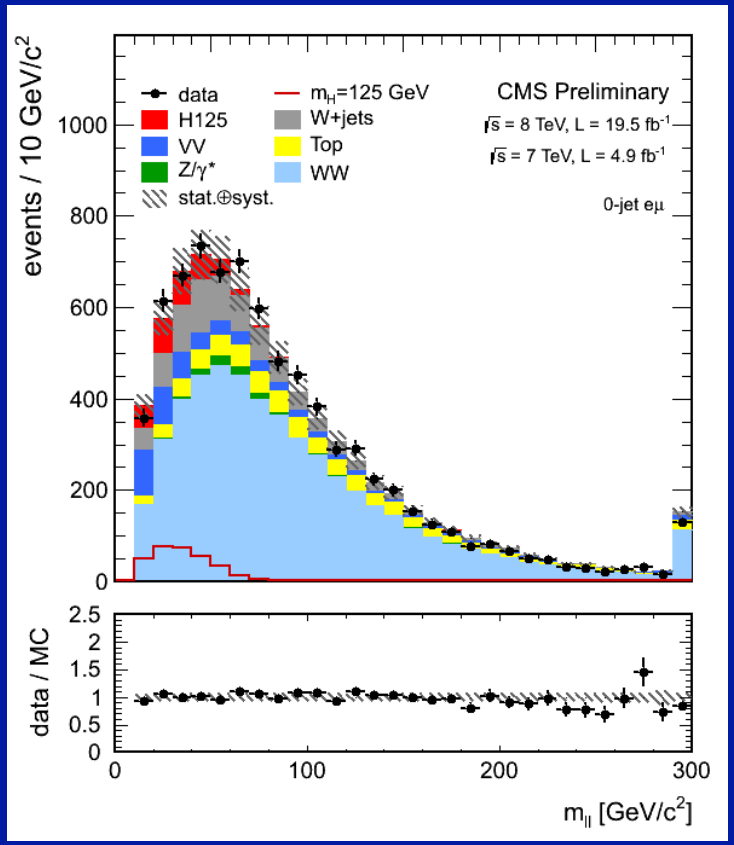
Combined VH limit

This channel is included in the inclusive analysis

$WW \rightarrow 2l2\nu$

The analysis is performed in 0, 1 and 2 jets categories,
for Same Flavor leptons (cut-based) and Different Flavor (m_T and m_{ll} shapes)

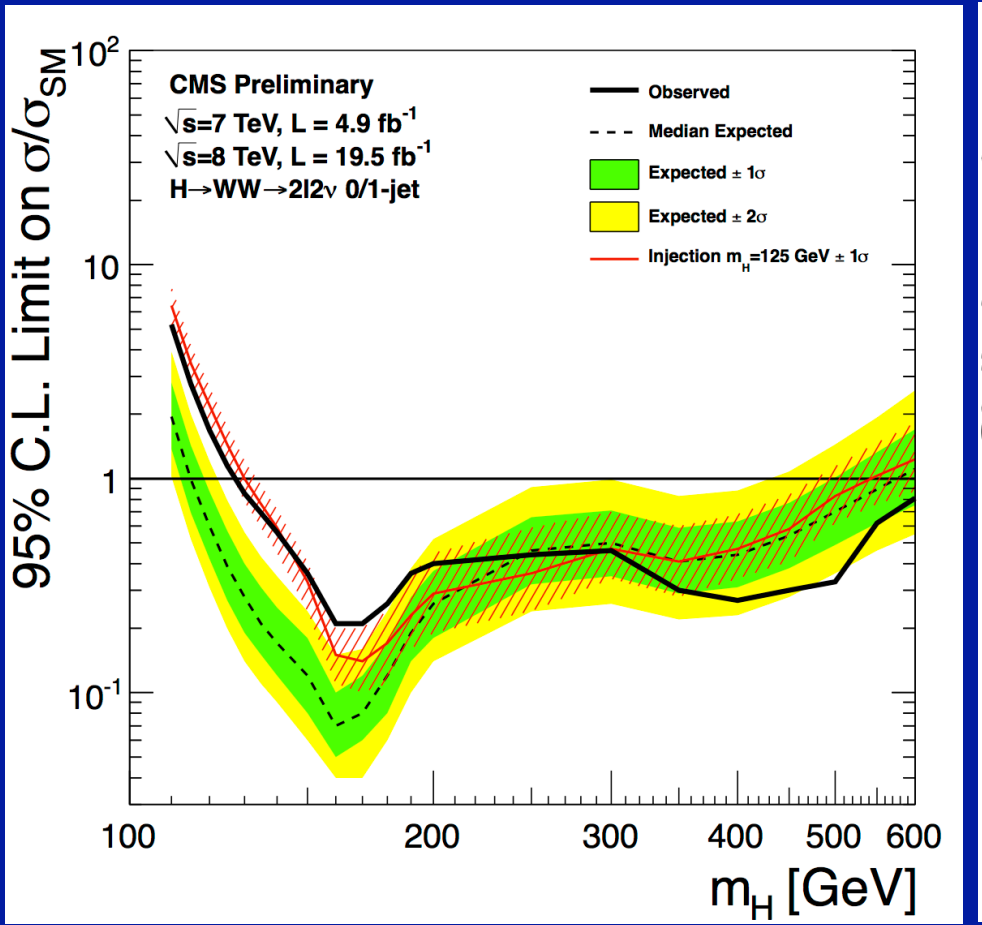


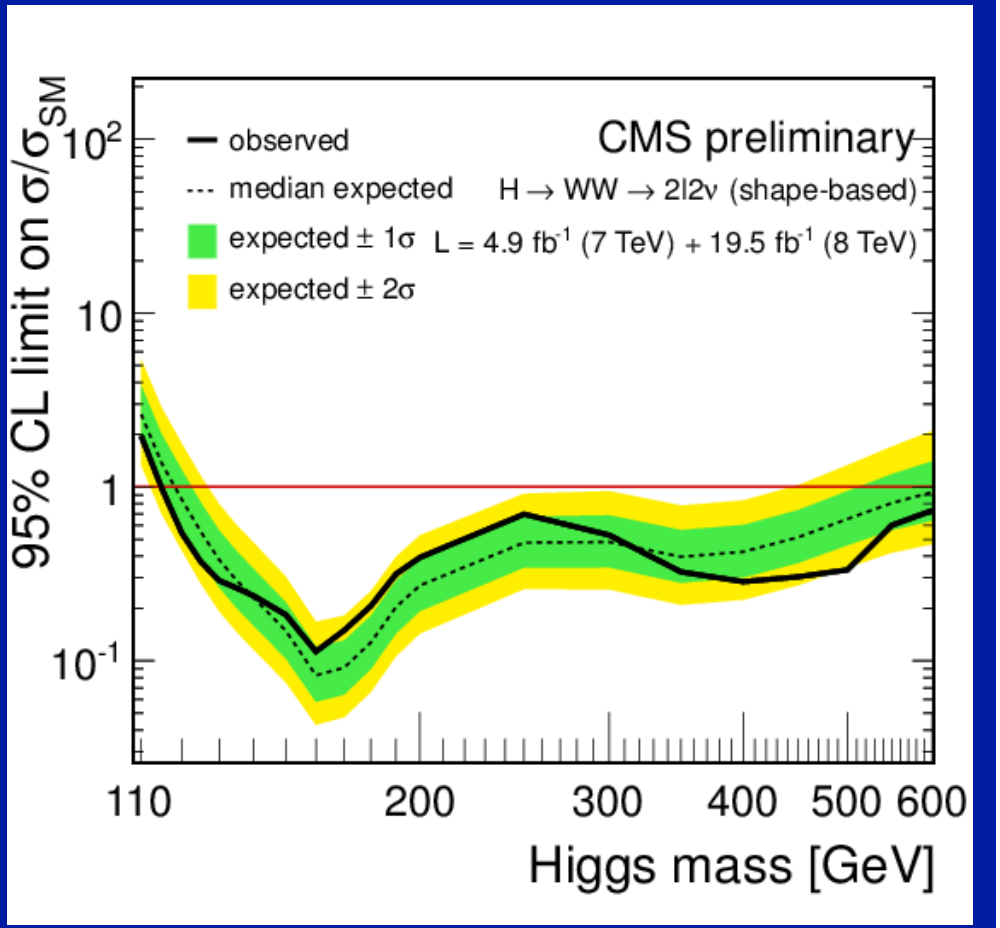


2D shapes m_T vs m_{ll} are used

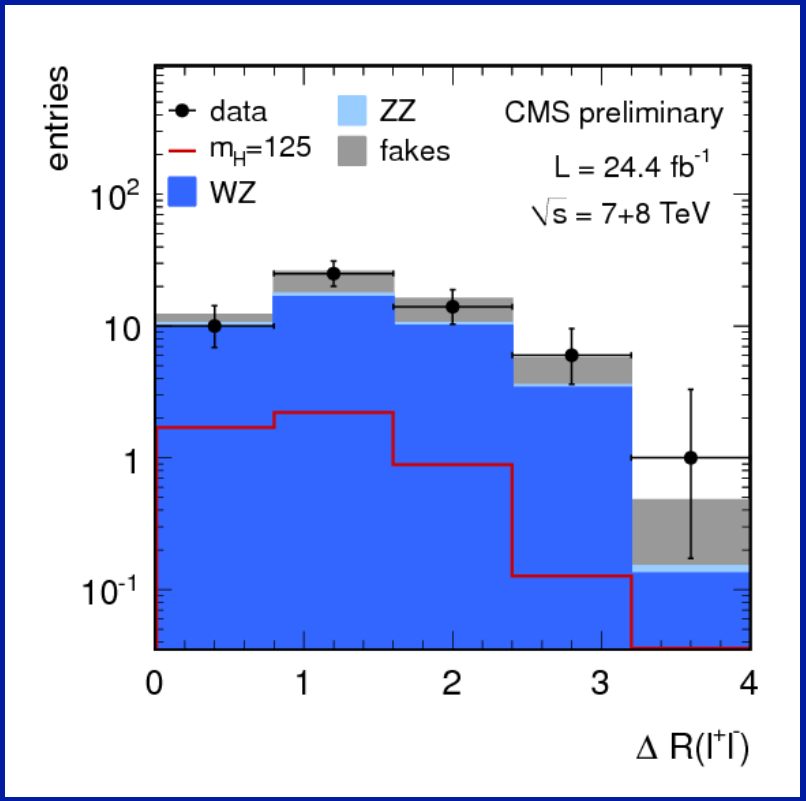
$WW \rightarrow 2l2\nu$

This channel has relatively poor mass resolution – presence of H125 effects also higher masses – to take this effect into account the H125 is considered as background at higher masses

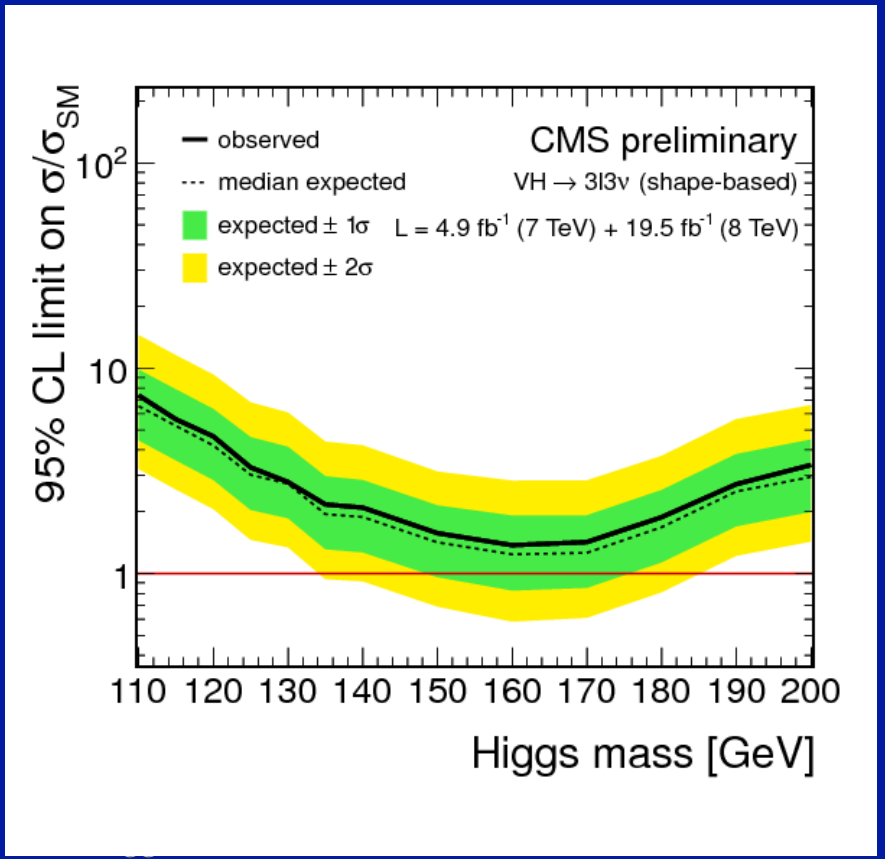




$WH \rightarrow WWW \rightarrow 3l3\nu$

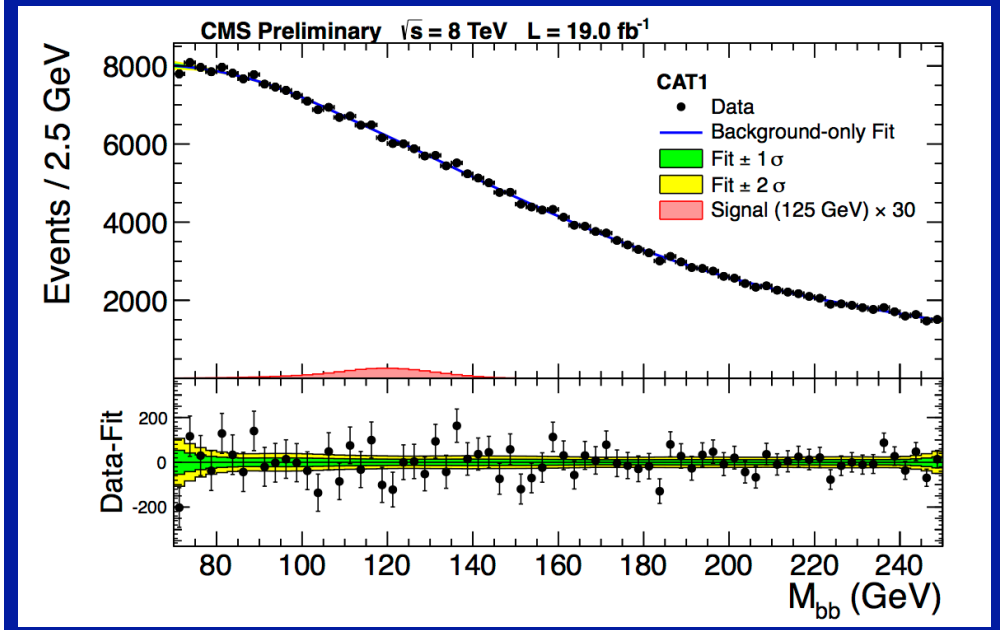


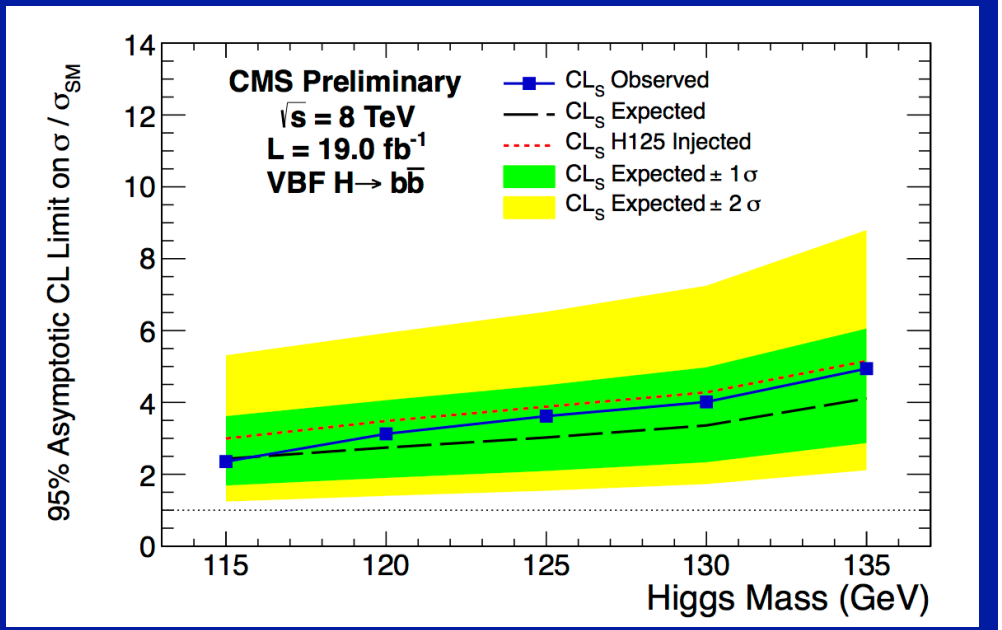
Events are selected with 3 high p_T leptons and MET
Backgrounds from Z, WZ and top events are vetoed



Cut based and shape analyses based on the smallest distance between opposite-charged leptons

$H \rightarrow b\bar{b}(VBF)$



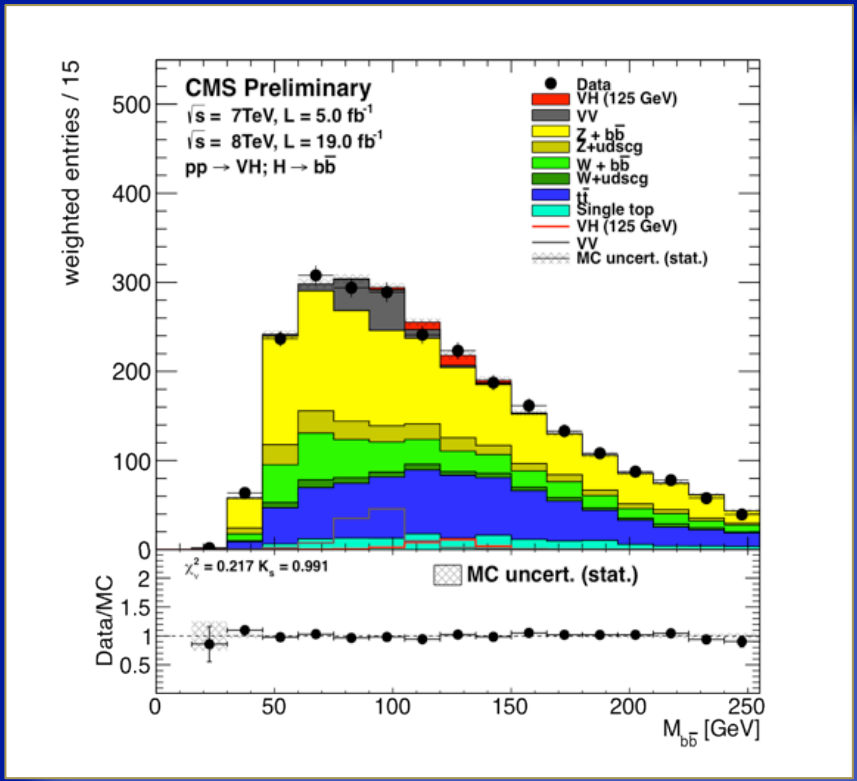


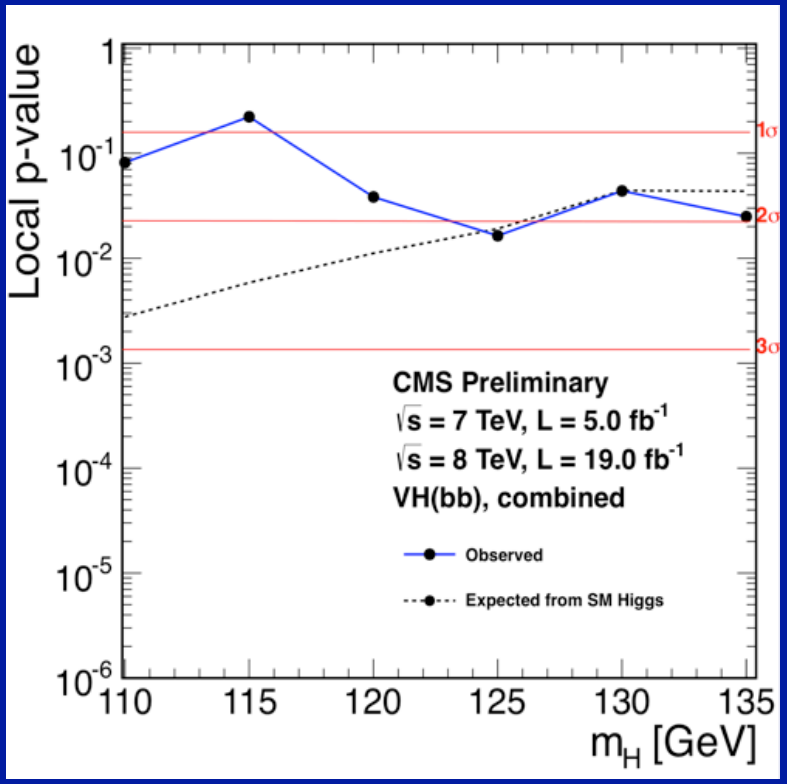
VBF production, followed by bb decay, 4 jets in the final state qqbb, dominant background is QCD. Signal - the only color connected region is bb

- select 4 jet events ;
- 2 b-tag jets ;
- Artificial Neural Network to separate from background – subdivided in categories

Shape of the m_{bb} is used.

$VH \rightarrow bb + X$



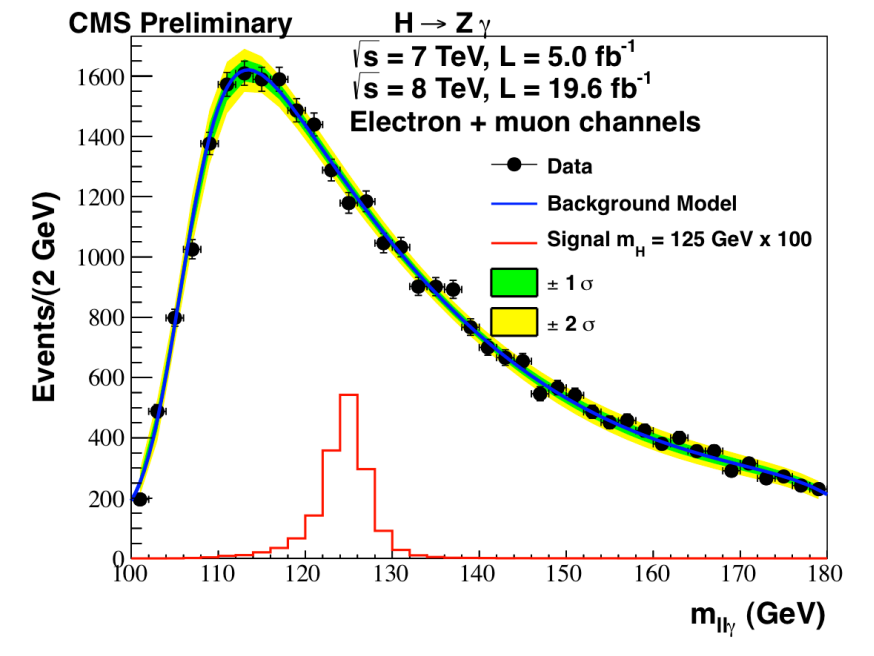


2 central b-jets and a W or a Z. Major backgrounds are V+jets, top+X, VV

BDT shape analysis.

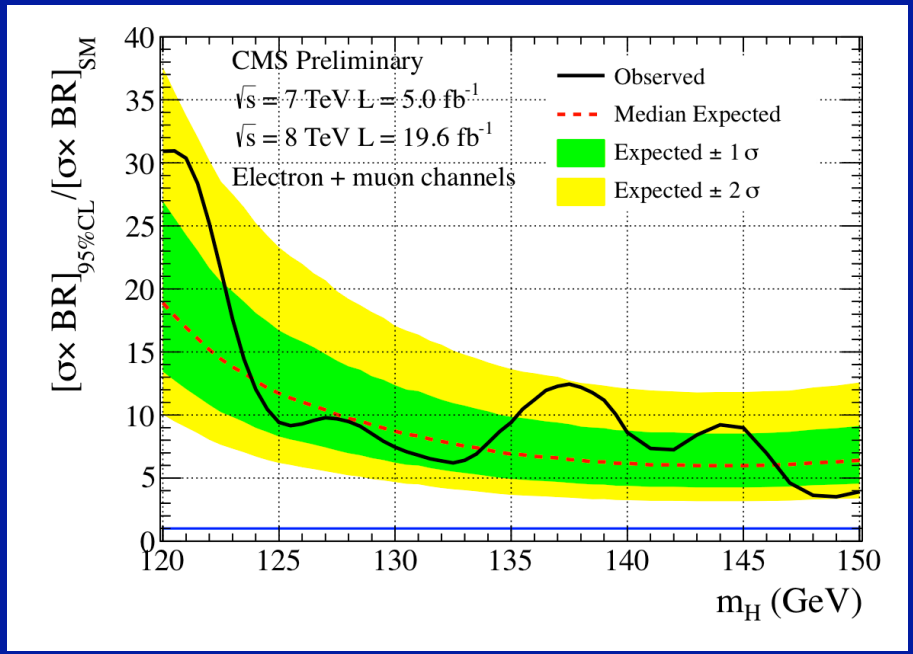
An excess of events is observed 2.1 standard deviations

$H \rightarrow Z\gamma$

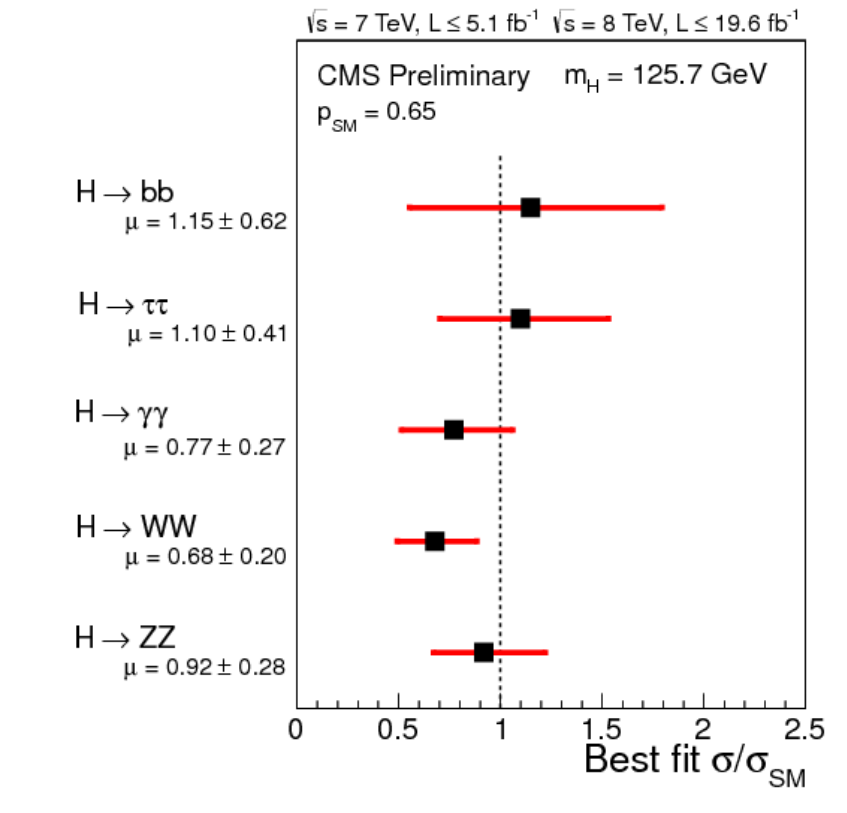


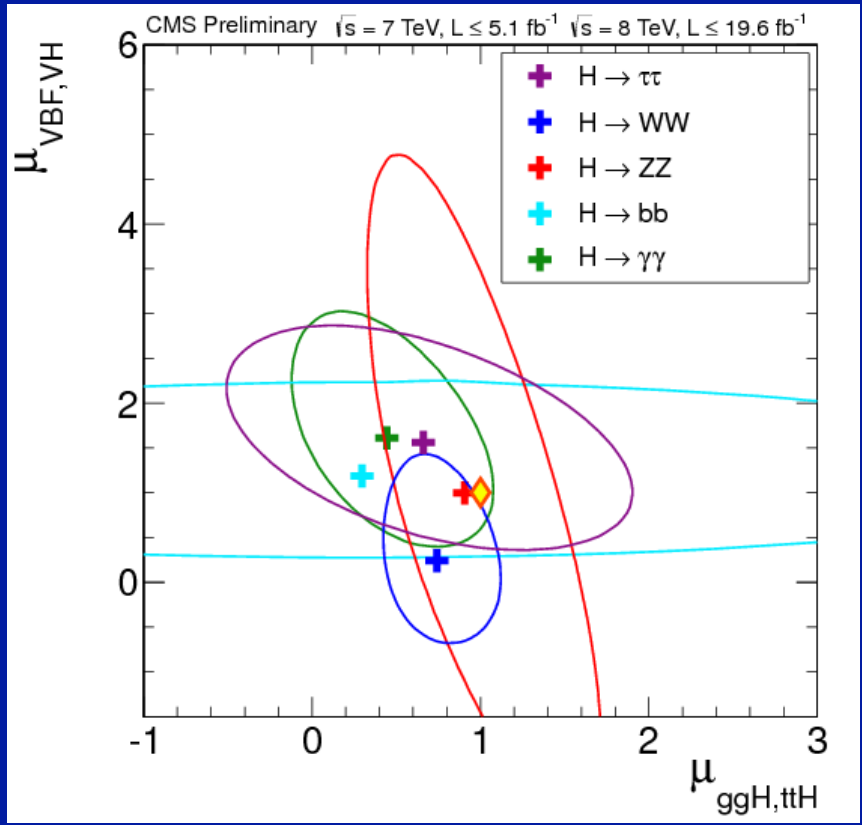
Search is performed in 4 categories

No access is found



Properties



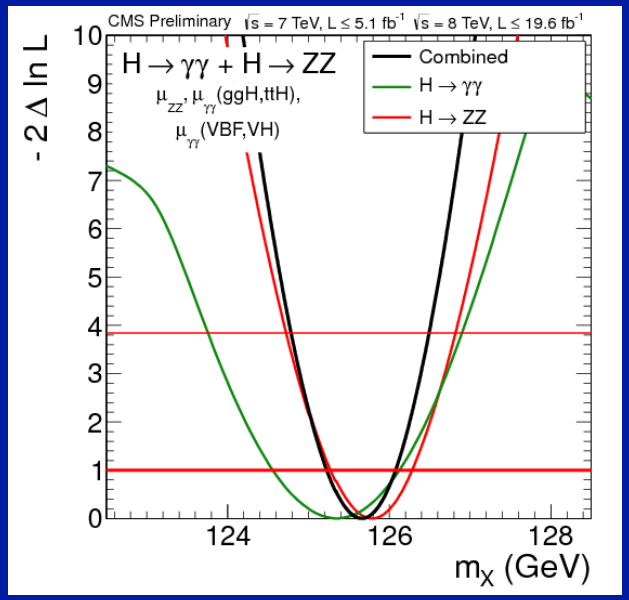


Measurements of the signal strength in all channels

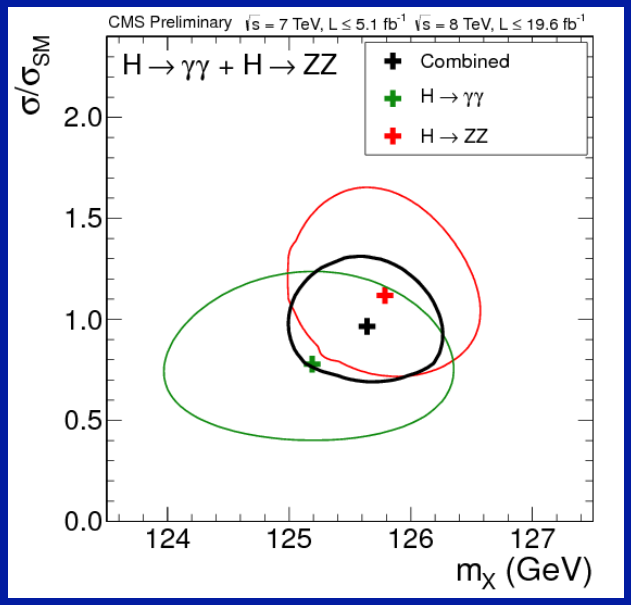
0.80 ± 0.14

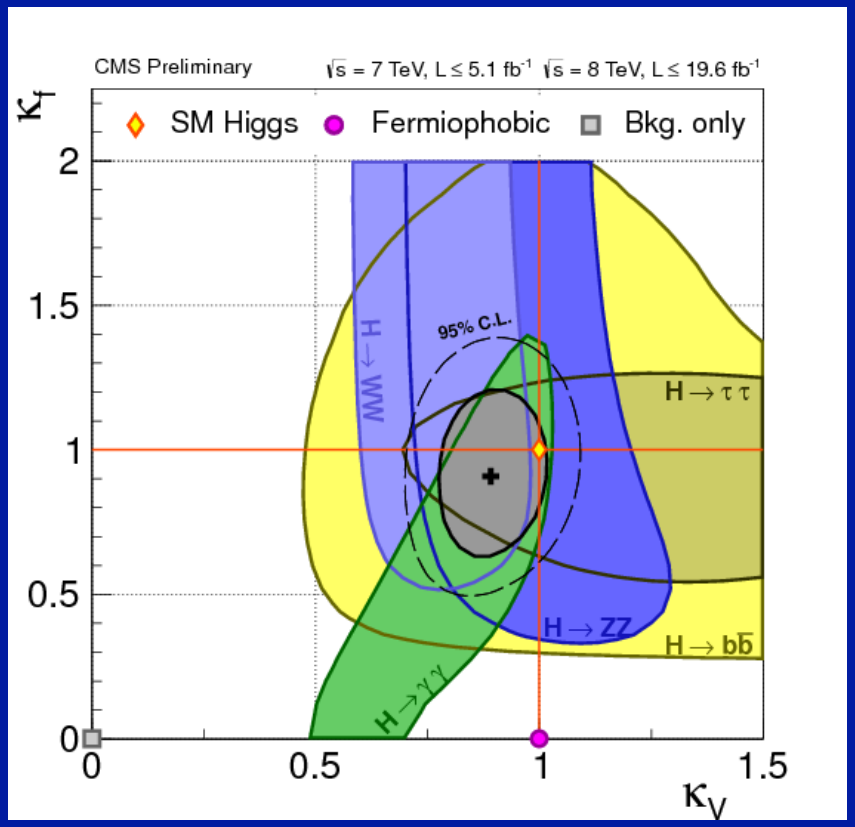
Compatibility of the observed states with the SM using signal strengths in the gluon-gluon-fusion-plus-ttH and VBF-plus-VH

Properties



$$125.7 \pm 0.3(stat.) \pm 0.3(syst.)$$



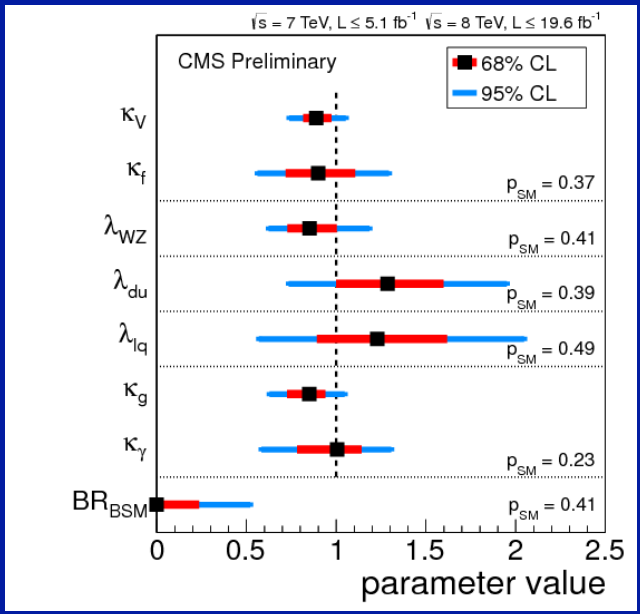


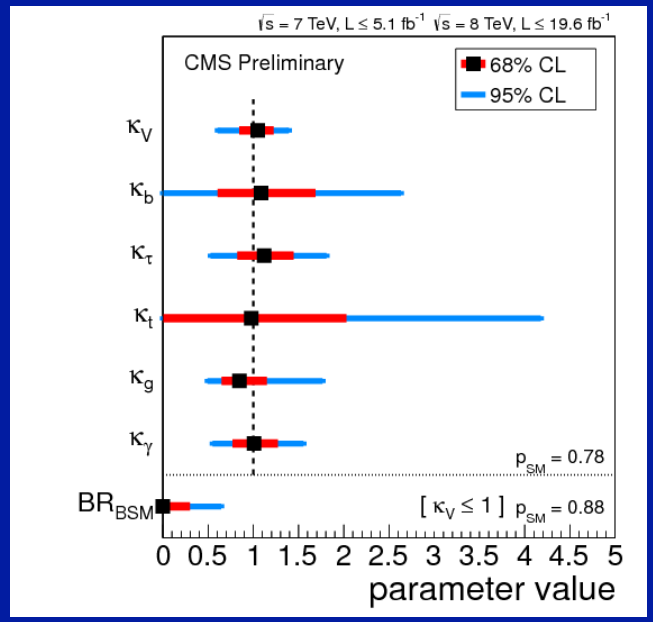
Couplings to fermions and bosons

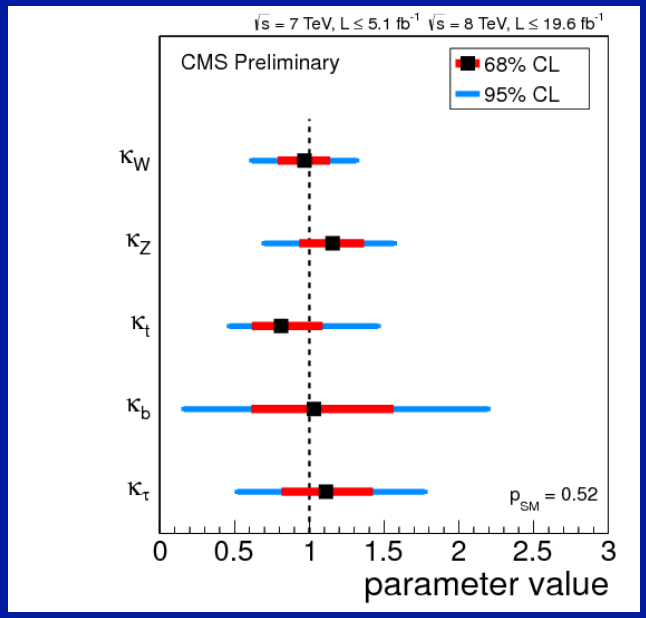
$$(\sigma \bullet BR)(x \to H \to ff) = \frac{\sigma_x \bullet \Gamma_{ff}}{\Gamma_{tot}}$$

Partial width is proportional to effective H couplings

Deviations in the couplings in different models







Summary of the fits for deviations in the coupling for the LHC XS WG benchmark models

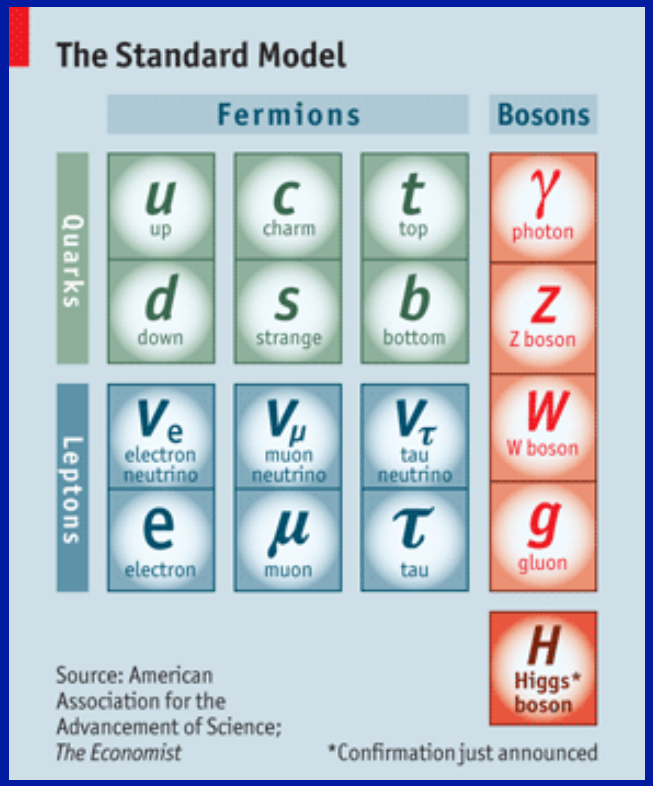
Summary of the fits for deviations in the coupling for the generic six-parameter model including effective loop couplings

Summary of the fits for deviations in the coupling for the generic five-parameter model not effective loop couplings.

The current data do not show any statistically significant Anomalies with respect to the SM Higgs boson hypothesis.

Conclusions

A boson signature we observe at 125 GeV in many channels has properties consistent with the SM expectations.



With more luminosity expected after shut down we will be able to perform more precise measurements and to better explore different decay channels and production mechanisms.