Searches for NON-Standard Model Higgs at CMS

Roberta Volpe

National Central University, Taiwan

on behalf of the CMS Collaboration

MCTP Higgs Symposium
Ann Arbor, April 16-20 2012

Why searching for BSM Higgs?

SM Higgs:

one doublet of complex scalar fields

$$\mathcal{L} = -\frac{1}{4}F^a_{\mu\nu}F^{a\,\mu\nu} + i\bar{\psi}\,\not{D}\psi + \psi^T\lambda\psi h + h.c. + |D_\mu h|^2 - V(h)$$

already experimentally established

no experimental evidence for it

SM has some issues

- Quadratic divergences of Higgs mass
- Existence of Dark Matter
- Asymmetry between matter and antimatter
- Neutrino masses
- it does not include gravity
- it provides three different kind of interactions, each one with its coupling
- .....

$$V = \mu^2|\phi|^2 + \lambda|\phi|^4$$

sign chosen in order to have EW symmetry breaking

SM does't justify the sign

we would like a theory which can explain the EWSB

many models have been developed that include the SM as its extrapolation at the energies explored so far, both within the SUSY scenario and in different frameworks

CMS has a wide research program which covers many of such models in several signatures

Outline

Model: Signatures covered in this talk:

SUSY

Model		Signatures covered in this talk
Minimal Supersymmetric Standard Model (2HDM type II)	(h^0, A^0, H^0) (H^+, H^-)	▶ search for Neutral Higgs decaying to tau leptons ▶ search for Charged Higgs in top pairs production
Next-to-Minimal Supersymmetric Standard Model	(H^+, H^-) (h_1, h_2, h_3) (a_1, a_2)	▶ search for a *light boson* decaying in opposite sign di-muon pairs

non SUSY *it means: *non exclusively SUSY*

SM with 4th generation (SM4)	cross sections enhanced w.r.t. SM	▶ interpretation in SM4 of the same analyses used for SM Higgs searches

Minimal Seesaw Model of type II
triplet of Higgs fields

- doubly charged Higgs → ▶ search for double charged Higgs in 3 or more leptons final states
- Neutral Fermiophobic Higgs

2HDM type I

technicolor

.....

→ ZZ — same SM signatures

→ WWW — three leptons final state

→ $\gamma\gamma + X$ — combination of exclusive (lepton and jet tagged) channels and the non tagged one

Higgs sector in SUSY (MSSM)

Minimal Supersymmetric extension to the SM

Higgs sector in SUSY theory needs 2 Higgs doublets each with 4 degrees of freedom

$$H_u = (H_u^+,\ H_u^0) \text{ and } H_d = (H_d^0,\ H_d^-)$$

$$v_u = \langle H_u^0 \rangle, \qquad v_d = \langle H_d^0 \rangle$$

$$\tan\beta \equiv v_u / v_d$$

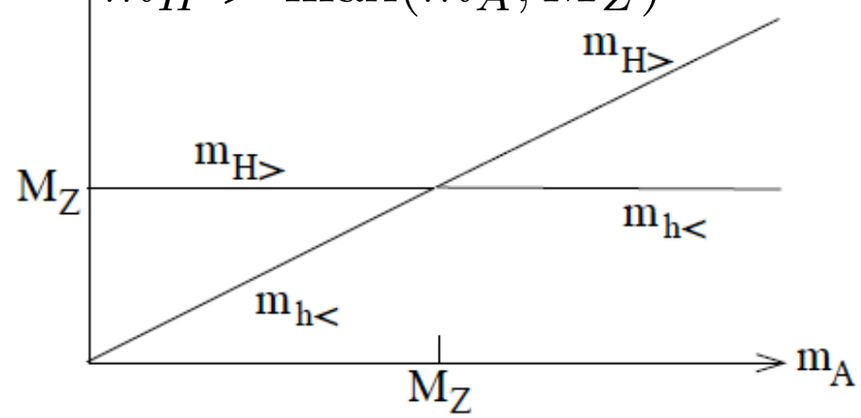
8 real scalar degrees of freedom

after
EWSB => 3 d.o.f. go to "Goldstone"
5 scalar mass eigenstates:

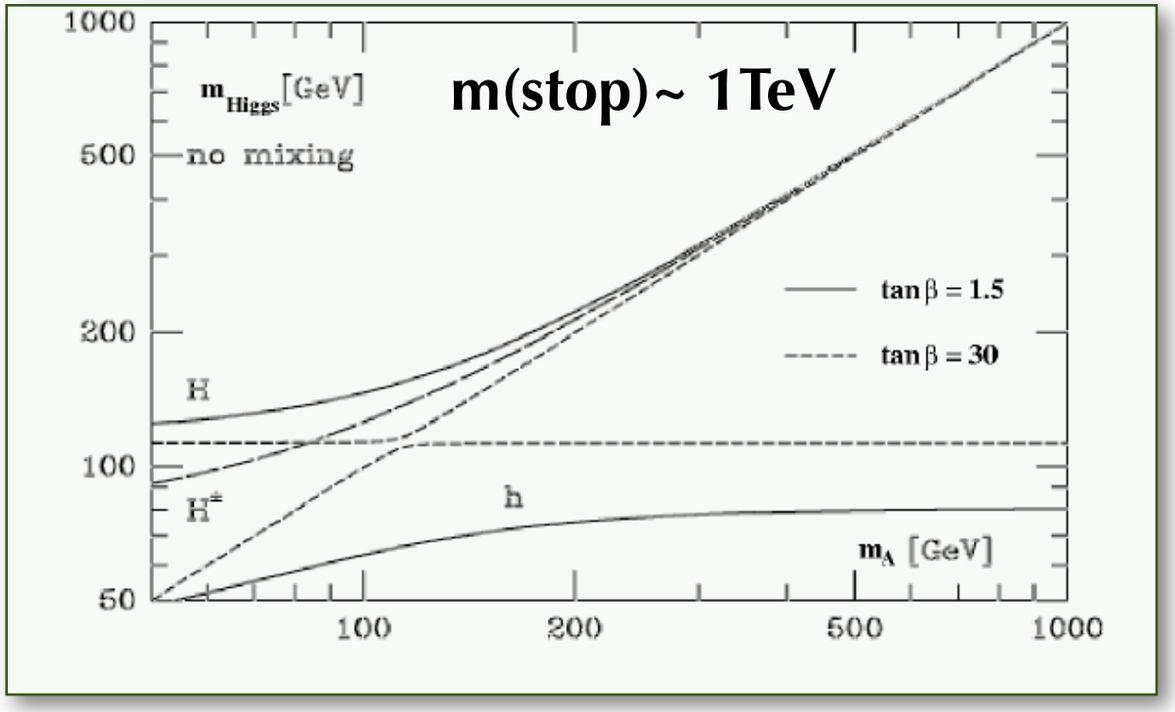
1 Standard Model like Higgs: h with CP=+1
2 neutral Higgs: A with CP=-1 and H with CP=1
2 charged Higgs: H^+ and H^-

m_h and m_H bounds as a function of m_A

$$m_h < \min(m_A, M_Z)|\cos 2\beta| < \min(m_A, M_Z)$$
$$m_H > \max(m_A, M_Z)$$



with radiative corrections:

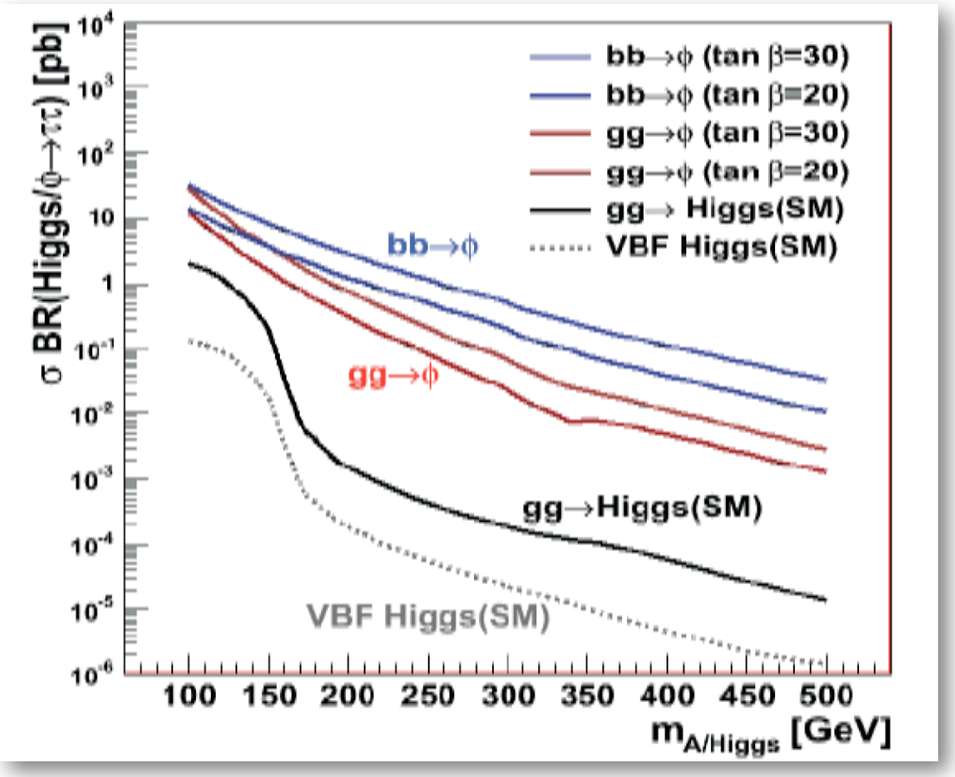


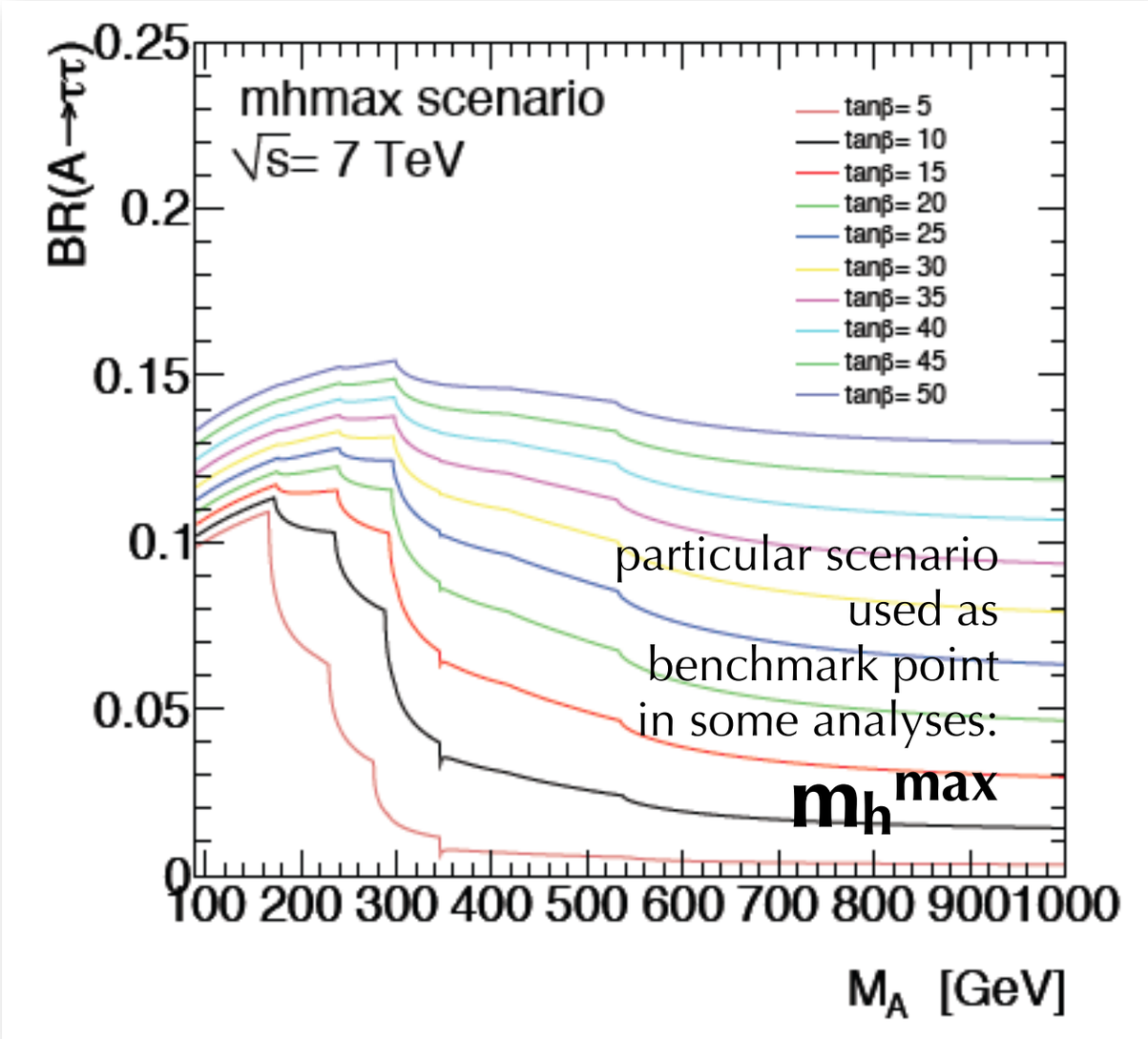
Theory and Phenomenology of Sparticles
Drees, Godbole, Roy

The importance of final states with taus

Decays to b-quark (~90%) and **τ (~10%) pairs enhanced at all masses**

Production rate enhanced by x **tan²β**





CMS has performant and robust algorithms to reconstruct the tau decaying hadronically. in addition, the Particle Flow technique is particularly suitable to reconstruct the taus products

see talk SM Higgs ->taus by Michail Bachtis for details

MSSM H->ττ

L=4.6 fb^{-1}

arXiv:1202.4083

selection

ττ reconstructed in
leptons (e,**μ**) + hadrons (1 prong+nπ^0, 3 prong)

3 channels: μτ$_h$, eτ$_h$, μe

the **neutrinos** produced in the decay tend to be produced **nearly collinear with the visible products**

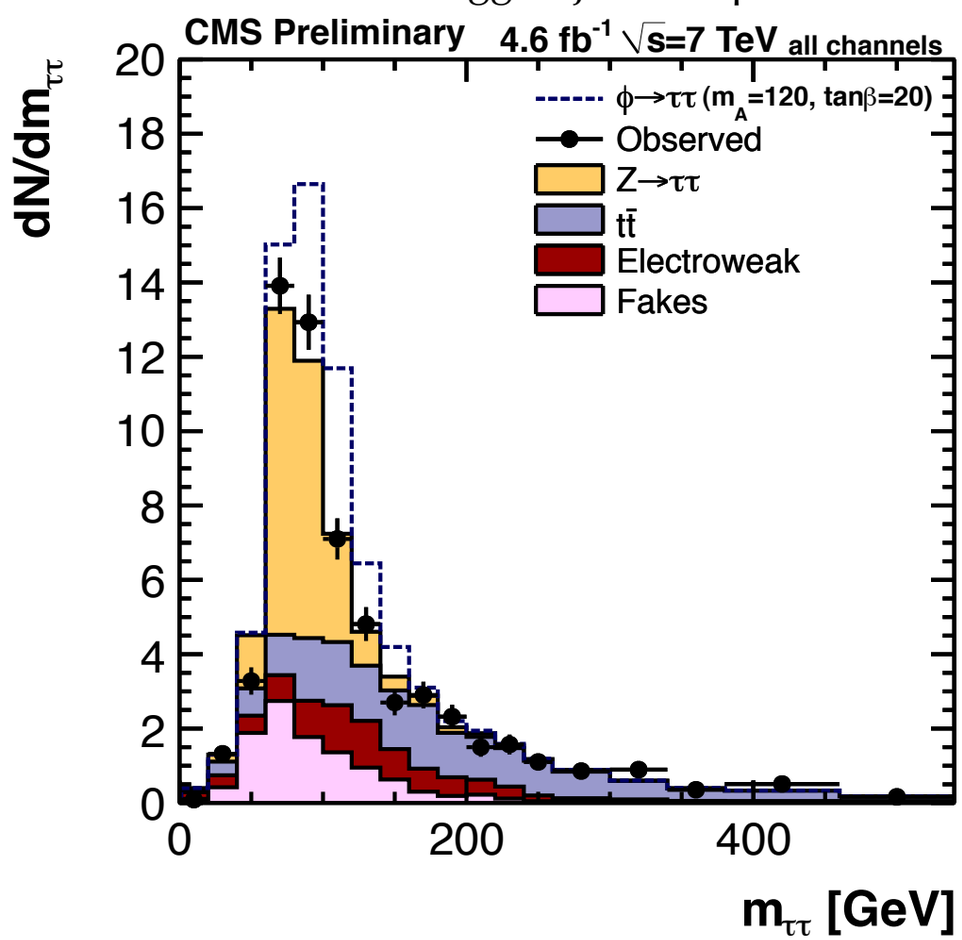
this feature is exploited to construct a variable is with discriminant power between signal and background

Kinematic Fit to improve the mass resolution with missing neutrinos δm/m~20% (25% without KF)

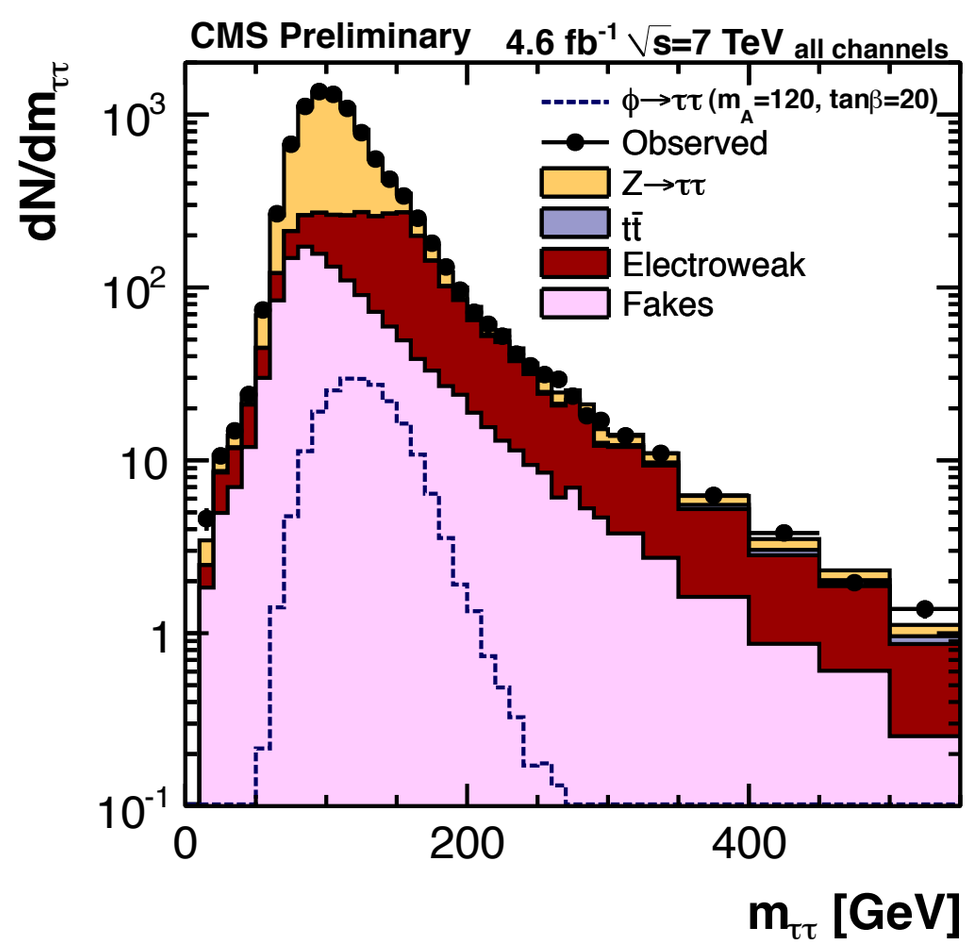
large probability for having a b-jet in the central region

two mutually exclusive categories:

b-Tag category: at most one jet with $p_T > 30$ GeV and at least one b-tagged jet with $p_T > 20$ GeV.



Non b-Tag category: at most one jet with $p_T > 30$ GeV and no b-tagged jet with $p_T > 20$ GeV.



Sum of the 3 channels

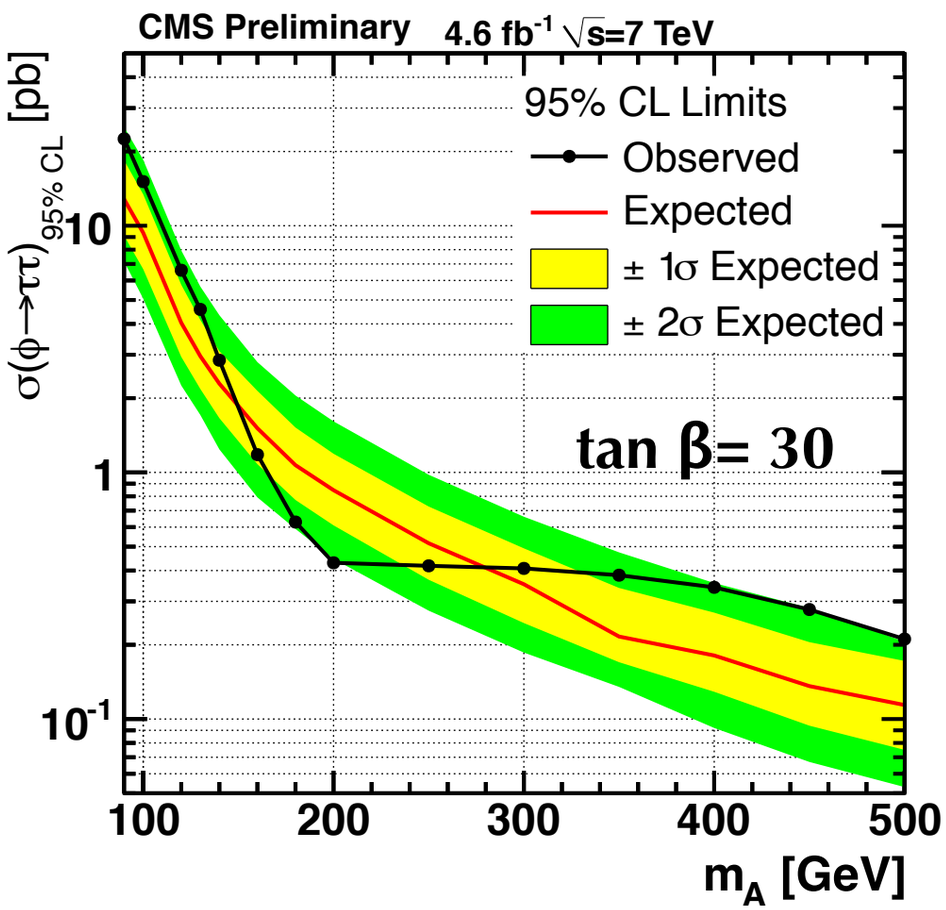
MSSM H->ττ

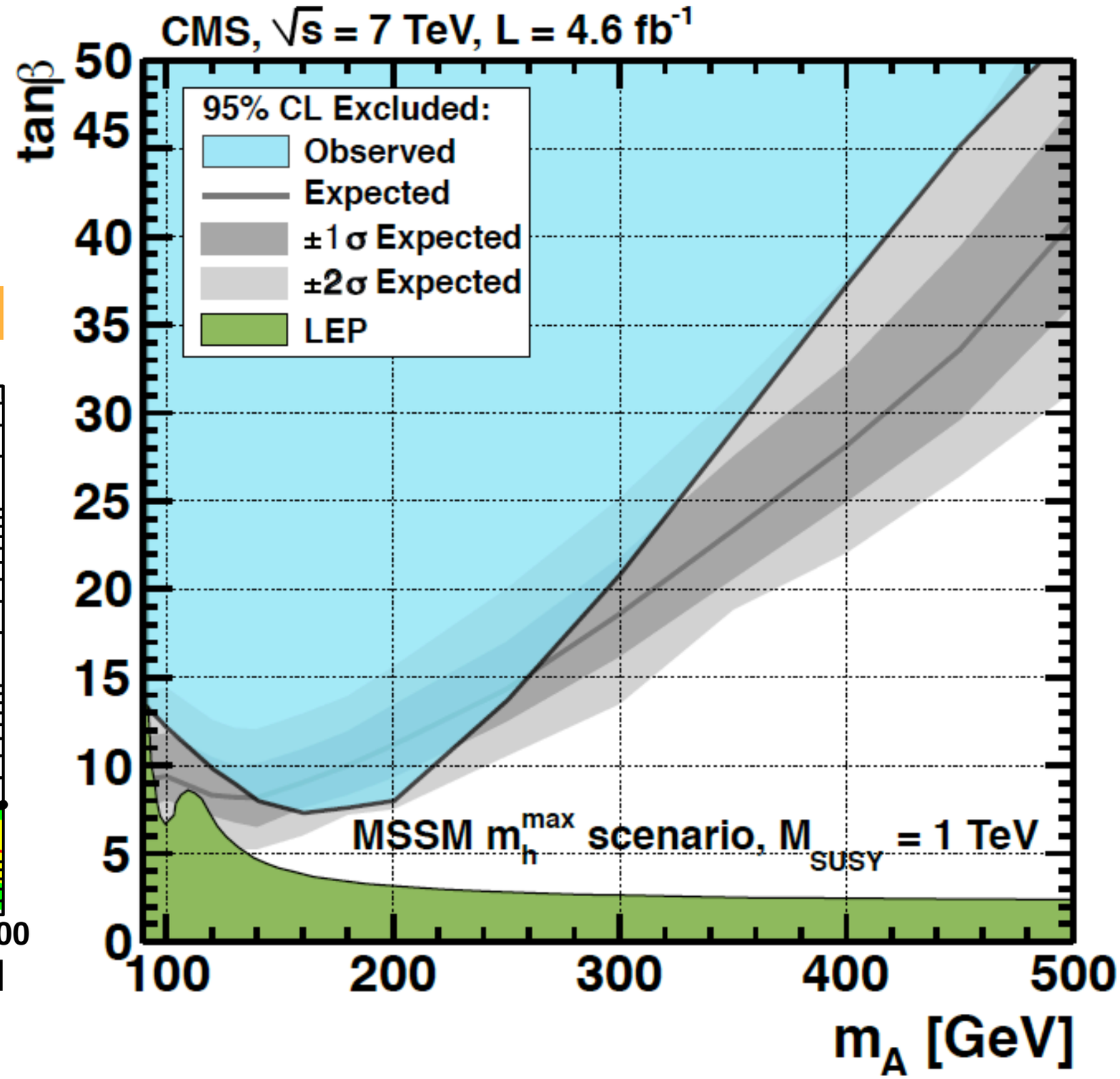
L=4.6 fb^{-1}

arXiv:1202.4083

for a fixed tan β

CMS PAS HIG-11-029





MSSM: charged Higgs in top pair

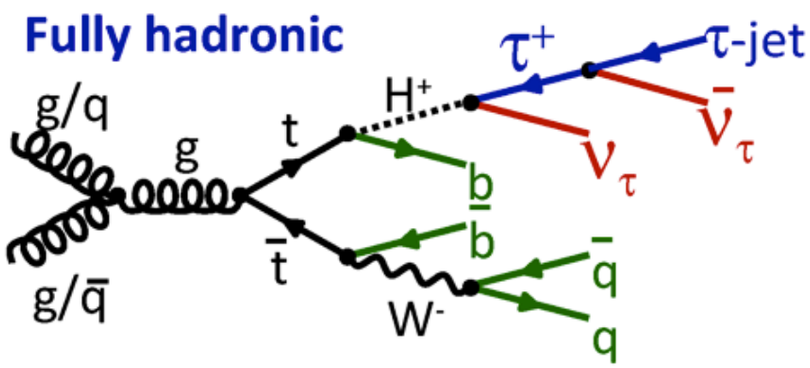
L=2.2 fb^{-1}

CMS PAS HIG-11-019

$m_{H^+} < m_t - m_b$ ⇒ $t \to H^+ b$

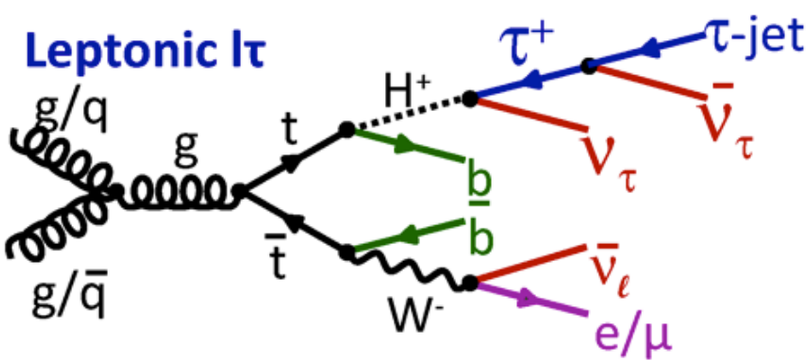
for $\tan\beta > 5$
H^+ preferentially decays as $H^+ \to \tau^+ \nu_\tau$ ⇒

analysis strategy:
Look for an enhancement of taus w.r.t. other leptons in the final state, in top pair events

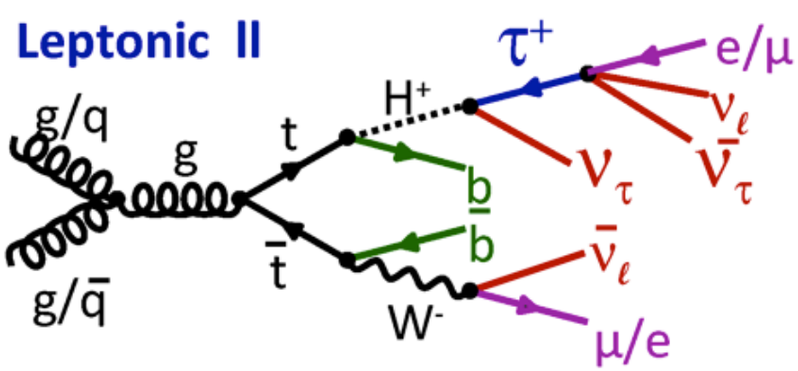


Selection:

- One isolated hadronic tau,
- no isolated leptons
- Large missing ET
- At least 3 jets with at least a b jet



- One isolated hadronic tau
- One isolated opposite sign lepton
- Large missing ET
- At least 2 jets with at least a b-jet

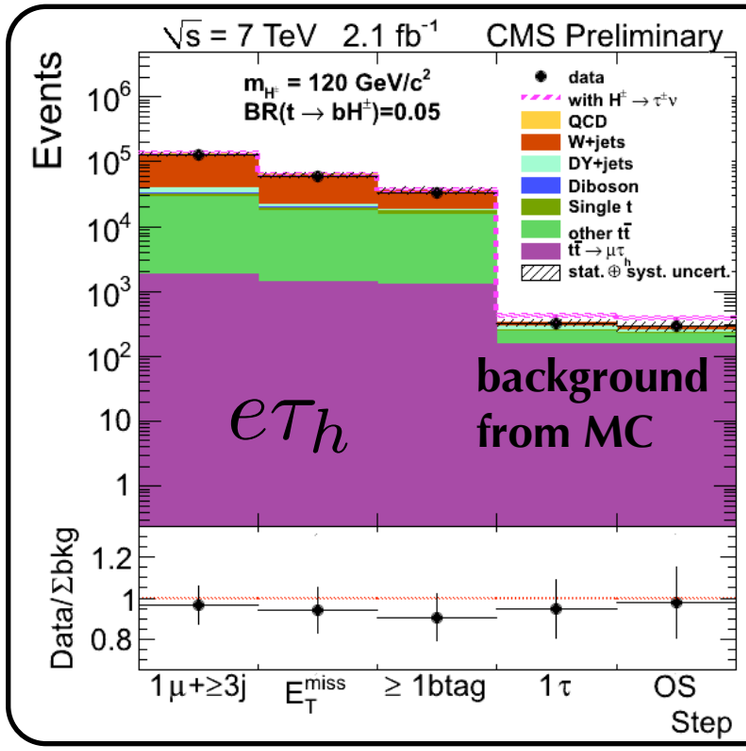


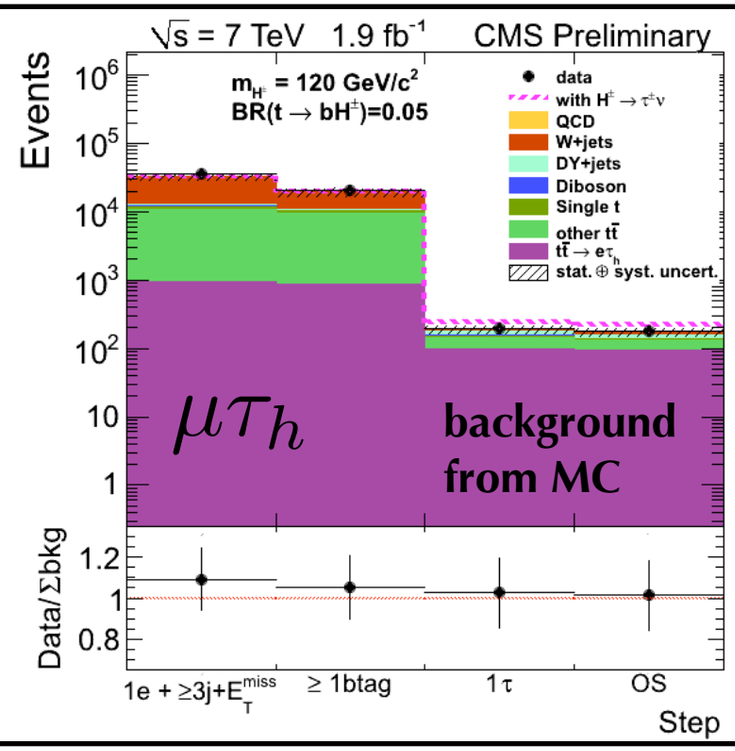
- One isolated muon and one isolated electron
- Large missing ET
- At least 2 jets with at least a b-jet

MSSM: charged Higgs in top pair

L=2.2 fb^{-1}

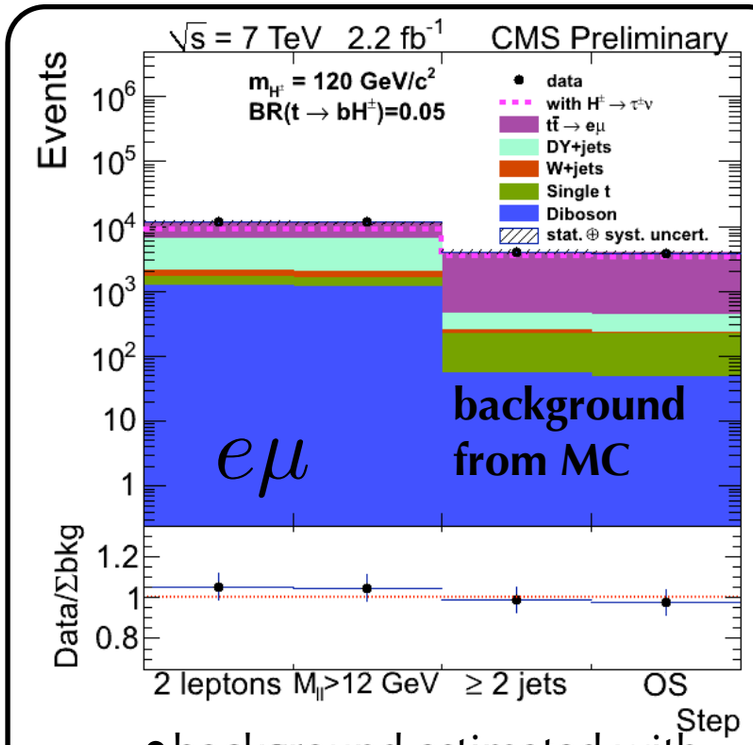
CMS PAS HIG-11-019



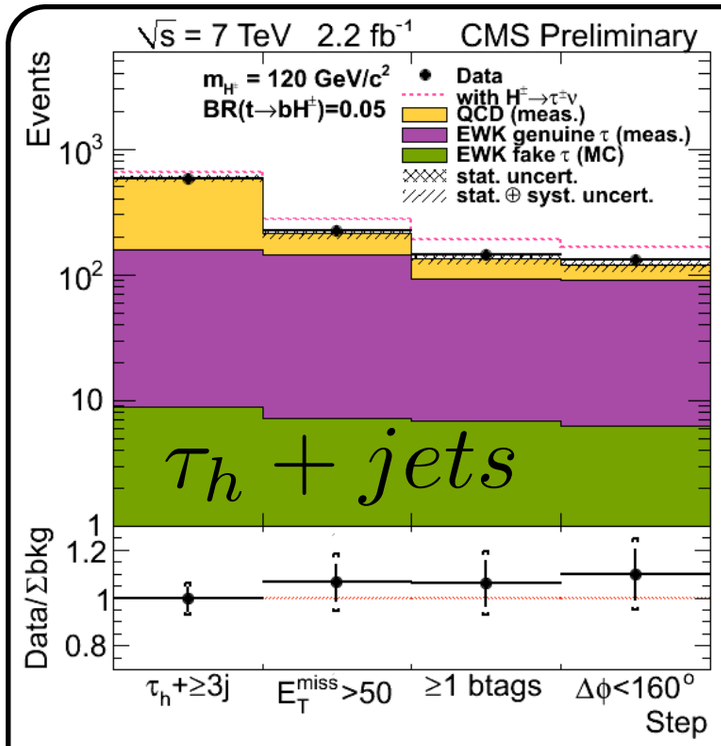


- data driven method used to estimate the fake taus background
- other bkg contributions are estimated with simulation and correction factors from data

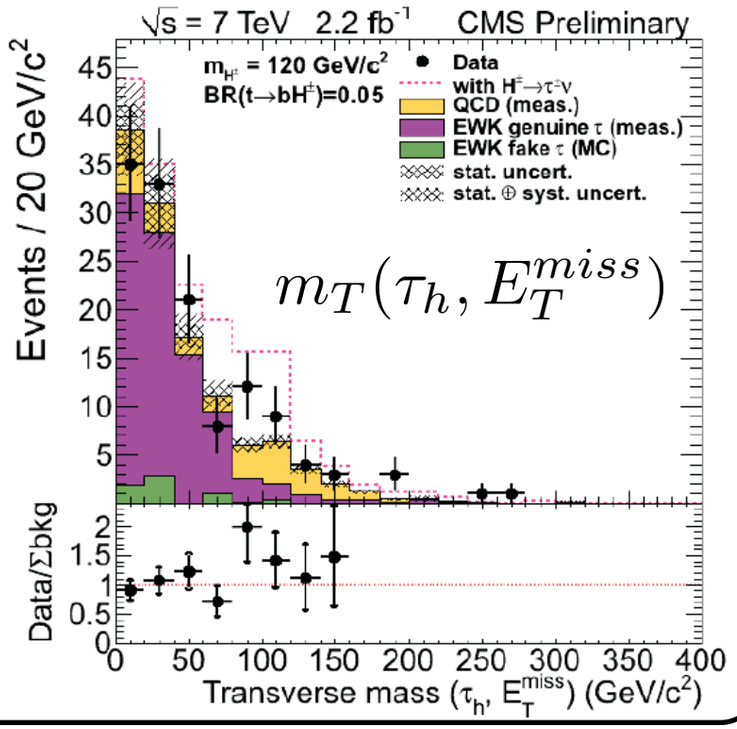
m_{H^+}=120 GeV
BR(t → H$^+$b)=0.05



- background estimated with simulation



to extract the signal: binned maximum likelihood fit to the distribution of:



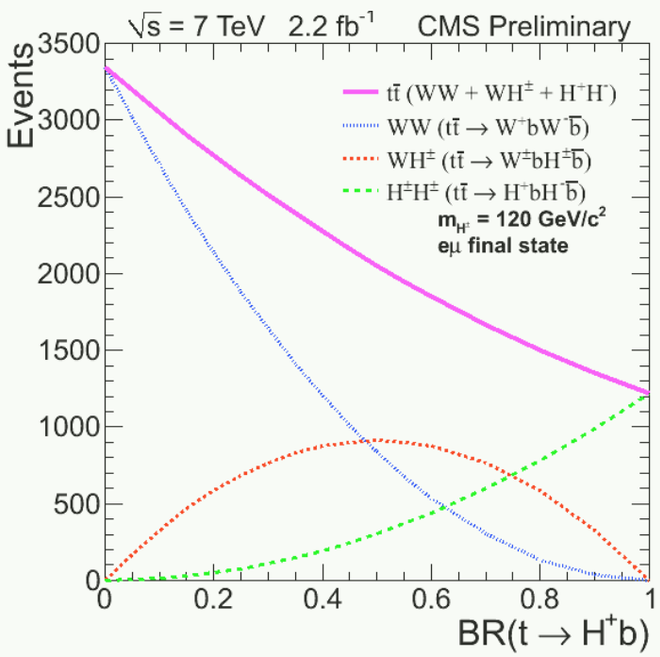
MSSM: charged Higgs in top pair

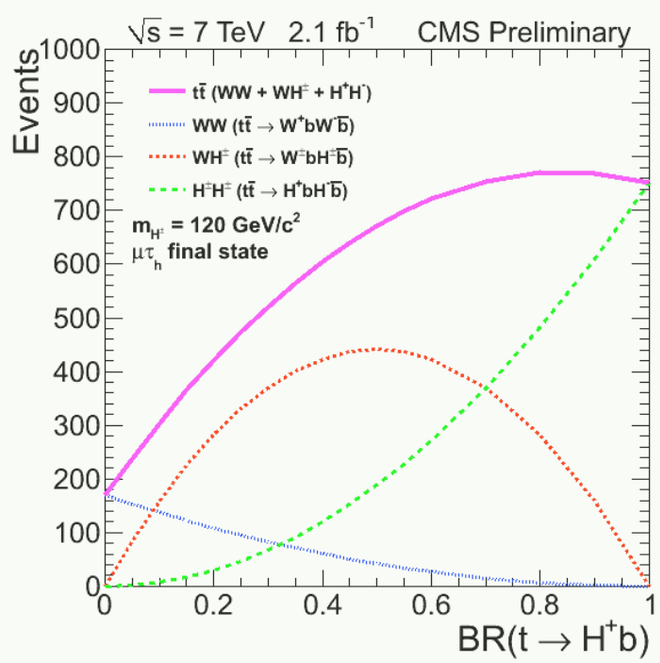
L=2.2 fb^{-1}

CMS PAS HIG-11-019

number of expected events assuming

$BR(H^+ \to \tau^+\nu)=1$





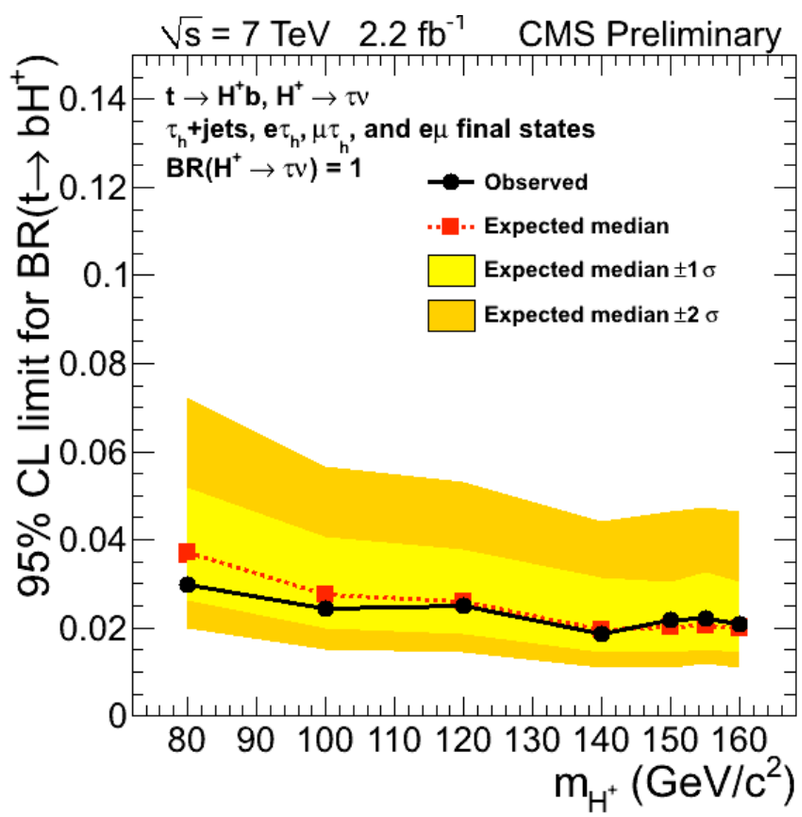
$$x = BR(t \to bH^+)$$

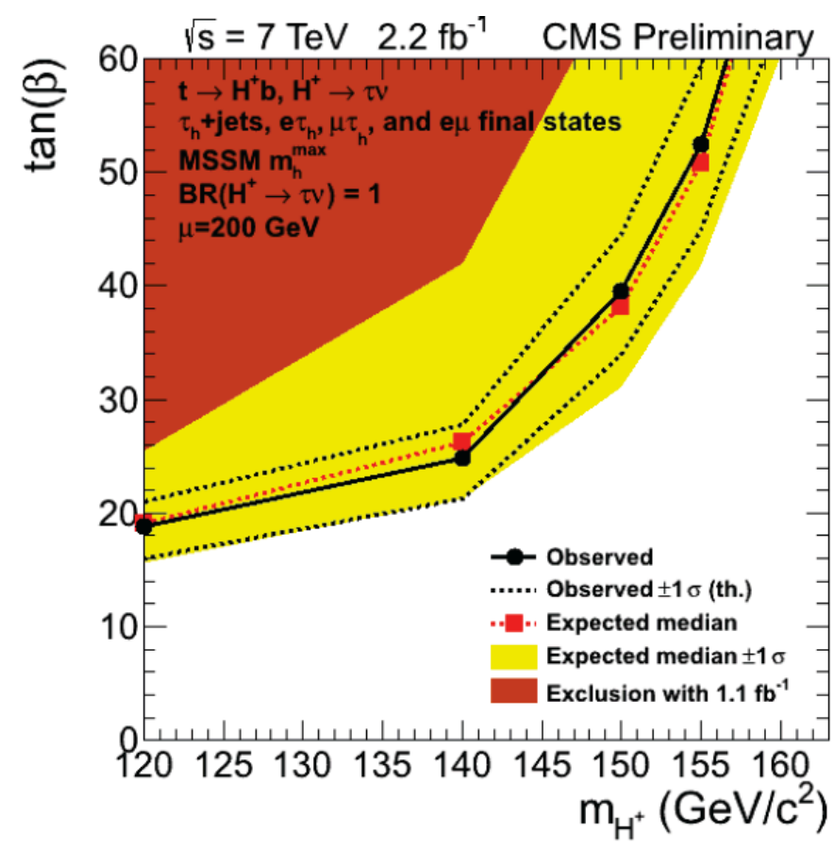
determine x for each channel by using:

from simulation

$$\Delta N = N_{t\bar{t}}^{MSSM} - N_{t\bar{t}}^{SM} = N_{WH} \cdot 2(1-x)\cdot x + N_{HH} \cdot x^2 + N_{t\bar{t}}^{SM} \cdot ((1-x)^2 - 1)$$

and set upper limit to *x* :





NMSSM a_1-> μμ

L=1.3 fb^{-1}

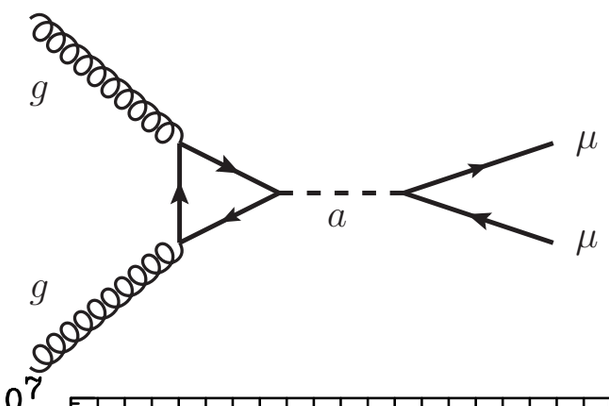
CMS PAS HIG-12-004

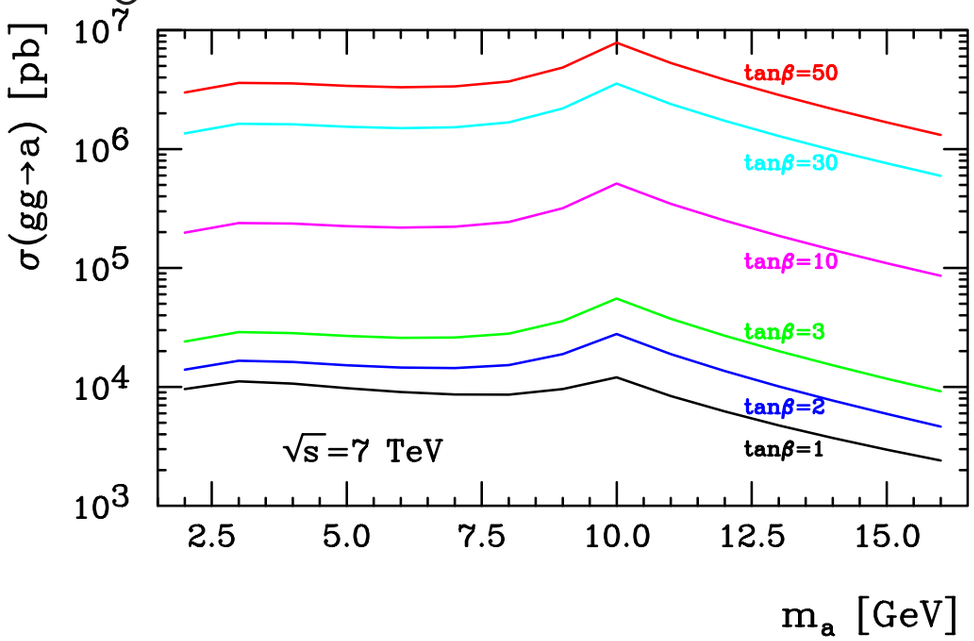
Next-to-Minimal Supersymmetric Standard Model (NMSSM):

Adds singlet scalar field, thereby expanding the Higgs sector to **three CP-even (h_1, h_2 and h_3), two CP-odd (a_1, a_2) and two charged scalars (H^+, H^-)**

this model can survive also with a Higgs at 125 GeV !

A light (~10 GeV) boson produced Search for a_1 in its decays to opposite sign di-muon pairs

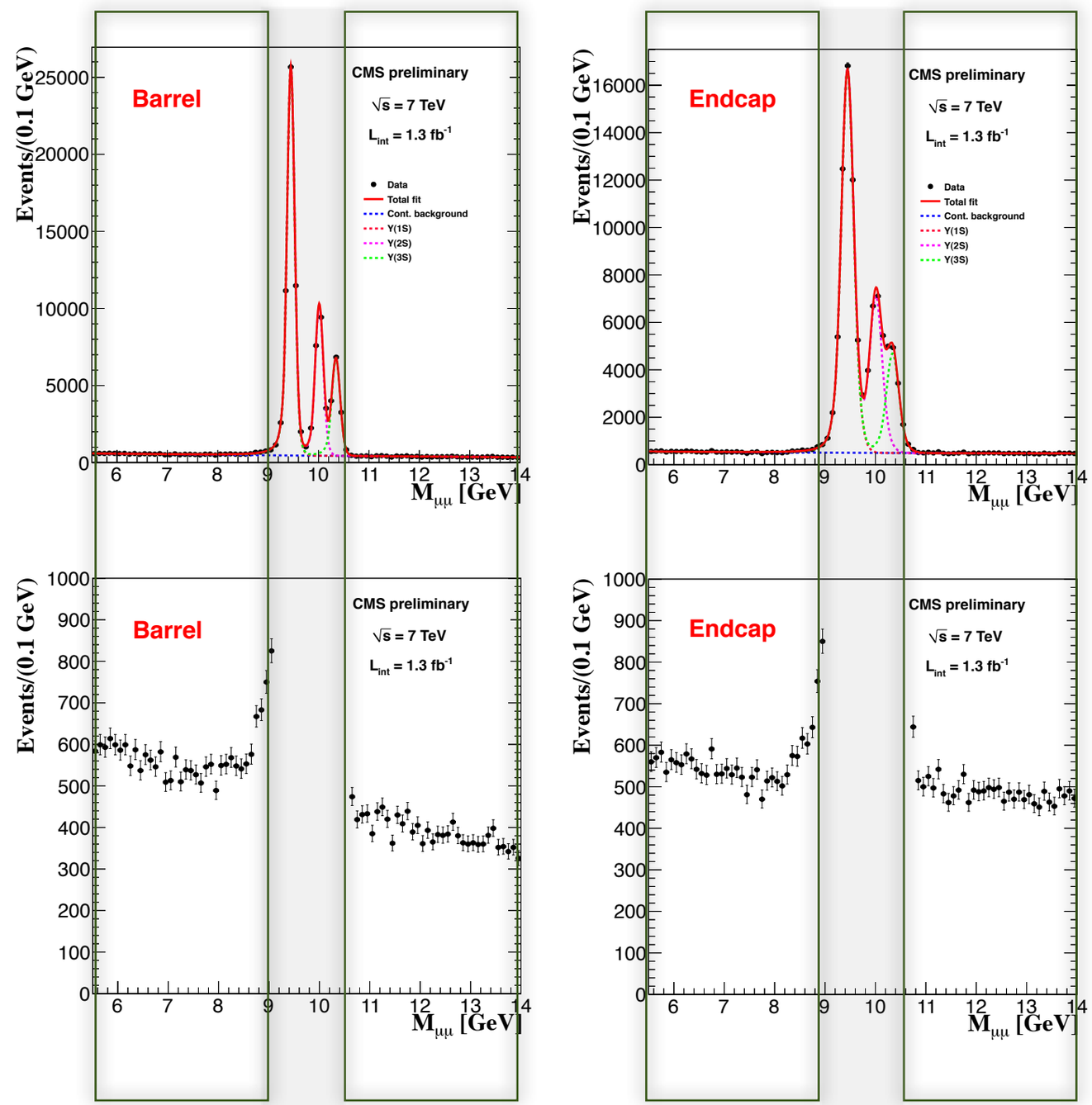




Analysis strategy

➡Chose isolated opposite sign dimuons with $p_T\mu > 4$ GeV & $p_T(\mu\mu) > 6$ GeV

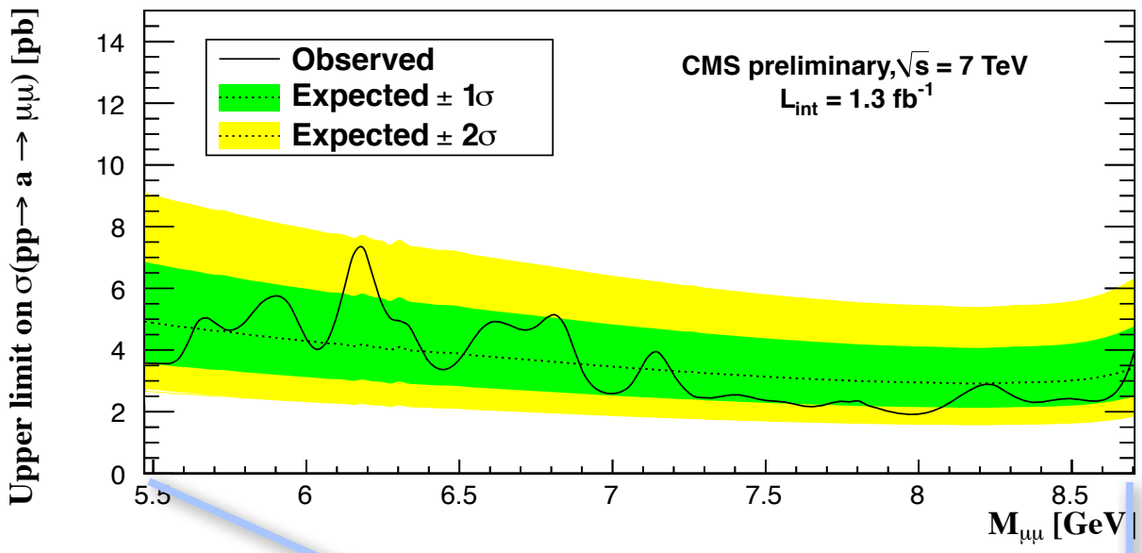
➡Search above/below the upsilon peaks in dimuon invariant mass

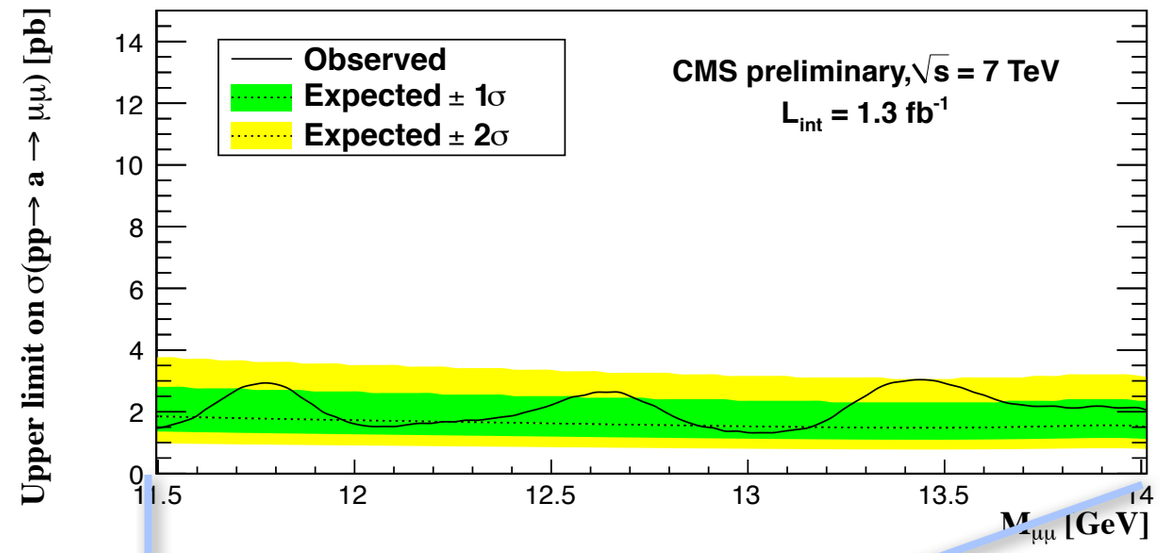


NMSSM a_1-> μμ

L=1.3 fb^{-1}

CMS PAS HIG-12-004

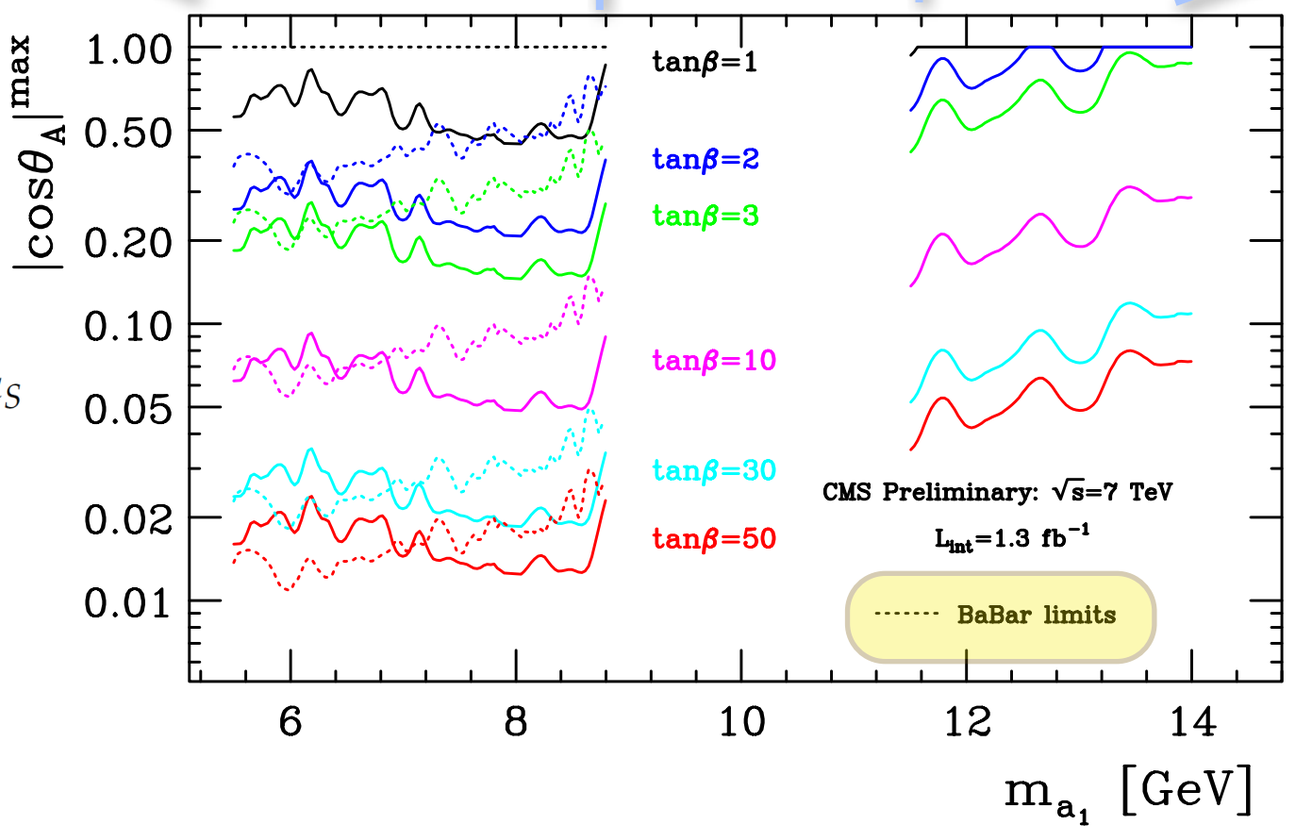




interpretation in NMSSM

Three parameters: $m(a_1)$,tanβ,$\cos\theta_A$

$$a_1 = \cos\theta_A a_{MSSM} + \sin\theta_A a_S$$



upper limits to $\cos\theta_A$ as a function of $m(a_1)$ for several values of tanβ

non SUSY

searches for Higgs in other models

Search for doubly charged Higgs

- **models with Higgs triplets (for example *Minimal Seesaw Model of type II*)**

Search for SM Higgs with xsec and BR foreseen by the

- **Standard Model with a fourth generation of fermions**

Four Statements about the Fourth Generation (B.Holdom, 2009)

1) The 4th generation is not excluded by EW precision data;
2) SM4 addresses some of the currently open questions;
3) SM4 can accommodate emerging possible hints of new physics;
4) LHC has the potential to discover or fully exclude it

Search for FermioPhobic(FP) Higgs:

EWSB mechanism responsible for generating the masses of gauge bosons is independent from the mechanism that generate fermion masses

- **H-> WW, ZZ : is SM-like**
- **H-> γγ : only W loop**
- **only VBF and VH production modes (assumed with the SM xsec) at least at tree level**

this scenario is common in

- **Two Higgs Doublet Model (2HDM) type I**
- **models with Higgs triplets (for example *Minimal Seesaw Model of type II*)**
- **.....**

non SUSY

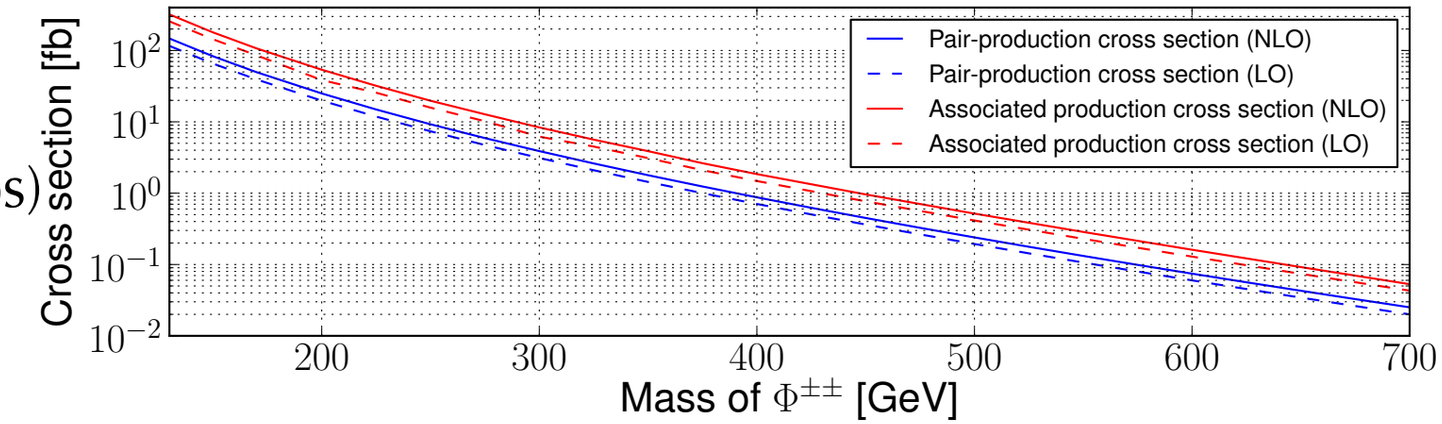
doubly charged H

L=4.6 fb^{-1}

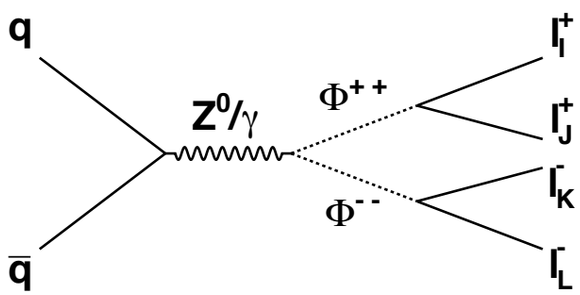
CMS PAS HIG-12-005

if there exist a ***triplet of Higgs fields?*** for example it is foreseen by the ***Seesaw mechanism type II*** (the most accredited model giving mass to neutrinos)

$\phi^{++/--}$ would decay to same sign leptons, also flavor violation

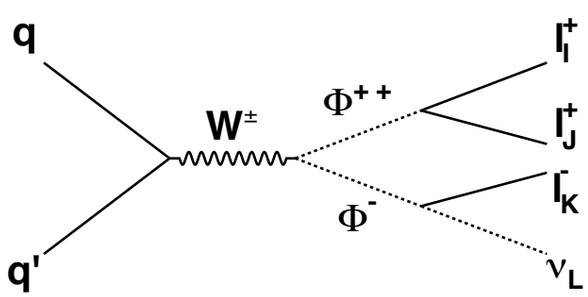


pair production



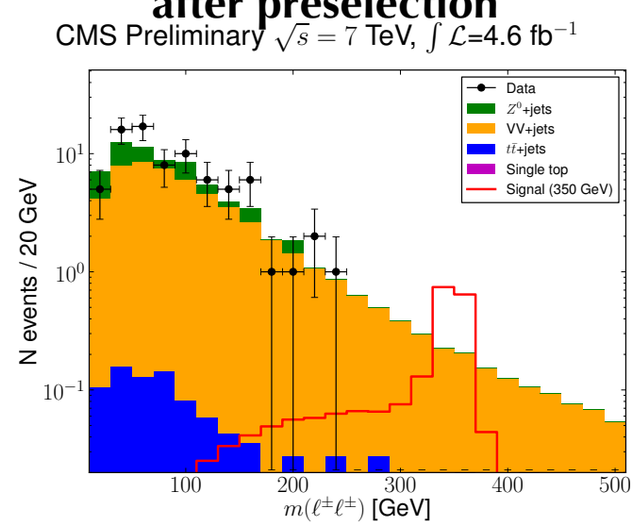
4 lepton selection

associated production

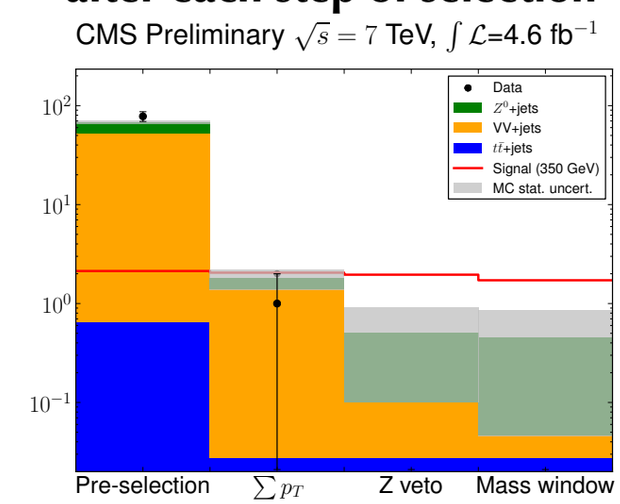


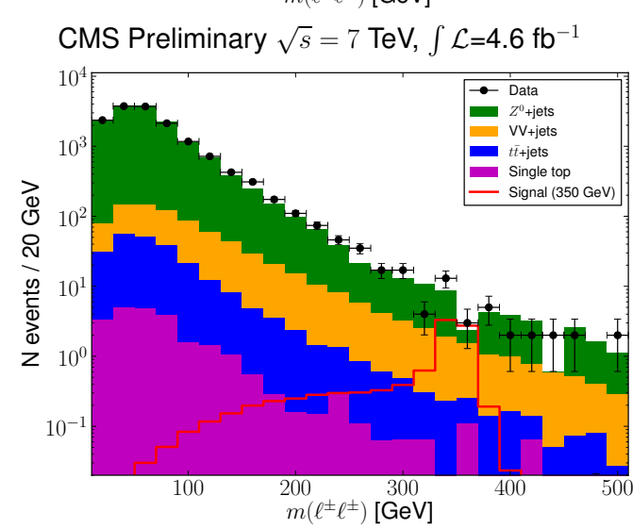
3 lepton selection

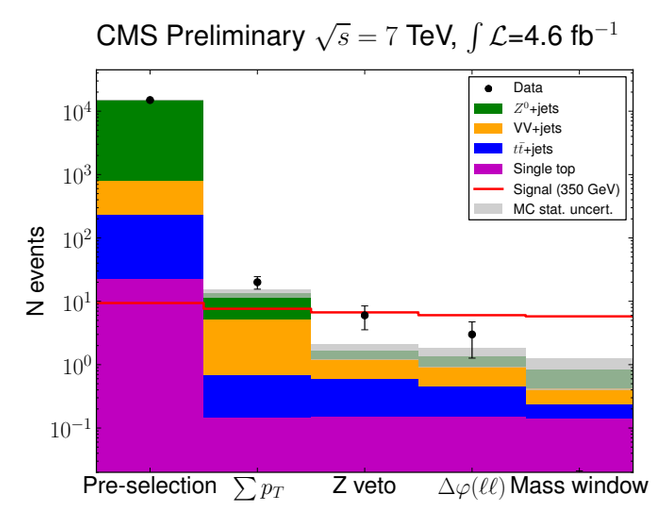
after preselection



after each step of selection







the model with BR (Φ->ττ) = 100% has a different selection (the kinematic of the final leptons is different)

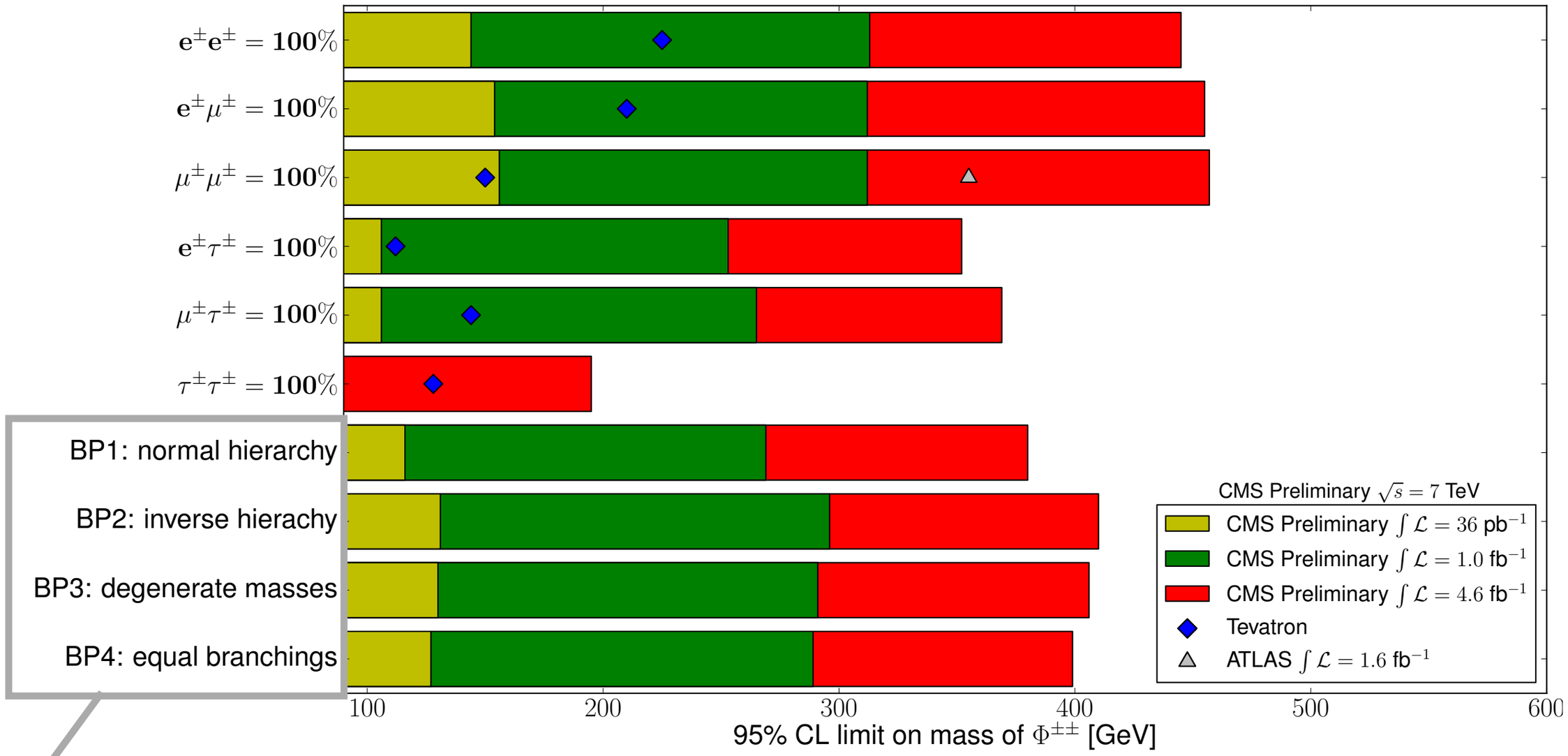
non SUSY

doubly charged H

L=4.6 fb^{-1}

CMS PAS HIG-12-005

data driven methods used to estimate the background (sidebands and ABC method)



BR(φ->ll)

Benchmark point	ee	$e\mu$	$e\tau$	$\mu\mu$	$\mu\tau$	$\tau\tau$
BP1	0	0.01	0.01	0.30	0.38	0.30
BP2	0.50	0	0	0.125	0.25	0.125
BP3	1/3	0	0	1/3	0	1/3
BP4	1/6	1/6	1/6	1/6	1/6	1/6

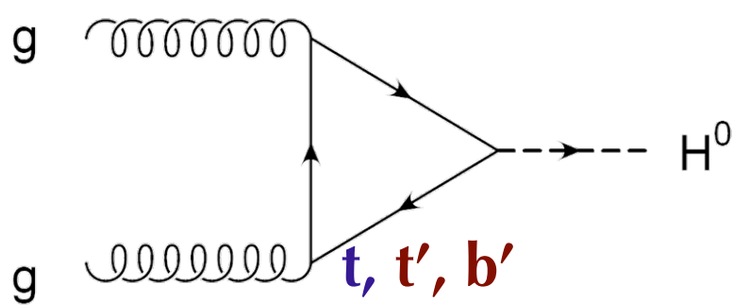
non SUSY

4th generation

L=4.6-4.8 fb^{-1}

CMS PAS HIG-12-008

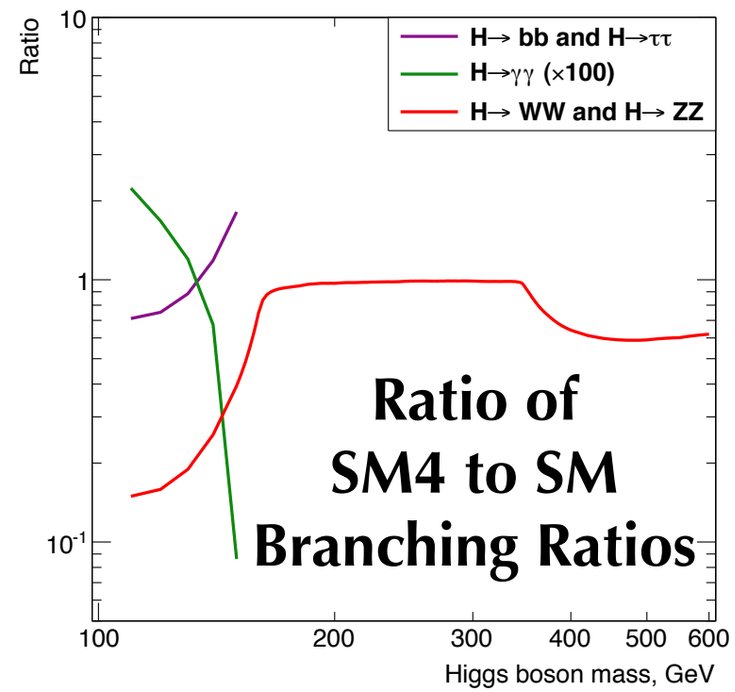
the existence of a 4th generation of fermions is not forbidden by any physical principle of the SM

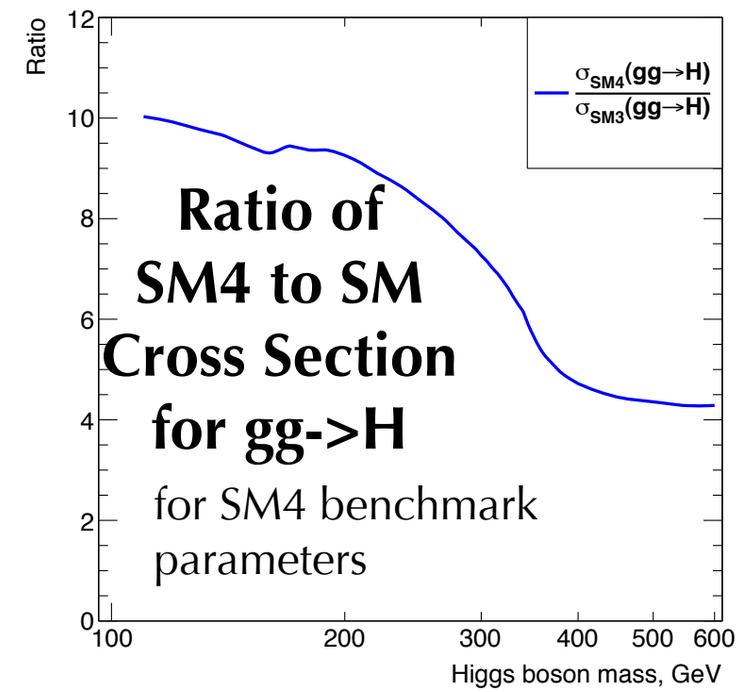


t, t′, b′ masses of ~600 GeV (for the benchmark)

m_{D4} ~ 600 GeV

m_{U4}-m_{D4} = (50 + 10 ln(m_H/115)) GeV





Channel	m_H range (GeV)	Luminosity (fb^{-1})	Sub-channels	m_H resolution
$H \to \gamma\gamma$	110–150	4.8	2	1–2%
$H \to \tau\tau \to e\tau_h/\mu\tau_h/e\mu + X$	110–145	4.6	9	20%
$H \to \tau\tau \to \mu\mu + X$	110–140	4.5	3	20%
$WH \to e\mu\tau_h/\mu\mu\tau_h + \nu$'s	100–140	4.7	2	20%
$(W/Z)H \to (\ell\nu/\ell\ell/\nu\nu)(bb)$	110–135	4.7	5	10%
$H \to WW^* \to 2\ell 2\nu$	110–600	4.6	5	20%
$WH \to W(WW^*) \to 3\ell 3\nu$	110–200	4.6	1	20%
$H \to ZZ^{(*)} \to 4\ell$	110–600	4.7	3	1–2%
$H \to ZZ \to 2\ell 2\nu$	250–600	4.6	2	7%
$H \to ZZ^{(*)} \to 2\ell 2q$	130–164	4.6	6	3%
	200–600			3%
$H \to ZZ \to 2\ell 2\tau$	190–600	4.7	8	10–15%

for some decay modes and Higgs mass ranges, xsec x BR in SM4 can be appreciably larger than in SM

same analyses developed for SM

see dedicated talks for details

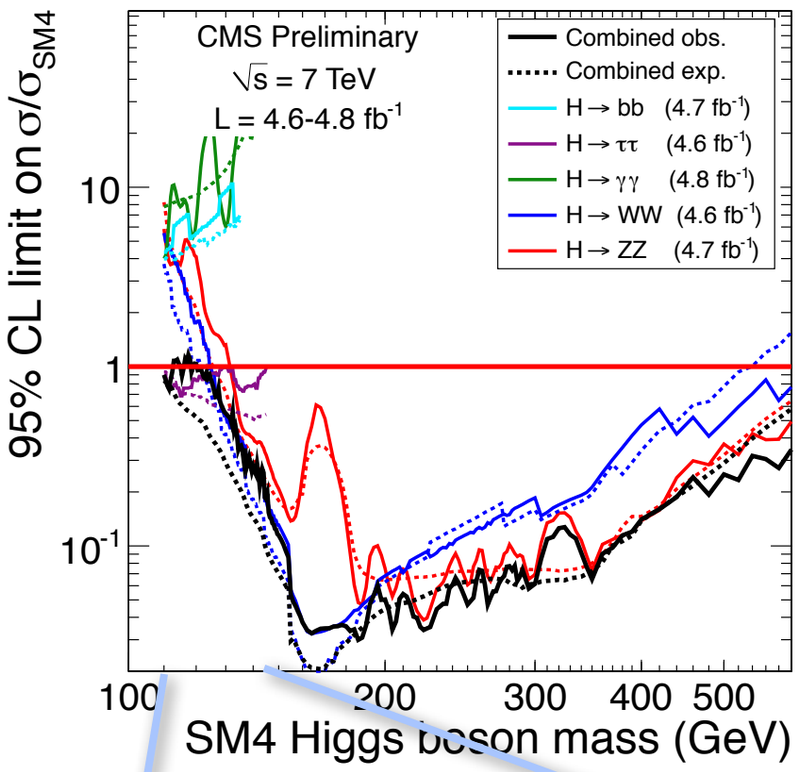
interpreted assuming SM4 cross sections and BRs

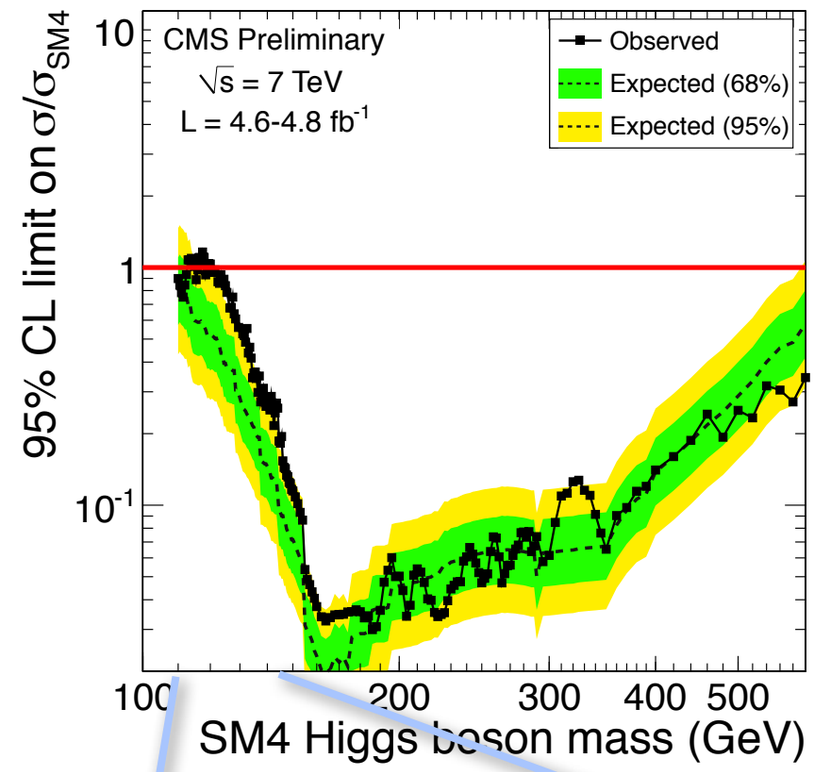
non SUSY

4th generation: results

L=4.6-4.8 fb^{-1}

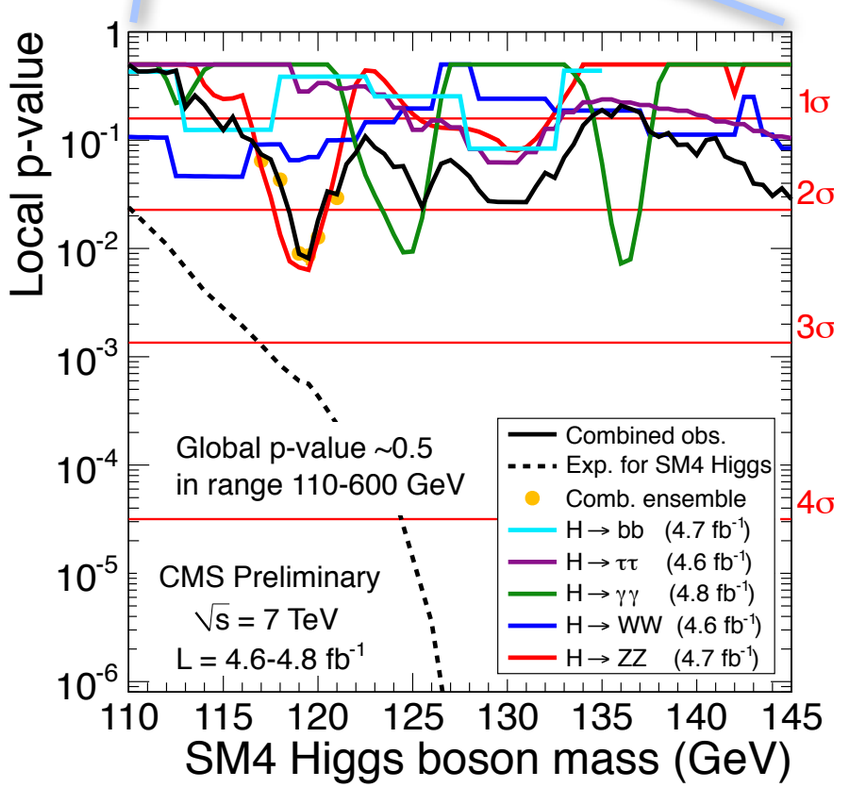
CMS PAS HIG-12-008

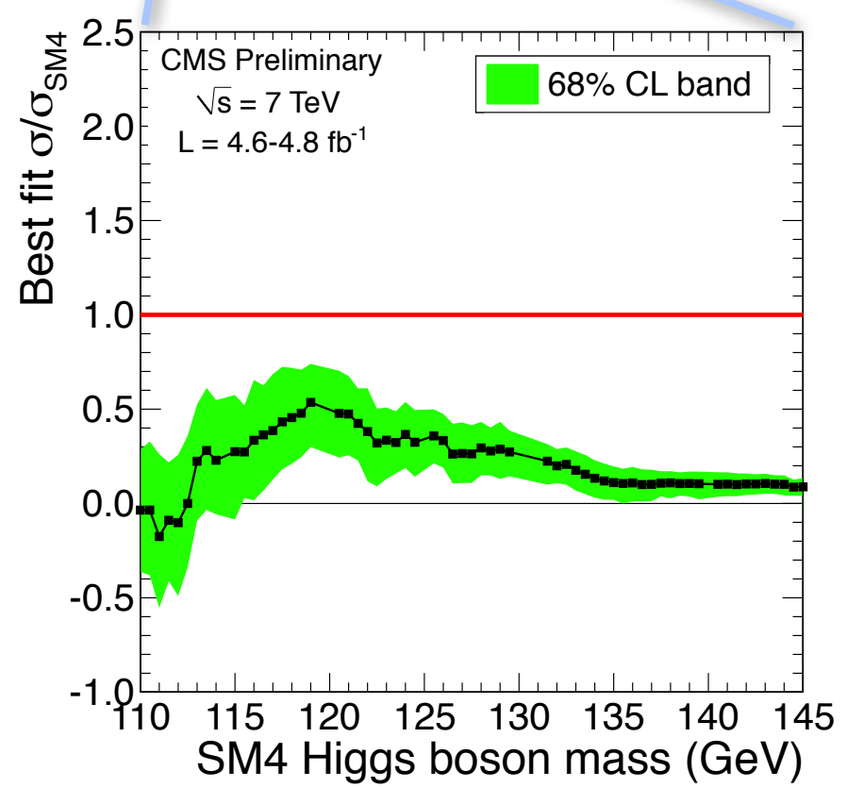




$H \to \tau\tau$ search is the most sensitive channel

excluded in the mass range 120-600 GeV at 95% CL and in 125-600 at 99% CL





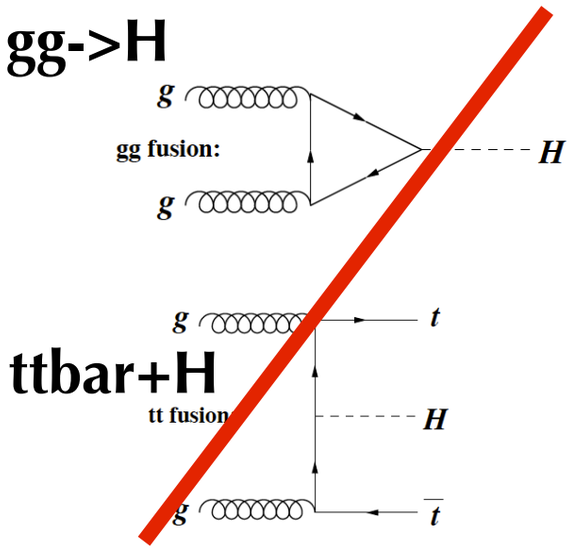
H->2 photons contributes little, so, despite the excess observed in that channel, the combined one is not consistent with SM4

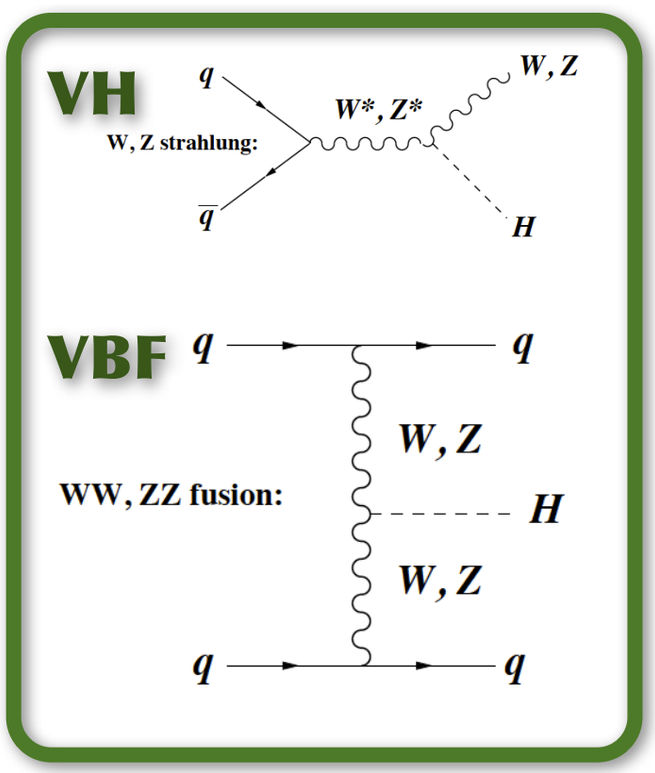
non SUSY

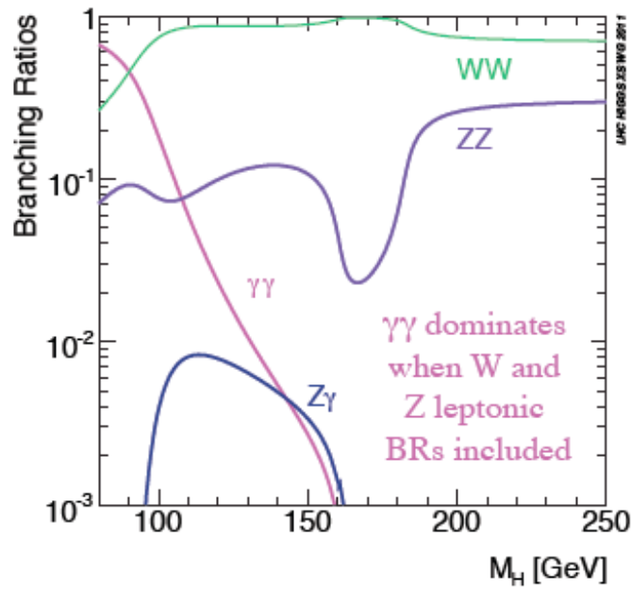
FermioPhobic (FP)- Introduction

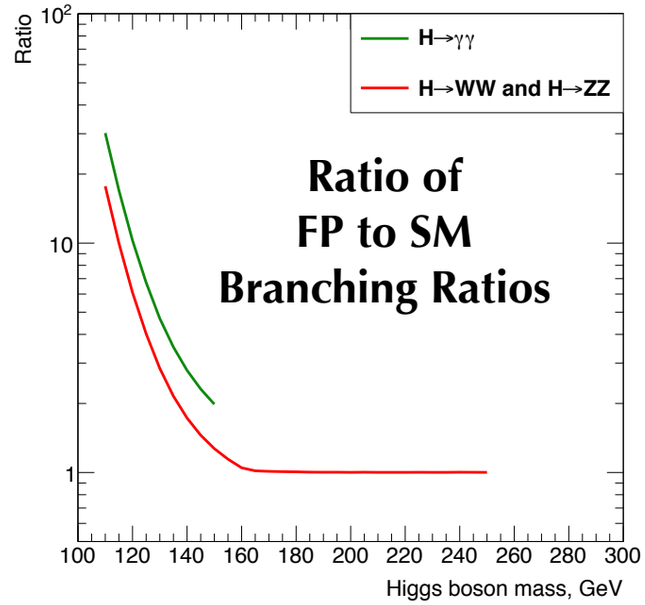
"definition":

gg->H

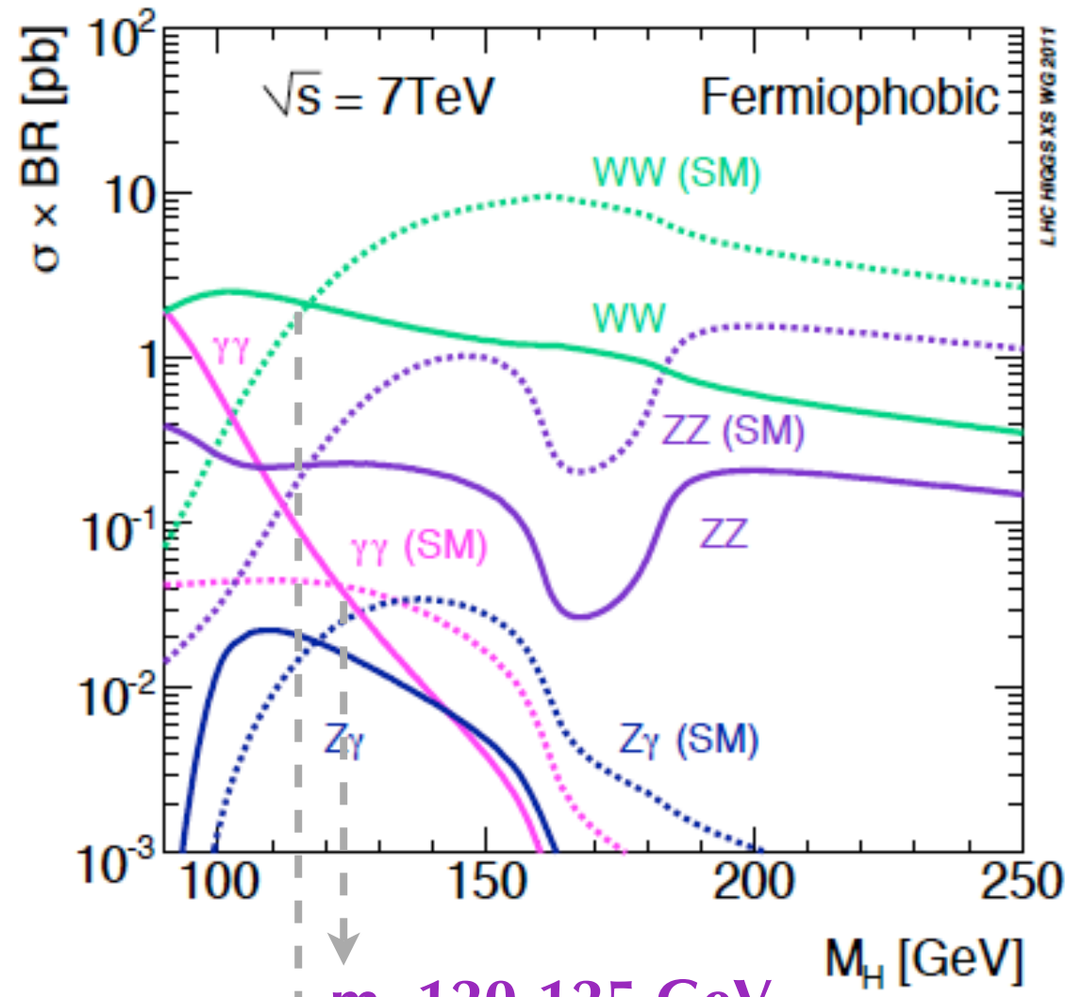








at low masses the FP rate can be much larger than in SM for some processes



m~120-125 GeV
rate(SM)~rate(FP)
for γγ

m~115 GeV
rate(SM)~rate(FP) for ZZ WW

non SUSY

FP: HW->WWW

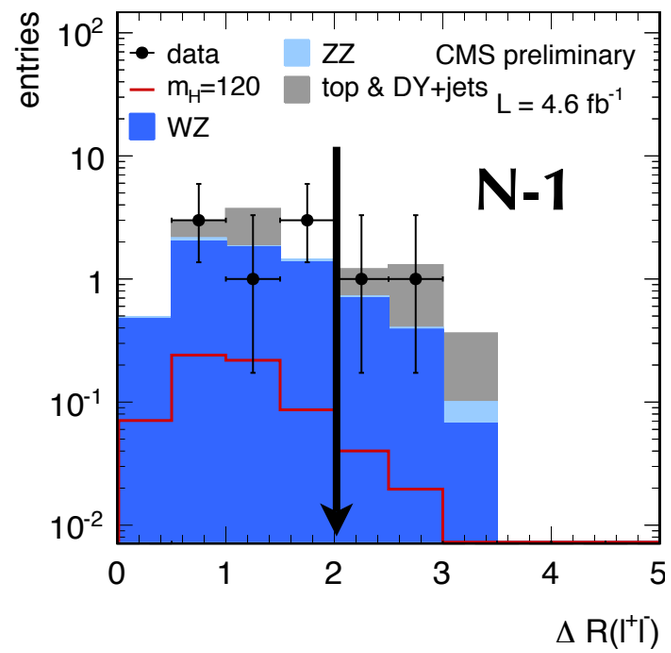
L=4.6 fb^{-1}

CMS PAS HIG-11-034

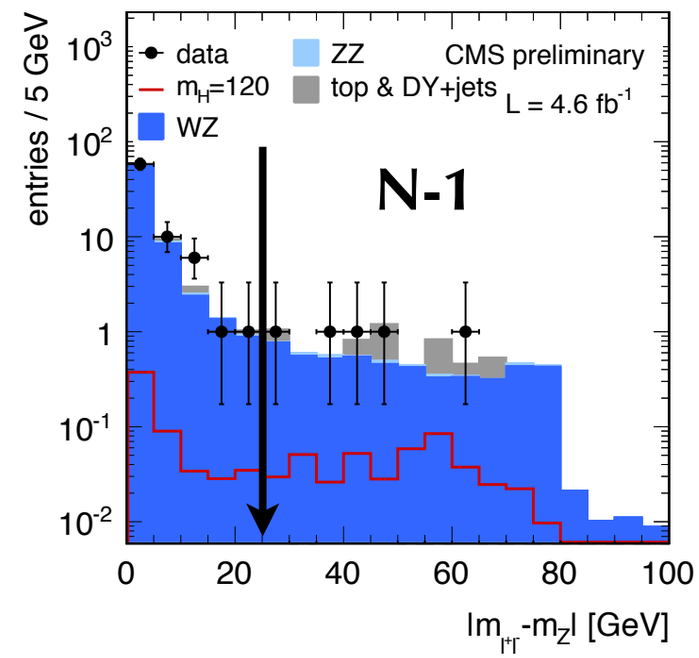
Selection:

- 3 high energy isolated leptons (e,μ)
- Large Missing transverse energy
- Z removal by cutting on the invariant mass of two leptons
- top pair veto by vetoing on btagged jets
- smallest $\Delta R(l^+l^-) < 2$
- 12 GeV<smallest $\Delta m(l^+l^-)$ <100 GeV

smallest $\Delta R(l^+l^-)$



$\Delta m(l^+l^-)$



background estimation:

ZZ, Zγ and WZ estimated with simulations and correction from data

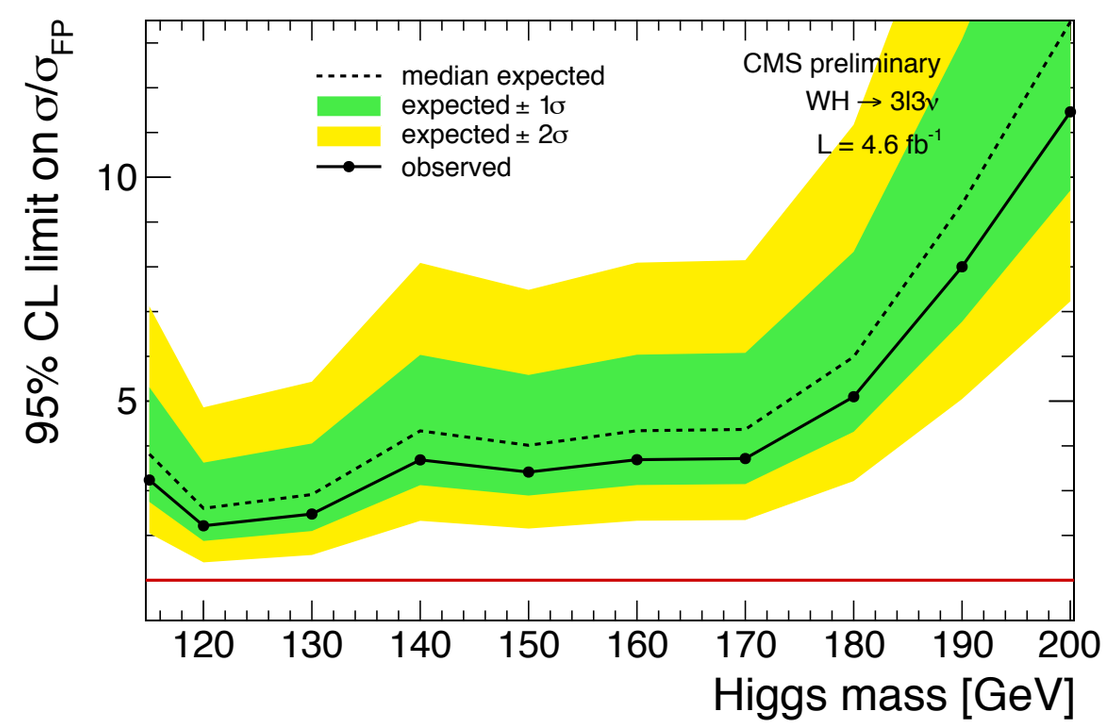
background with at least a fake lepton:

top pairs, tW, DY, + jets

completely data-driven background:

the "Tight to Loose" method

syst: 30%



non SUSY

FP: 2 photons

L=4.8 fb^{-1}

CMS PAS HIG-12-002

diphoton selection as in baseline analysis (NON-MVA)

- **HLT**
- **vertex finding**
- **4 di-photon categories to optimize the photon selection:**

1. **both photons in EB and not converted**
2. **both photons in EB and at least one converted**
3. **at least a photon in EE and both not converted**
4. **at least a photon in EE and at least one converted**

corrections to MC:

- PU re-weighting
- efficiency scale factors due to possible data/MC disagreement

$p_T(\gamma)$ cuts slightly different

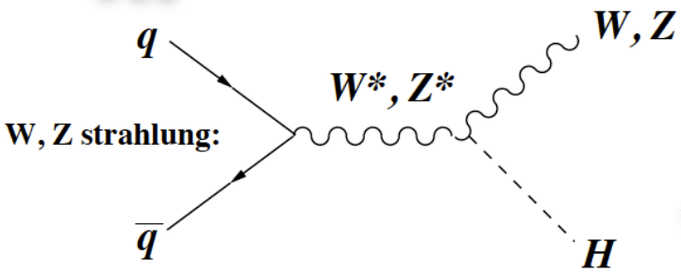
- isolation
- shower shape
- conversion rejection
- electron veto

Details on the di-photon selection have been explained by Olivier Bondu last Monday

besides the diphoton selection, a dedicated analysis has been developed to enhance the sensitivity to the FP model

different sub-channels in order to improve the S/B in specific production mechanisms

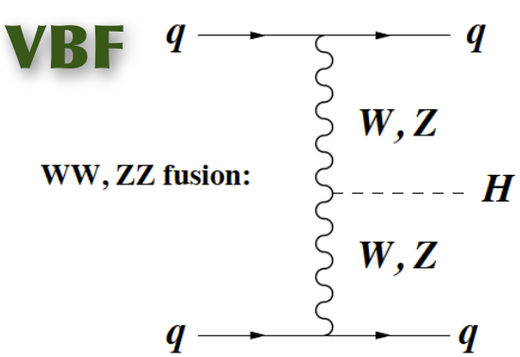
VH



1 or 2 charged leptons

require at least 1 lepton (μ or e)

VBF



require two energetic forward jets

and, for the non tagged events, exploitation of the main kinematic feature of the FP Higgs production:

the Higgs is always produced with other objects, so it is more boosted w.r.t. the SM one (where the gg->H is the main production mode)

$p_T(\gamma\gamma)$ has a good discriminant power against the background it's used in addition to $m(\gamma\gamma)$ to model the background

non SUSY

FP 2 photons VH lep, VBF sel

L=4.8 fb^{-1}

CMS PAS HIG-12-002

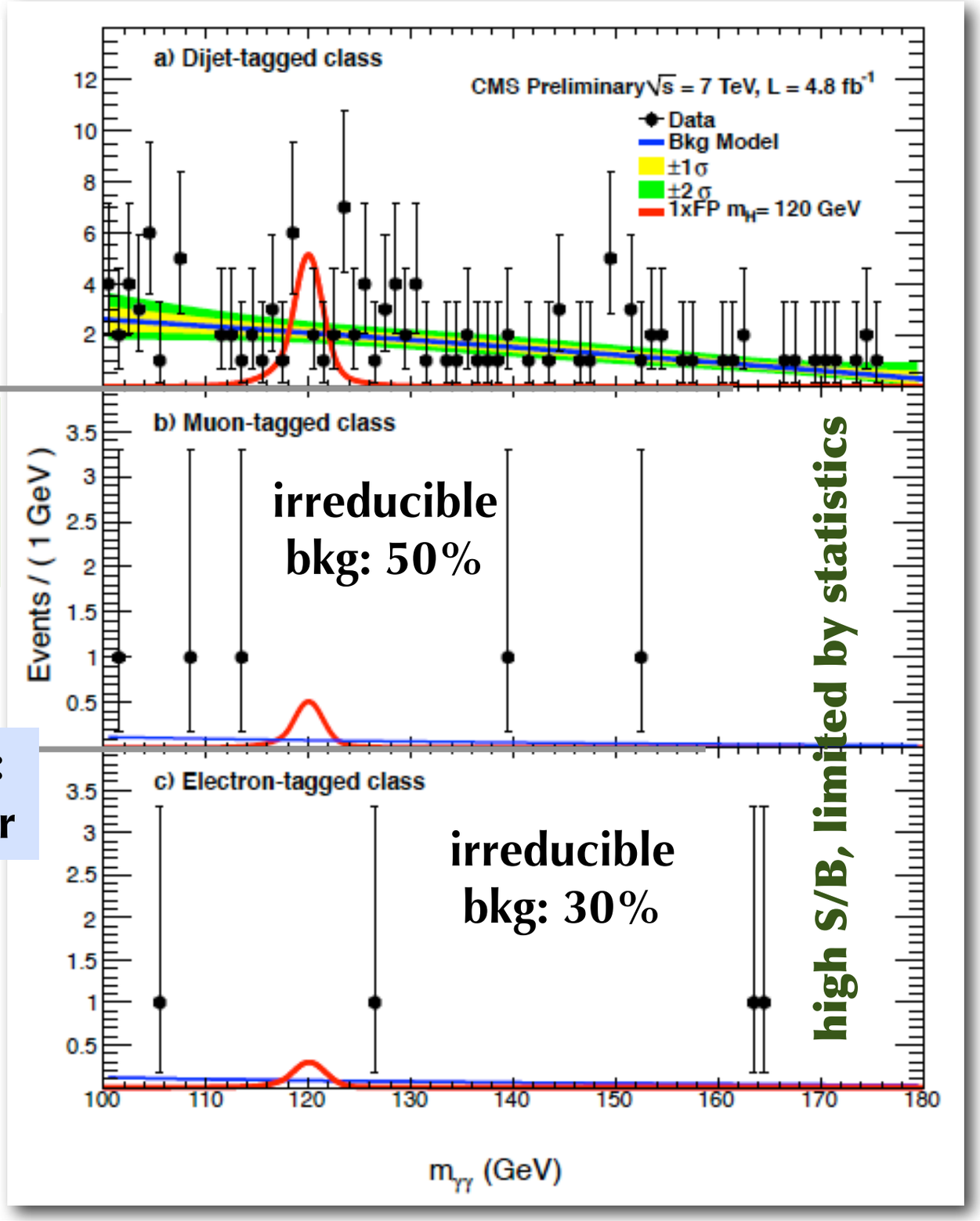
exclusive channels with tagged objects: start looking for muon (1), then for electron (2), then for two jets (3)

3) Dijet tag

2 energetic forward jets, Zeppenfeld variable

Variable	Selection
$p_{T1}/m_{\gamma\gamma}$	55/120
p_{T2}	> 25 GeV
p_{Tj1}, p_{Tj2}	$> 30, 20$ GeV
$\Delta\eta_{jj}$	> 3.5
$\Delta\phi(jj, \gamma\gamma)$	> 2.6
$\lvert Z\rvert = \lvert\eta - \frac{1}{2}(\eta_{j1} + \eta_{j2})\rvert$	< 2.5
m_{jj}	> 350 GeV

$m_{\gamma\gamma}$ fit with data BG (2nd order polyn.)



1) Muon tag

$\Delta R(\gamma\mu) > 1$

photon pt:
p_{T2}>25GeV
p_{T1}/m>45/120
lepton pT > 20 GeV

- MC for the shape
- selected data for normalization

irreducible bkg: $\gamma\gamma$ + W/Z/ttbar

2) Electron tag

$\Delta R(\gamma e) > 1$
$|M(e\gamma)-MZ|$ Z-veto

- shape obtained from MC and control sample dominated by the largest reducible background: Z(->ee) γ
- normalization from selected data

non SUSY

FP 2 photons: 2D analysis

L=4.8 fb^{-1}

CMS PAS HIG-12-002

after removal of dijet and lepton tagged events,
the remaining signal is ~74%
the remaining data are ~99%

4 γγ categories
(Like in γγ non-MVA)
$E_{T\gamma 1} > 40 \times M_{\gamma\gamma}/120$ GeV,
$E_{T\gamma 2} > 30 \times M_{\gamma\gamma}/120$ GeV

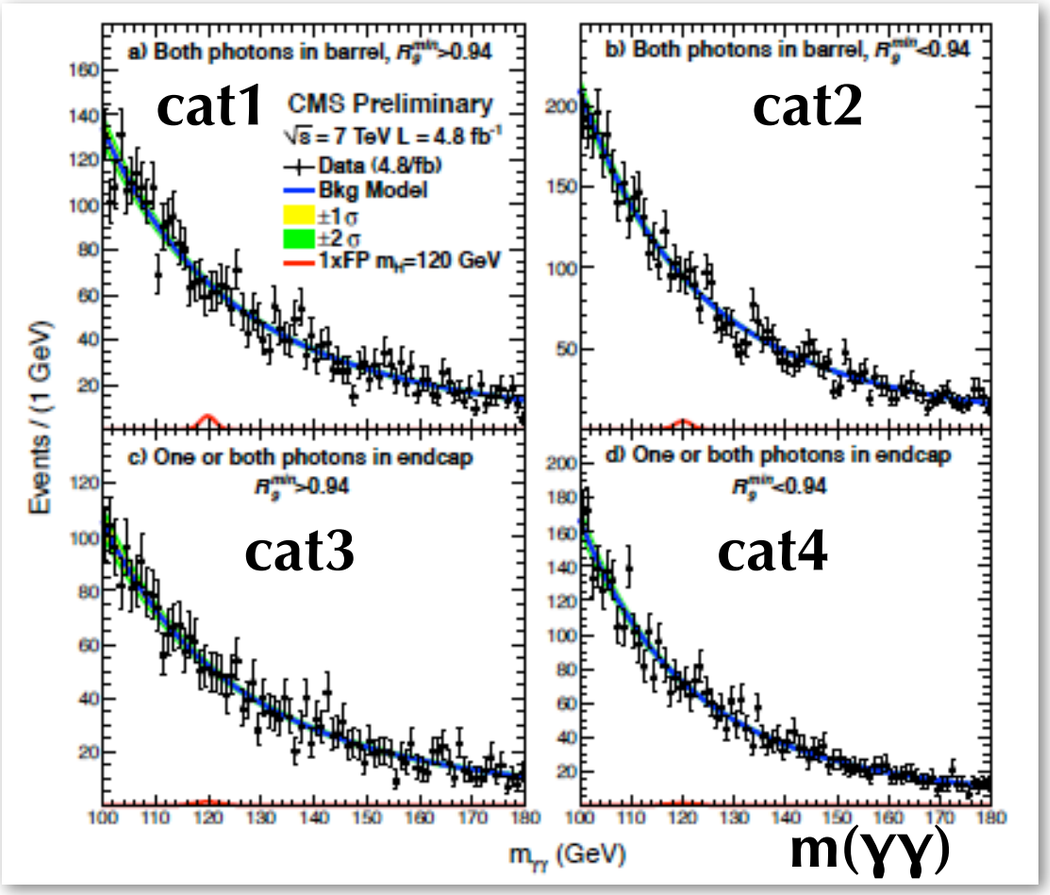
aim: use information from both m(γγ) and p_T(γγ)
main issue: possible correlation between the 2 variables

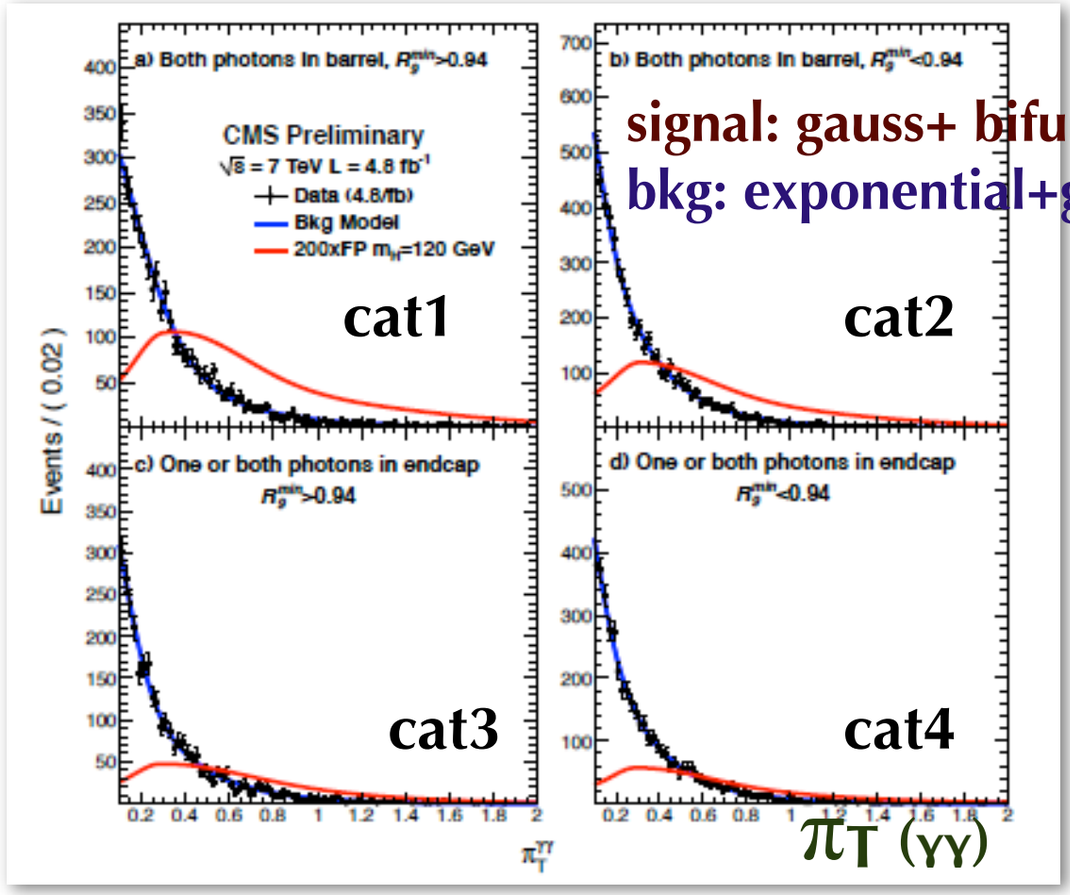
p_T(γγ) and m(γγ) are correlated.

π_T (γγ) =p_T(γγ)/m(γγ) (def.)

π_T (γγ) and m(γγ) ~uncorrelated

for π_T (γγ)> 0.1 --> cut





signal: gauss+ bifurcated gauss
bkg: exponential+gauss(centr. at 0)

2D fit to (m(γγ), π_T (γγ)) projected on single dimensions

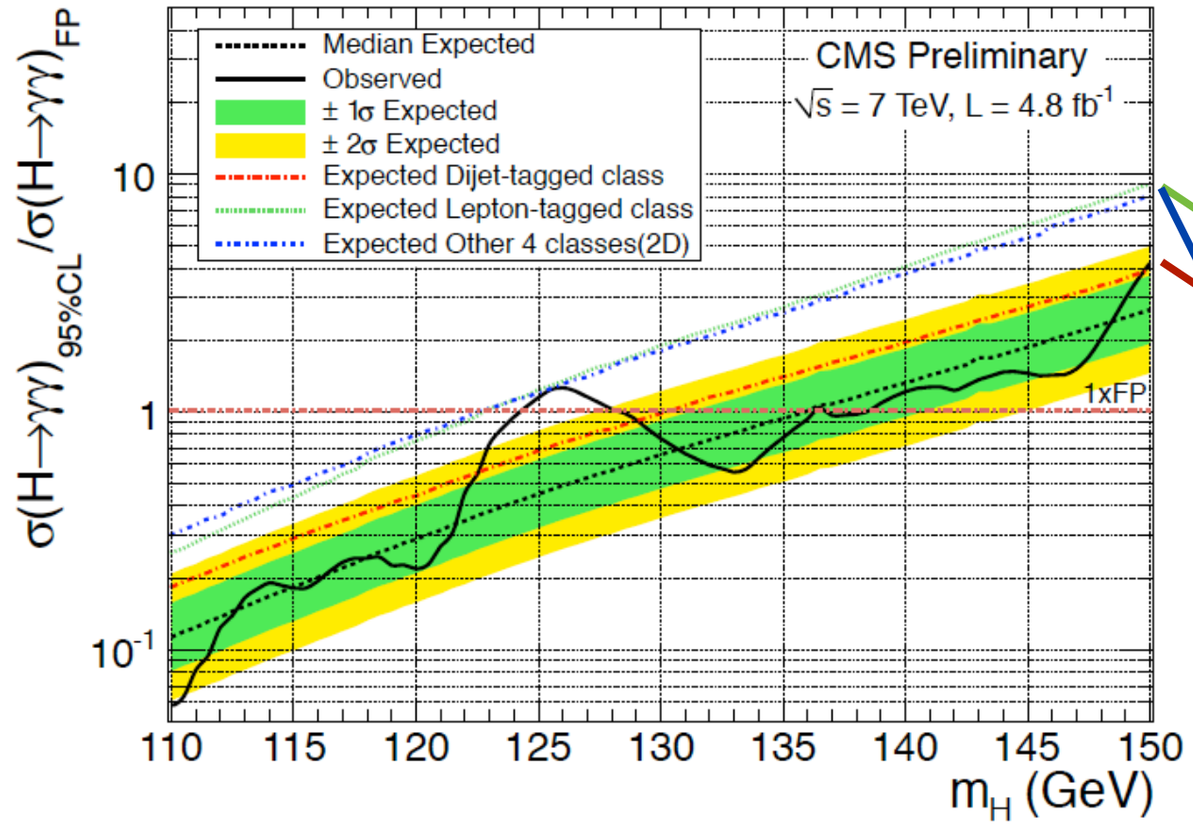
signal: no correlations
bkg: assume linear correlation

non SUSY

FP 2 photons: combination

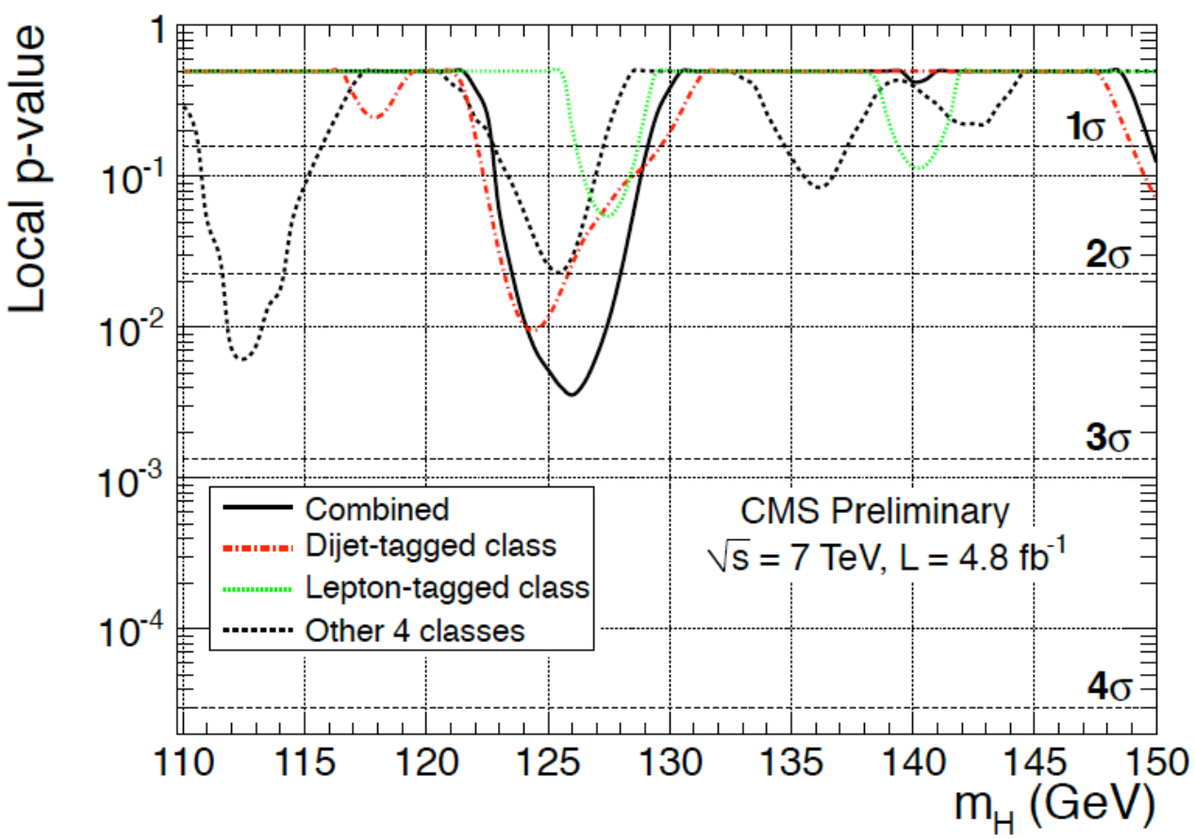
L=4.8 fb^{-1}

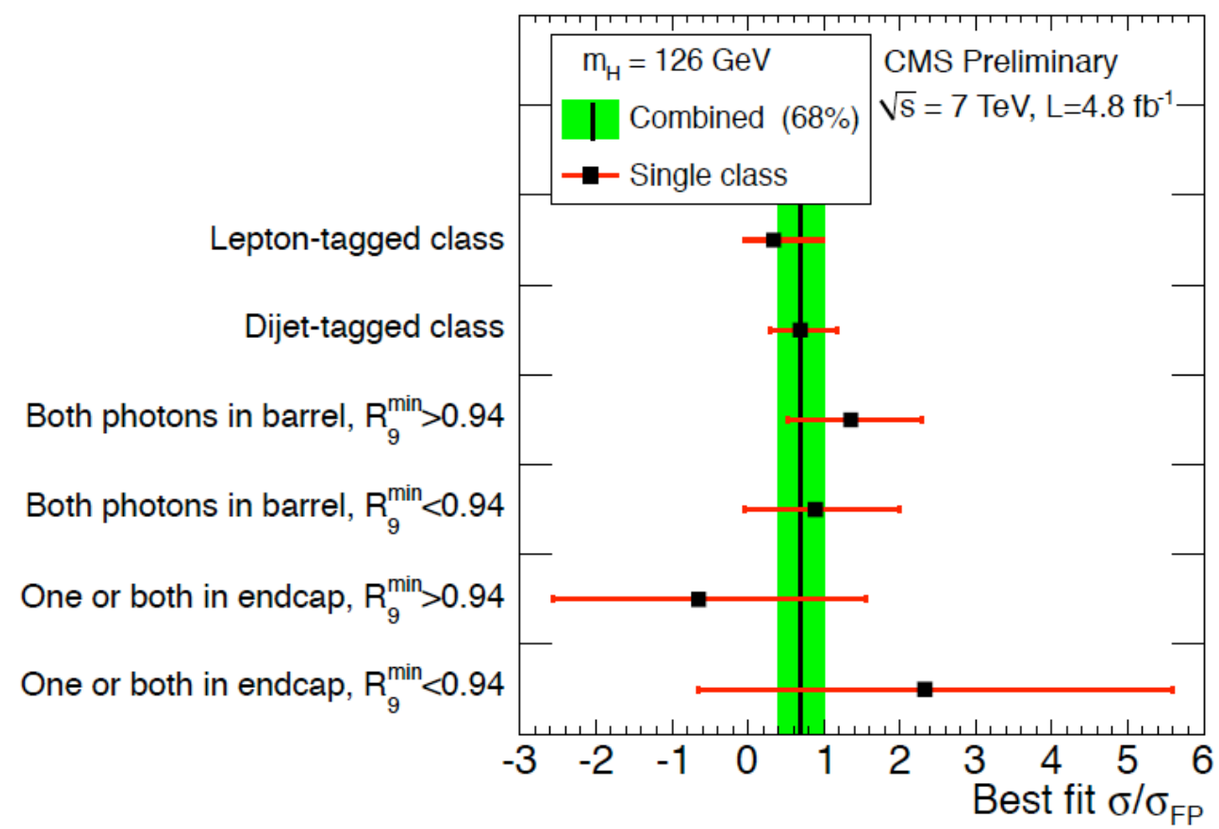
CMS PAS HIG-12-002



combination of the exclusive statistically uncorrelated classes:

- muon tag, electron tag
- di-jet VBF tag
- 4 diphoton classes of the rest of the events with $p_T(\gamma\gamma)/mass(\gamma\gamma)>0.1$





non SUSY

FP: combination

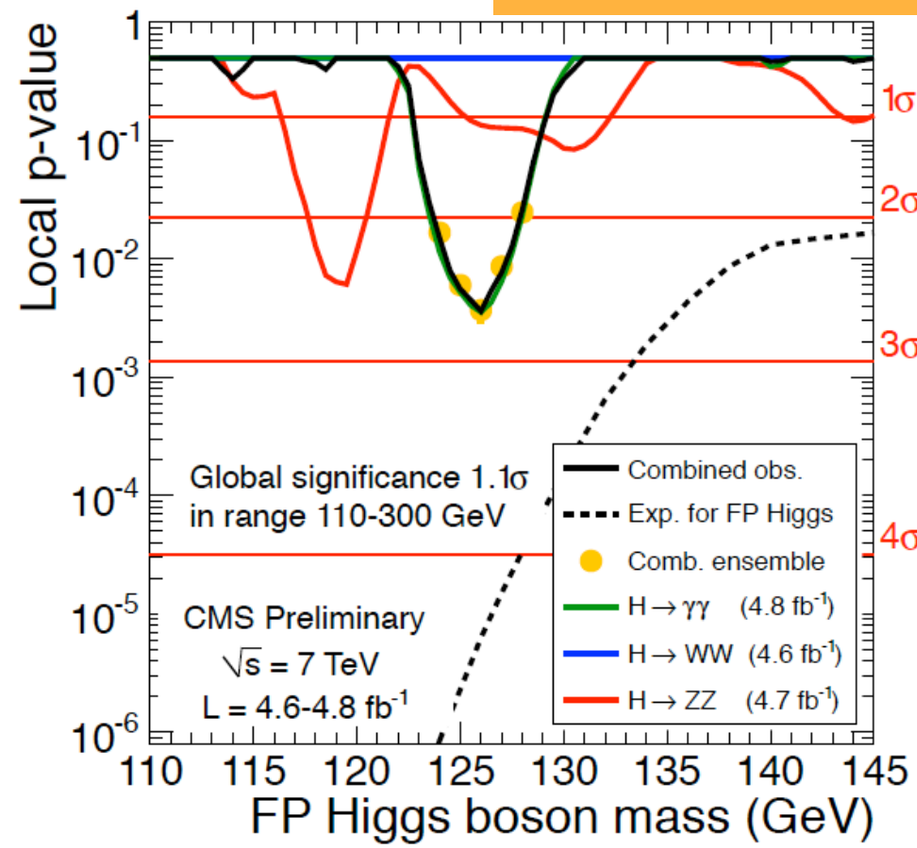
L=4.6-4.8 fb^{-1}

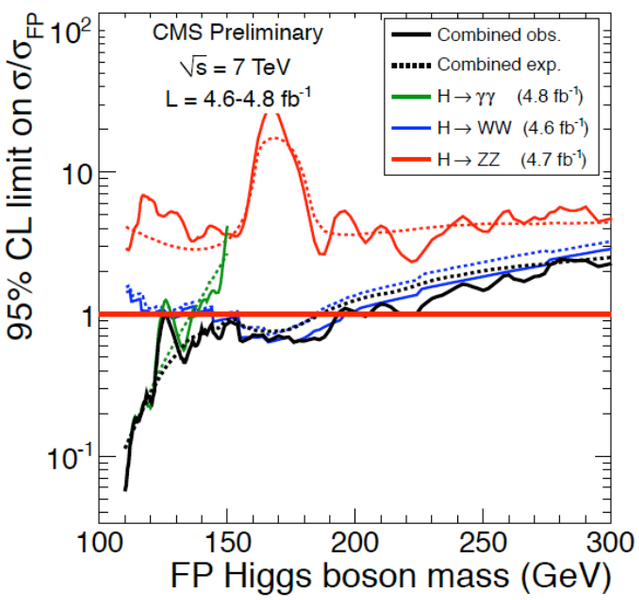
CMS PAS HIG-12-008

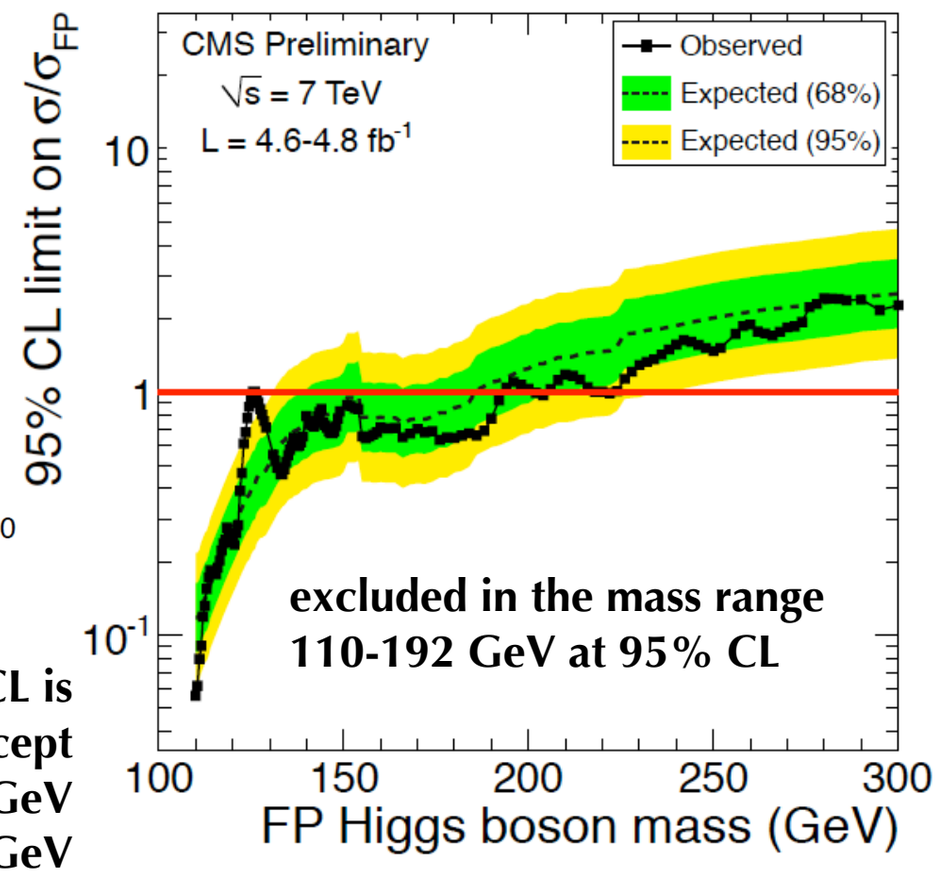
Channel	m_H range (GeV)	Luminosity (fb^{-1})	Sub-channels	m_H resolution
$H \to \gamma\gamma$ (fermiophobic)	110–150	4.8	4	1–3%
$H \to WW^* \to 2\ell 2\nu$	110–600	4.6	5	20%
$WH \to W(WW^*) \to 3\ell 3\nu$	110–200	4.6	1	20%
$H \to ZZ^{(*)} \to 4\ell$	110–600	4.7	3	1–2%
$H \to ZZ \to 2\ell 2\nu$	250–600	4.6	2	7%
$H \to ZZ^{(*)} \to 2\ell 2q$	130–164 200–600	4.6	6	3% 3%
$H \to ZZ \to 2\ell 2\tau$	190–600	4.7	8	10–15%

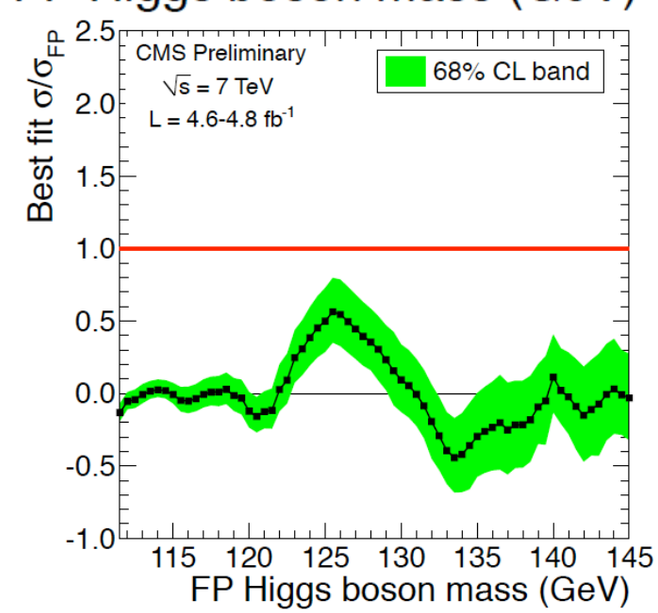
dedicated analyses

SM analyses









the exclusion at 99% CL is in the range 110-188 GeV except for the ranges 124.5 - 128 GeV and 148 - 154 GeV

excess at ~ 125 GeV is too weak to be consistent with a FP Higgs signal (partial fermiophobia?)

Summary

- ☑ excluded considerable region in the parameters space of MSSM thanks to the H->ττ analysis and to the search for t->bH+
- ☑ limit to parameters in the NMSSM with a_1-> μμ
- ☑ the search for doubly charged H in multilepton final state allowed for the exclusion of several benchmark points of models with Higgs triplet
- ☑ SM4 has been excluded in a wide mass range: 120-600 GeV
- ☑ Analyses developed specifically to search for FP Higgs allowed for exclusion at 95%CL of FP models in the mass range 110-192 GeV. The famous excess at ~125 GeV doesn't look like a FP Higgs signal

waiting for 2012 LHC data in order to use
these and new ideas to kill many other
Higgs masses, benchmark points, and possibly whole scenarios
... or (better) decide which is the real one

BackUp

mhmax

$M_{SUSY} = 1\ \mathrm{TeV}/c^2,\ \mu = +200\ \mathrm{GeV}/c^2,\ M_2 = 200\ \mathrm{GeV}/c^2$

$m_{\tilde{g}} = 0.8 M_{SUSY},\ X_t = 2 M_{SUSY}$ (FD calculation), $X_t^{\overline{MS}} = \sqrt{6} M_{SUSY}$ (RG calculation), $A_b = A_t$

H++/--

selection of doubly charged H

Variable	$ee, e\mu, \mu\mu$	$e\tau, \mu\tau$
$\sum p_T$	$> 0.6 \cdot m_{\Phi^{++}} + 130\,\text{GeV}$	$> m_{\Phi^{++}} + 100\,\text{GeV}$ or > 400 GeV
$\lvert m(\ell^+\ell^-) - m_{Z^0}\rvert$	none	$> 10\,\text{GeV}$
Mass window	$[0.9 \cdot m_{\Phi^{++}}; 1.1 \cdot m_{\Phi^{++}}]$	$[m_{\Phi^{++}}/2; 1.1 \cdot m_{\Phi^{++}}]$

Variable	$ee, e\mu, \mu\mu$	$e\tau, \mu\tau$
$\sum p_T$	$> 1.1 \cdot m_{\Phi^{++}} + 60\,\text{GeV}$	$> 0.85 \cdot m_{\Phi^{++}} + 125\,\text{GeV}$
$\lvert m(\ell^+\ell^-) - m_{Z^0}\rvert$	$> 80\,\text{GeV}$	$> 80\,\text{GeV}$
$\Delta\varphi$	$< m_{\Phi^{++}}/600\,\text{GeV} + 1.95$	$< m_{\Phi^{++}}/200\,\text{GeV} + 1.15$
E_T^{miss}	none	$> 20\,\text{GeV}$
Mass window	$[0.9 \cdot m_{\Phi^{++}}; 1.1 \cdot m_{\Phi^{++}}]$	$[m_{\Phi^{++}}/2; 1.1 \cdot m_{\Phi^{++}}]$

Variable	3τ	4τ
$\sum p_T$	$> m_{\Phi^{++}} - 10\,\text{GeV}$ or $> 200\,\text{GeV}$	$\sum p_T > 120\,\text{GeV}$
$\lvert m(\ell^+\ell^-) - m_{Z^0}\rvert$	$> 50\,\text{GeV}$	$> 50\,\text{GeV}$
$\Delta\varphi$	< 2.1	< 2.5
E_T^{miss}	$> 40\,\text{GeV}$	none
Mass window	$[m_{\Phi^{++}}/2 - 20; 1.1 \cdot m_{\Phi^{++}}]$	none

H-> tau tau

$e\tau_h$	MSSM	
Process	*Non B-Tag*	*B-Tag*
$Z \to \tau\tau$	13115 ± 908	126 ± 8
Fakes	6482 ± 305	101 ± 9
W+jets	5441 ± 377	32 ± 2
$Z \to ll$	6029 ± 646	26 ± 3
$t\bar{t}$	44 ± 7	69 ± 10
Di-Boson	98 ± 21	1 ± 1
Total Background	31208 ± 2264	355 ± 35
$H \to \tau\tau$	44 ± 4	4 ± 1
Data	32062	391

Signal Efficiency

$gg \to \phi$	8.22e-05
$gg \to bb\phi$	1.34e-03

MSSM Higgs	Expected $\tan\beta$ limit					
m_A [GeV]	-2σ	-1σ	Median	$+1\sigma$	$+2\sigma$	Obs. $\tan\beta$ limit
90	5.19	7.01	8.37	10.6	12.8	12.2
100	6.49	7.45	8.78	10.8	13.4	11.8
120	4.50	6.47	8.09	9.89	12.0	9.84
130	5.37	6.71	7.85	9.69	11.5	9.03
140	5.62	6.63	7.90	9.69	11.6	8.03
160	5.57	6.99	8.51	10.4	12.5	7.11
180	6.75	8.14	9.53	11.3	13.8	7.50
200	7.84	9.12	10.5	12.8	15.0	8.46
250	10.3	12.3	13.9	16.8	19.4	13.8
300	13.5	15.7	18.4	21.4	24.5	20.9
350	17.7	20.1	23.0	26.9	31.1	29.1
400	21.9	24.3	27.9	32.4	37.3	37.3
450	25.0	29.2	33.3	38.8	44.7	45.2
500	30.3	35.7	40.5	47.1	55.0	51.9

FP 2 photons

	Dijet + lepton tag	Both photons in barrel		One or both in endcap	
		R_9^{min} >0.94	R_9^{min} <0.94	R_9^{min} >0.94	R_9^{min} <0.94
FP signal expected	24.7 (27.4%)	22.3 (24.7%)	23.0 (25.5%)	9.5 (10.5%)	10.7 (11.9%)
Data (events)	129 (0.8%)	3740 (22.9%)	5363 (32.9%)	2991 (18.3%)	4090 (25.1%)
σ_{eff} (GeV)	1.72	1.39	1.84	2.76	3.19
FWHM/2.35 (GeV)	1.37	1.19	1.53	2.81	3.18

	All	EB high R_9 (0)	EB low R_9 (1)	non EB high R_9 (2)	non EB low R_9 (3)
MC Signal					
Dijet tag	0.79	0.74	0.77	0.85	0.85
Dijet or lepton tag	0.74	0.70	0.73	0.80	0.81
Data					
Dijet tag	0.995	0.992	0.994	0.998	0.996
Dijet or lepton tag	0.994	0.991	0.993	0.997	0.996

WWW

stage	WH (120) $H \to \tau\tau$	WH (120) $H \to WW$	data	all bkg.	WZ $\to 3\ell\nu$	ZZ $\to 4\ell$	top+Z/γ^*
3-lepton preselection	2.1 ± 0.0	3.5 ± 0.1	950	968.3 ± 11.9	482.9 ± 1.8	78.4 ± 0.9	348.0 ± 9.7
min-MET > 40 GeV	1.0 ± 0.0	1.8 ± 0.1	244	270.5 ± 4.4	208.2 ± 1.1	7.9 ± 0.3	54.5 ± 4.3
Z removal	0.4 ± 0.0	1.0 ± 0.1	40	47.9 ± 3.1	15.9 ± 0.4	0.7 ± 0.1	31.3 ± 3.1
top veto	0.1 ± 0.0	0.6 ± 0.1	12	14.2 ± 1.3	8.8 ± 0.4	0.4 ± 0.1	4.9 ± 1.3
$\Delta R_{\ell^+\ell^-}$ & $m_{\ell\ell}$	0.1 ± 0.0	0.5 ± 0.1	7	8.4 ± 0.9	5.7 ± 0.2	0.3 ± 0.1	2.6 ± 0.9